OCEAN CONSERVATION RESEARCH

Science and technology serving the sea

Chief, Marine Mammal and Sea Turtle Conservation Division,
Office of Protected Resources,
National Marine Fisheries Service,
1315 East-West Highway,
Silver Spring,
MD 20910-3226

Re: Acoustic Guidance - EO13795 comments.

To Whom It May Concern,

We are a bit perplexed by the instructions in the President's Executive Order 13795 (EO13795), section 10, which calls for a review of NMFS' "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing" (hereinafter "Technical Guidance") as follows: "The Secretary of Commerce shall review [NMFS' Technical Guidance] for consistency with the policy set forth in Section 2 of this order and, after consultation with the appropriate Federal agencies, take all steps permitted by law to rescind or revise that guidance, if appropriate."

The stated objective of Section 2 of EO 13795 is "to encourage energy exploration and production, including on the Outer Continental Shelf, … while ensuring that any such activity is safe and environmentally responsible."

It should be known by the Administration that the Technical Guidance is not a regulatory document; it does not impose any restrictions or infer any limitations on offshore energy operations, it merely provides what is stated in the title, "guidance" for noise exposures of marine mammals in any offshore enterprise. This useful guidance informs the application of the Marine Mammal Protection Act, the Endangered Species Act, and considerations for Incidental Harassment Authorizations in the planning of any offshore enterprise under Federal regulatory jurisdiction.

It should also be known by the Administration that the Technical Guidance is not an opinion that can be disputed, it is a guidance document that has been in development for over ten years. The document has been through three rounds of peer review, and three rounds of public comment (see Appendix). And while there is room for improvement, it represents the least offensive compromise of the synthesis of the best available science at the time of its publication. It also has open provisions for revising the document to reflect advances in data collection and scientific understanding.[1]

[1] Technical Guidance Section III
http://www.nmfs.noaa.gov/pr/acoustics/Acoustic%20Guidance%20Files/opr-55_acoustic_guidance_tech_memo.pdf

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It should also be known by the Administration that the one of the more contentious compromises applied to the most speculative section of the document (weighting curves for Low Frequency Cetaceans[2]) was revised in accommodation to the Geophysical Industry.[3] So in this case where the data was not indisputable, instead of the precautionary principle being applied, the document deferred to the industry.

The Administration has made it clear in EO 13795 that the agenda of fossil fuel industries overshadows all other considerations for conservation and life quality – both animal and human. But should the Technical Guidance be rescinded, the exposure guidance would return to the original guidelines. These original guidelines were rudimentary and treated all marine mammals under three broad-band exposure thresholds (Level A, Level B for impulse noise, and Level B for continuous noise) regardless of the hearing threshold contours of the five hearing families identified in the 2016 Technical Guidance. It was in fact the inconsistency of observed responses to noise exposure, and the high take levels inferred by applying the legacy threshold guidance that brought about the 2016 Technical Guidance. So in effect, by rescinding the Technical Guidance, the very industry that EO 13795 seeks to appease would be most deeply affected by the regression to the earlier standard.

Should the "review" of the Technical Guidance suggest revisions, these revisions would likely include the most current scientific data, as it would be hard to imagine regulators or the public accepting revisions of a scientifically-informed document by "reviewers" not conversant in marine mammal science. And given that it has taken ten years to arrive at a document that annoys all stakeholders almost equally, the prospect of crafting another agreement with equal bona fides would be a long, legally costly, and ultimately a futile task.

Consistent with the EO13795, Section 10 stated objectives of "ensuring that any [energy exploration] activity is safe and environmentally responsible," we recommend that the NMFS' 2016 "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing" remain as is; the guiding framework for marine mammal noise exposures.

Sincerely,

Michael Stocker
Director

[2] See OCR Comments in Appendix: Feb. 26, 2104 p.2, Sept 14, 2015 p3, Mar. 28, 2016 p.2

[3] "IAGC Successful in Influencing Revision of Acoustic Threshold Guidelines" *The Voice of the Geophysical Industry* 4th Quarter 2105 Issue 8 International Association of Geophysical Contractors http://www.iagc.org/uploads/4/5/0/7/45074397/2015_iagc_newsletter_final__002_4.pdf

APPENDIX

Ocean Conservation Research comments to the NMFS' Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing

Feb. 26, 2104 – p. 1 – 17

Sep. 14, 2015 – p. 1 – 9

Mar. 28, 2016 – p. 1 - 5

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February 26, 2014

Chief, Marine Mammal and Sea Turtle Conservation Division,
Office of Protected Resources,
National Marine Fisheries Service,
1315 East-West Highway,
Silver Spring,
MD 20910-3226

Re: Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals

To Whom it May Concern;

It is clear that much work and consideration has been put into the "Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals" (hereinafter "Draft Guidance document"), gathering together and including many of the studies that have been executed, reviewed, and published over the past decade. The guidelines represent a significant improvement over the broad-brush threshold guidelines that have been used to date and as such should more accurately represent potential noise induced physiological impacts of noise exposures on marine mammals. The preparers should be applauded for their work.

I am also encouraged that the Draft Guidance document has provisions for updating the thresholds as new data become known, reflecting the best available science.[1] It is important in this context to assure that all of the best available science is considered when updating the guidelines.

Even with all of the work that has been put into achieving a greater understanding of marine mammal acoustical sensory systems, there remains many shortcomings in what we know, how we frame our inquiries, and our assumptions about the impacts of noise on these animals. Our concerns are outlined in the following body of this letter.

[1] Draft Guidance document section IV

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The paucity of data:

Establishing Temporary Threshold Shift exposure levels the document relies heavily on so few subjects, and many tests on these few animals from the SPAWARS studies.[2] This dependence is also woven into the fabric of the main reference studies used to substantiate the Draft Guidance document (Finneran and Jenkins; 2012 and Southall et. al. 2007) wherein the mature (13 – 20 y.o.) to old (35 – 40 y.o.) animals are used to examine auditory performance. The Draft Guidance document also relies heavily on the University of Hawaii studies of the hearing responses of one captive born Atlantic bottlenose dolphin. (Mooney et.al. 2009, Nachtigall et. al. 2003, 2004)

All of the SPARWAR subjects and the University of Hawaii subject have been systematically exposed to noise studies for many years. The dolphin and beluga whale subjects of these studies have lived in a busy environment full of anthropogenic noise, and continuously exposed to noise testing, so it is highly likely that they have been habituated to the test environment. It is clear that these animals do not represent approximately 125 different species of wild marine cetaceans in their own environment.

This paucity of data from a limited number of subjects discussed in the Draft Guidance document text,[3] but because there are so many ingrown layers of these references through Finneran and Jenkins 2012, and Southall et. all. 2007, and that these studies are used to conjecture the hearing performance of "Low Frequency" cetaceans, are all facts that should be clearly established as significant caveats in interpreting the guidelines. These interpretations should be founded on the precautionary principal that lacking data to prove otherwise, an assumption of harm should direct actions with unknown impacts.[4]

For the record, all cetacean TTS models – including the models for the "Low Frequency cetaceans are based on six bottlenose dolphins (five from SPAWAR, one from Univ. of Hawaii) three belugas (two from SPAWAR, one from Popov et. al. 2011b) two harbor porpoises (one from Kastelein et. al. 2012a, and one from Lucke et. al. 2009) and two Yangtze finless porpoises (Popov et.al. 2011a). Additionally all pinniped thresholds are derived from only four individual animals, two California sea lions (aged between 12 and 21 years), three harbor seals (one from Long Marine Lab, the other two from SEAMARCO), and a northern elephant seal (Kastak et.al 1999, Kastak et.al.2005). The California sea lions were

[2] Finneran, J.J. 2011; Finneran and Schlundt 2009; Finneran and Schlundt 2010; Finneran and Schlundt 2011; Finneran and Schlundt 2013; Finneran et.al. 2000; Finneran et.al. 2002; Finneran et.al. 2005; Finneran et.al. 2007; Finneran et.al. 2010a; Finneran et.al. 2010b

[3] Section 1.1 directly under the introductory paragraph of the Draft Guidance document.

[4] "Precautionary Tools for Reshaping Environmental Policy" MIT Press 2005 Edited by Nancy Myers and Carolyn Raffensperger

mature to old, aged 12 -21 years in the two cited studies,[5] the domesticated harbor seal (named "Sprouts") from Long Marine Lab had been inadvertently exposed to damaging airborne construction noise at four years of age [6] which may have had long term impacts on its hearing sensitivities,[7] the two harbor seals from SEAMARCO were captive bred, and a young (4 – 7 years) elephant seal whose provenance was not articulated in the citations.

All data are taken from captive animals:

All of these animals – cetaceans and pinnepeds, are captive so we can assume a few things about them: With the exception of the captive bred harbor seals from SEAMARCO, they were likely rescued and thus either suffered some trauma or were not as fit as their wild kin. Additionally their captive habitat is not fraught with predation, nor are they taxed with the necessity of locating their own food supplies, so it is possible that these animals are less alert due their provenance and to habituating to these less stimulating (sensory-deprived relative to their natural habitat) circumstances. Although it is not surprising that the captive bred harbor seals had significantly lower auditory thresholds[8] and lower onset of TTS[9] than the Long Marine Lab harbor seal given their "cushy" captive life and not having been acoustically traumatized and an early age.

It should also be noted that the three species of pinnipeds are species that are commonly found in coastal mid-latitudes in close proximity to high concentrations of human activity. It would be hard to determine how this proximity to what is now noisy habitat is reflected in their physiology as opposed to the polar seals. We know behaviorally that the polar seals are extremely songful, which is not found in the harbor seal, the elephant seal, or the California sea lion. It would stand to reason that the polar seals have different, if not more complex acoustical adaptations than the two captive phocid species.

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[5] Schusterman, Ronald J., Brandon Southall, David Kastak and Colleen Reichmuth Kastak "Age-related hearing loss in sea lions and their scientists" J. Acoust. Soc. Am. 111, 2342 (2002)

[6] Kastak, David and Ronald J. Schusterman (1996) "Temporary threshold shift in a harbor seal (*Phoca vitulina*) J. Acoust. Soc. Am. 100 (3)

[7] Lin, H.W., A.C. Furman, S.G. Kujawa, and M.C. Liberman. 2011. Primary neural degeneration in the guinea pig cochlea after reversible noise-induced threshold shift. Journal of the Association for Research in Otolaryngology 12:605-616

[8] Kastelein,Ronald A., Paul J. Wensveen1, Lean Hoek, Willem C. Verboom and John M. Terhune. (2009) "Underwater detection of tonal signals between 0.125 and 100kHz by harbor seals (*Phoca vitulina*)" J. Acoust. Soc. Am. 125, 1222

[9] Kastelein, R.A., R. Gransier, L. Hoek, A. Macleod, and J.M. Terhune. (2012b). Hearing threshold shifts and recovery in harbor seals (Phocina vitulina) after octave-band noise exposure at 4 kHz. Journal of the Acoustical Society of America 132:2745-2761

Natural protective hearing mechanisms are not included in the threshold model:

Model inaccuracies due to habituation to captivity may be compounded by the fact that the test animals may employ biological protections to prepare them for their tests – protections akin to the "wincing" that visual animals use to protect their eyes from damage. Terrestrial animals have a mechanism, like "wincing" in their middle ears that protect them from damaging sounds. This mechanism is a tightening of the tensor tympani muscles around the middle ear ossicles, protecting the hearing organ from physical damage. While this mechanism is fast acting in response to unexpected stimulus, once terrestrial animals are habituated to expect loud noise, the system is activated by the expectation. In humans the mechanism kicks in when noise levels reach 75dB SL (re: 20μPa)[10] – about 10dB SL below where OSHA guidelines for TTS-level noise exposures occur in humans, and about 50dB SL below where PTS occurs.

The middle ear structure of marine mammals differs significantly from the middle ears of terrestrial animals. We are learning about how environmental sounds are conveyed into the odontocete's inner ears. This mechanism seems to include the lipid channels in their lower jaws,[11] and the mobility of the bulla (the bone envelope that houses the cochlea and semicircular canals). While this mechanism does include the same middle ear ossicles of terrestrial mammals, these bones in cetaceans can be rigidly attached to each other and connected differently (by way of ligaments) to the tympanic membrane.[12] While the ears of the odontocetes or mysticetes do not have the same tensor tympani found in terrestrial mammals, it is probable that these hearing specialist animals would have an analogous system to protect their inner ears from periodic or occasional sound levels that would otherwise damage their organs of hearing.[13] In fact it stands to reason that echolocating odontocetes would necessarily have some form of "automatic gain control" (AGC) because they need to discriminate bio-sonar return signals much quieter than their outgoing signal. If they did not have some form of AGC their own outgoing signal might induce a temporary threshold shift that would defeat their receiving sensitivity, given that outgoing clicks of *tursiops* can be as loud as $227dB_{(peak)}$ re: 1μPa[14] and TTS for continuous signals in MF cetaceans is $224dB_{(peak)}$.

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[10] Pierre Buser and Michel Imbert "Audition" 1992. MIT Press. p. 110 - 112.
[11] Heather Koopman, Suzanne Budge, Darlene Ketten, Sara Iverson "The Influence of Phylogeny, Ontogeny and Topography on the Lipid Composition of the Mandibular Fats of Toothed Whales: Implications for Hearing" 2003 Paper delivered at the Environmental Consequences of Underwater Sound conference, May 2003.
[12] G.N. Solntseva, "The auditory organ of mammals"1995 p. 455 in "Sensory Systems of Aquatic Mammals" R.A. Kastelein, J.A. Thomas and P.E. Nachtigall eds. De Spil press.
[13] This system might involve thermo-regulating the viscosity, and thus the acoustical compliance of the lipids through regulating blood circulation around the organs – thereby attenuating or accentuating acoustical transfer through the organ as needed.
[14] Aroyan JL, McDonald MA, Webb SC, Hildebrand JA, Clark D, Laitman JT, Reidenberg JS (2000) "Acoustic Models of Sound Production and Propagation." In: Au WWL, Popper AN, Fay RR (eds), *Hearing by Whales and Dolphins.* New York: Springer-Verlag, pp. 409-469.

If this assumption is correct, then the "sound test" habituated odontocetes [15] would obviously yield much higher thresholds for TTS than their wild, un-habituated counterparts – given that they will always "prepare" for acoustical assaults when asked to perform in a given testing situation.[16]

Lab data are derived from signals that are not representative of exposure signals:

In terms of the range of impact relative to signal amplitude, Kastelein and Rippe (2000) studied younger animals (harbor porpoise *Phocena phocena*) [17] with more appropriate test signals yielded significantly different results than what was found in the much older, test-habituated subjects. These animals demonstrated an aversion to more complex signals in the frequency range of the proposed sonars and at 130dB re: 1µPa@1m. (Animals used in the Kastelein and Rippe study had been recently taken into captivity and approximately three years old at the time of the study.)

It should also be noted that all non-impulsive signals used in the citations upon which the thresholds are established are sinusoids or sinusoidal-derived band-limited 'pink' noise.[18] While these signals do lend consistency to audiometric testing, they do not necessarily reflect the characteristic signals being introduced into the sea. We are particularly concerned with the exponential proliferation of acoustical communication signals being used in underwater multimodal communication networks for control and monitoring of autonomous and remotely operated equipment for resources extraction, scientific research, and industrial exploration.

These communication signals include characteristically rapid rise-times either in set frequencies such as square waves or other high "crest factor"[19] signals which are not sinusoidal, or they include signals that are rapid rise time in frequency switching of sinusoids such as "Frequency Shift Key" (FSK) and spread spectrum frequency hopping schemes such as Orthogonal Frequency-Division Multiplexing (OFDM), Trellis Coded Modulation (TCM), and Time Domain Multiplexing (TDM). Many of these schemes, when used in short to intermediate distance acoustic communication technologies (1km – 10km) operate in the 10kHz – 100kHz ranges that overlap all of the marine mammal hearing groups. Furthermore

[15] e.g. J. J. Finneran, C. E. Schlundt, D. A. Carder, J. A. Clark, J. A. Young, J. B. Gaspin, S. H. Ridgway Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and a beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. J. Acoustical Soc. of America. V.108(1) July 2000.
[16] Nachtigall, Paul E., and Alexander Ya. Supin (2013) "False killer whale reduces its hearing sensitivity when a loud sound is preceded by a warning" J. Exp. Biology 216, 3062-3070
[17] R.A, Kastelien, H.T. Rippe " The Effects of Acoustical Alarms on the Behavior of Harbor Porpoises (*Phocena phocena*) in a floating pen" Marine Mammal Science 16(1) p. 46 – 64. January 2000
[18] Band limited "Pink Noise" is typically derived from Fourier Transfer derived Gaussian noise constructed from sine waves without any coherent time-domain component.
[19] Crest factor is the ration of peak to RMS value of a signal. Pure sinusoidal waves have a crest factor of .707; pure "square waves have a crest factor of 1; repetitive impulse sounds have a crest factor greater than 1.

due to the need for well-defined leading edges required for reliable state-change detection, the signals read more like impulsive signals and are characterized by high kurtosis in amplitude and frequency variability over time.

Kurtosis (β) describes the shape of a probability distribution on an x-y graph. It is equated with the "peakedness" of the curve as a product of the distribution of observed data around the mean:

$$\beta = \frac{1}{N}\sum_{\infty}^{N}\left(\frac{X_i - \overline{X}}{S}\right)^4$$

Where:

N = the number of elements in the distribution.
S = Standard deviation
X= are the discreet peaks in data stream (for sound, the pressure/time waveform) over some interval of time.

Kurtosis then is an expression weather the data are peaked or flat relative to a Gaussian distribution. This matters because noise impacts from high kurtosis signals induce significantly higher hearing losses than exposures from sinusoidal signals[20] and is associated with "unpleasantness" or aggravating characteristics of sound.[21] This characteristic is only taken into consideration in Draft Guidance document relative to impulsive sounds and the Equal Energy Hypothesis (EEH) (Danielson et al. 1991; Hamernik et al. 2003; Henderson and Hamernik 1986; Henderson et al. 1991).

Unfortunately there is a dearth of data on the physiological impacts of high kurtosis continuous signals or tone bursts on hearing systems, but avoidance behavior which is a proxy for self-protection is clearly influenced by sound quality characterized by high kurtosis signals.[22,23]

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[20] Hamernik, R. P., Qiu, W., and Davis, B. (2003). "The effects of the amplitude distribution of equal energy exposures on noise-induced hearing loss: "The kurtosis metric," J. Acoust. Soc. Am. 114, 386–395

[21] Sukhbinder Kumar, Helen M. Forster, Peter Bailey, Timothy D. Griffiths (2008) "Mapping unpleasantness of sounds to their auditory representation" J. Acoust. Soc. Am. 124: 6

[22] R.A. Kastelien, D. Goodson, L. Lein, and D. de Haan. "The effects of acoustic alarms on Harbor Porpoise (*Phocena phocena*)" 1997 P.367-383 in A.J. Read, P.R. Wiepkema, and P.E. Nachigall eds. "The Biology of Harbor Porpoise" de Spil publishers, Woerned, The Netherlands.

The Verboom and Kastelein (2005) study extrapolates a TTS level for these animals at 150 dB(*w*) re:1µPa@1m for the harbor seal, and 137dB(*w*) re:1µPa@1m[24] for the harbor porpoise. These levels are significantly lower than the TTS levels of 160dB SEL_{CUM} for HF Cetaceans and 183dB SEL_{CUM} for Phocids suggested in Draft Guidance document Table 6. The paper also goes on to suggest that hearing injury – PTS, will occur in the Harbor seal at 190dB – Less than half the energy of the 197dB level found in Draft Guidance document Table 6. While this is just one paper, it evaluates various responses to different sounds and is one of the earlier papers to suggest segregating species into their various hearing function groups. As such the paper should be included and brought into consideration in the Draft Guidance document.

The foregoing also suggests that noise exposure guidelines should include a metric for sound quality, not just instantaneous, periodic, or cumulative exposure amplitude as suggested in the Draft Guidance document table 6b. We need a metric that expresses actual signal quality, not merely exposure profile. And while we do not have enough data to derive a precise "quality" metric, we do have enough information to know that not all signals inflict equal impact and that if signals are anything other than sinusoidal-derived continuous signals or tone bursts that the exposure should be reviewed on a case-basis (as provided for in Draft Guidance document section 2.3 "TTS and PTS Onset Acoustic Threshold Levels.")

For example: when digital communication signal exposures are subject to impact assessment, the thresholds should be established using data from Kastelein et.al (2005) and Kastelein et.al (2006) where actual communication signals were used. In these studies it was found that discomfort thresholds in Harbor porpoise were at 103 – 104 dB for Direct Sequence Spread Spectrum signals, and 111 – 112 dB for Modulated Frequency Shift Key signals (all re: 1µPa, frequency range: 6.3kHz – 18kHz). In a similar study with Harbor seals it was found that the discomfort thresholds were all around 107 (dB re: 1µPa) for all communication signal types.[25]

While "discomfort thresholds," are not a defined term in the Draft Guidance document, they are indicative of pain and avoidance behavior well below the TTS levels suggested in the Draft Guidance document. Kastelein et.al were not measuring TTS in these studies, but there is a probable correlation between avoidance behavior and physiologically damaging (TTS inducing) sound types (not just sound levels).

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[23] W.C. Verboom and R.A. Kastelein. "Some examples of marine mammal 'discomfort thresholds' in relation to man-made noise." June 22, 2005. Proceedings from the 2005 Undersea Defense Technology conference 2005, Sponsored by TNO, P.O. Box 96864, 2509 JG The Hague, The Netherlands.
[24] "dB(*w*) re: 1µPa@1m" is not a standard metric but was an attempt by the authors to weight broadband noise for the inverse shape of the relevant audiogram. Not equal energy but equal perceived loudness for the subject, so direct comparison to dB SEL_{CUM} is not precise, but approximate (time dimension notwithstanding).
[25] Kastelein et.al. (2006) Continuously varying frequency sound, Direct Sequence Spread Spectrum, frequency sweep, and Modulated Frequency Shift Key signals.

It is noted in the Draft Guidance document that there are no data on PTS in marine mammals, but the estimated PTS levels used in the DEIS, like the PTS figures from the Verboom and Kastelein (2005) study are extrapolations – extrapolating from behavioral responses to noise exposure of young, healthy marine mammals against known human and terrestrial mammal auditory responses. The disparity between the TTS figures used by Verboom and Kastelein (2005) and the numbers used in the DEIS indicate a high degree of scientific uncertainty in the models and extrapolation methods used in both sets of assumptions. I am more inclined to accept the Verboom and Kastelein (2005) data because they are inherently more precautionary in that they examine the thresholds of behavioral response, not the upper limits of physiological response.

PTS Thresholds based on terrestrial and hearing generalist species:

Regarding the estimation of PTS onset relative to TTS levels used in the DEIS, I find the statement that TTS extrapolation for PTS onset "based on data from humans and terrestrial mammals"[26] a bit troubling. Firstly because beyond this cursory statement there is no explanation of the way the relationship was derived. Due to its historic use throughout the NMFS DEIS's over the years[27] I presume they are linear regressions adapted from the W.D. Ward et. al. (1960) papers [28] (also cited in the Draft Guidance document). Ward's data were all taken from human subjects – highly visually adapted terrestrial mammals. Ward's research indicates a threshold of PTS by examining the maximum recoverable TTS in human and finds that humans can recover from a TTS of 50dB without permanently damaging their hearing. The Ward studies are "conservatively" tempered in the legacy DEIS's (see ref. 19) by incorporating a study of cats by Miller et.al. (1963)[29] that indicates that cat's threshold of PTS is at 40dB recoverable TTS.[30]

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[26] Draft Guidance document section 2.3.4 "Development of TTS and PTS Onset Acoustic Threshold Levels" item #6

[27] e.g. "Gulf of Alaska Navy Training Activities Preliminary Final Environmental Impact Statement/ Overseas Environmental Impact Statement." March 2011. Section 3.8-88–92 "Relationship between TTS and PTS, and "Overseas Environmental Impact Statement/Environmental Impact Statement. Undersea Warfare Training Range." October 2005. 4.3.3.2 Relationship Between TTS and PTS

[28] e.g.: Ward, W.D. "Recovery from high values of temporary threshold shift." J. Acoust. Soc. Am., 1960. Vol. 32:497–500.

[29] Miller, J.D., C.S. Watson, and W.P. Covell. 1963. "Deafening effects of noise on the cat."Acta Oto-Laryngologica Supplement Vol. 176:1–91.

[30] The Gulf of Alaska DEIS states further that "A variety of terrestrial mammal data sources point toward 40 dB as a reasonable estimate of the largest amount of TS that may be induced without PTS" though no citations are provided to substantiate this statement. The Undersea Warfare Training Range DEIS cites Kryter et al. (1966) stated: "A TTS that approaches or exceeds 40 dB can be taken as a signal that danger to hearing is imminent." Then the DEIS speculates: "These data indicate that TSs up to 40 to 50 dB may be induced without PTS, and that 40 dB is a reasonable upper limit for TS to prevent PTS."

The cat is also a highly visually adapted terrestrial animal, though it is more dependent on aurality than humans.[31] One correlation that can be deduced here is that animals that are more dependent of sound cues are less able to recover from extreme TTS. Thus if there is a 10 dB disparity in recovery levels between humans (50dB difference on onset of TTS and PTS) and cats (40dB difference on onset of TTS and PTS), it might reasonably follow that cetaceans who rely almost exclusively on acoustical cues would be even less likely to recover from extreme TTS. While we don't know what these differences are between these onset thresholds, it is appropriate to bear in mind that this framing again calls in the precautionary principal; inasmuch as we should assume harm where data does not exist.

The threshold difference between TTS and PTS vary in the Draft Guidance document tables, depending on whether the exposures are weighted or un-weighted, which demonstrate a more thorough evaluation of the literature than what had been used in the legacy guidelines. In the threshold tables the level difference between onset of TTS and onset of PTS thresholds are 15dB for impulsive noise exposure, and 20dB for non-impulsive noise exposure (14dB for the pinnepeds) in all frequency classes of animals.

While we appreciate that the extrapolations used to derive onset of PTS from onset of TTS are much more conservative than what has been used in the legacy guidelines, they are based on assumptions that are still of questionable validity inasmuch as they are based on extrapolated models that meld terrestrial, highly visual animals with (mostly) old, test-weary odontocetes. I feel that these assumptions provide a poor stand-in for a diverse variety of wild marine mammals, in their own habitat, being subjected to extreme levels of noise that they are not biologically adapted to or trained to expect.

Current data on long-term neural damage from "TTS" not included in the DEIS:

Additionally, while the Draft Guidance document does allude to the Kujawa and Liberman (2009) [32] and Lin et. al. (2011)[33] findings to the that "temporary" threshold shift is a predictor of a longer-term permanent damage to the inner hair cell ganglion, these findings are "soft-pedaled" in the document for wont of more data.[34] This position flies in the face of the precautionary principal – particularly in light of the knowledge that TTS is NOT "temporary"

[31] Ralph E. Beitel "Acoustic pursuit of invisible moving targets by cats" JASA – 1996. Vol.105(6) p.3449 This paper indicates that cats will follow acoustic cues without needing to visually identify the cue, unlike humans, who will use an auditory cue to help localize a source of noise which they will then "look for the source."

[32] Kujawa, S.G., and M.C. Liberman. 2009. Adding insult to injury: Cochlear nerve degeneration after "temporary" noise-induced hearing loss. The Journal of Neuroscience 29:14077-2

[33] Lin, H.W., A.C. Furman, S.G. Kujawa, and M.C. Liberman. 2011. Primary neural degeneration in the guinea pig cochlea after reversible noise-induced threshold shift. Journal of the Association for Research in Otolaryngology 12:605-616.

[34] Draft Guidance document section 3.2.1 Temporary Threshold Shift Acoustic Threshold Levels: "It is not known whether smaller levels of TTS would lead to similar changes. NOAA acknowledges the complexity of noise exposure on the nervous system, and will re-examine this issue as more data become available."

and thus TTS is a "Level A take" We should be confident that there is true recoverability of compromised hearing which does not cause long-term synaptic damage before we abuse these animals − to later find that the abuse causes irreversible harm. I suspect than once any of the SPAWARS subjects dies, a histology of their auditory nervous system will tell us volumes about the TTS and PTS assumptions that have been made using these animals.

SEL_{CUM} accumulation period modeled for convenience but not substantiated by the literature:

Regarding setting the baseline for the SEL_{CUM} metric (Draft Guidance document 2.3.1.1 Recommended Baseline Accumulation Period), while helpful for modeling simplification, we find this whole section troubling. Using a 24 hour accumulation window is only a convenience which only has meaning in terms of how we set our watches; exposed animals do not "clear the stack" after 24 hours and start anew. Accumulation of sound form the purposes of SEL_{CUM} should continue as long as the sound continues. This is particularly germane as the noises we are using in the ocean are increasingly becoming continuous – from the "around the clock" seismic surveys, to the increasing array of autonomous vehicles and stationary equipment, to the continuously operating communication and navigation beacons.

"Avoidance behavior" used as an exposure mitigation strategy:

We also find it troubling that this section is loosely hinged on the idea of "avoidance behavior" being a mitigating factor in the exposure. With the understanding that the Draft Guidance document is specifically about MMPA "Level A Takes" and not behavioral impacts Castellote et.al. (2010) notes that seismic survey noise disrupted an entire migration season of fin whales. In this case the avoidance behavior was at cause for a loss of entire breeding year (which is not strictly physical damage to the organism but does have a profound bearing on survival). That this "avoidance behavior" occurred at hundreds of kilometers from the airgun source points to a fallacy in the assumption that animals can escape the impacts of noise by moving out of the noise field. It may be that case that animals would avoid the most direct physiological impacts of noise by moving away from the source, although this is not always the case as commonly seen in dolphins that gambol in the bow waves of ships and in the "diner bell" effect of net predator pinnipeds[35] that for one reason or another have elected not to avoid noise exposure. Thus "avoidance behavior" cannot be relied upon as a mitigation strategy and should not be incorporated into any exposure models.

This brings forth a larger concern about framing. It is well known that behavioral responses to any stimulus are dependent on situations and circumstances; courting animals will be less

[35] Jefferson, T. A. and B. E. Curry, 1996, "Acoustic methods of reducing or eliminating marine mammal-fishery interactions: do they work?" Ocean and Coastal Management 31:41–70

disturbed by alien noises than resting animals; net predator animals will even be attracted to noises designed to harass them if they know that food is available for the mere cost of their suffering.[cit.35] Regulators like clear guidelines, but by viewing all animals mechanistically we are assuming that all animals will predictably respond, or be impacted similarly. Segregating animals into frequency groups is an improvement – expressing our deeper understanding of marine mammal bioacoustics derived over the past decade of research, but given the paucity of quality data the guidelines remain a very blunt gauge to measure our impacts on the marine acoustic habitat.

In summary, while we find the Draft Guidance document a significant improvement over the previous guidelines and we welcome its final implementation, as it is currently written there remain many shortcomings. We are pleased that the document includes provisions and a schedule for revising as more data become available, because it is clear that much data is lacking and significant revisions will be required.

The following points have been detailed in the foregoing review:

- Where data are lacking, assume harm until the data clearly indicates otherwise.
- All models for TTS depend on very few animals and thus are incomplete.
- The animals from which the TTS data are derived are captive and test-regime habituated and thus are a poor proxy for their wild counterparts.
- The four species of captive odontocetes are a data-poor approximation of the 125+ species of all cetaceans.
- The two species of phocids found in the Draft Guidance document are commonly found in close proximity to human population centers and are not good stand-ins for Arctic and Antarctic seals.
- Captive animal's provenance further segregates them from wild animals due to their differing survival tactics relative to food provision and predator awareness.
- Signals used in auditory test regimes are not representative of typical exposure signals found in the field and this are inadequate models for actual exposure impacts.
- Where there is a disparity in TTS onset thresholds, the lower thresholds should be used, not cast out as "outliers." (Draft Guidance document App. B Section 2.2 III)
- Currently there is no metric to express various sound qualities that do have bearing on impacts (e.g. rise time, kurtosis).
- Extrapolating PTS from TTS by way of terrestrial, visually dominant animals (from Ward et.al. 1960 and Miller e.al. 1963) requires a deeper discussion and a precautionary approach.
- Findings by Kujawa and Liberman (2009) and Lin et.al. (2011) indicate that TTS is <u>not</u> temporary, but is an injury and should be classified as a MMPA "Level A Take." This data has been excluded from the Draft Guidance document because there are no equivalent data on marine mammals and lower TTS levels. It should be included.

- SEL_{CUM} accumulation period should not "dump and reset" after 24 hours (for complex models) or integrate over 1 hour (for simple models); rather accumulation should continue for the entire duration of the exposure.
- Avoidance behavior of an exposed animal should not be incorporated into any mitigation model.

There is a larger philosophical discussion here that while our focus on regulatory thresholds does drive the very reason we are engaged in this exercise, in attempting to find clear numeric guidance we sometimes lose track of our relationship with our mutually inhabited marine (and terrestrial) habitats. The noise exposure guidelines we have in place for our own neighborhoods are not based on physiological damage to our neighbor; rather they are based on annoyance. Our neighbor's "ability to recover their hearing sensitivity" from acoustical assault is not an acceptable threshold for our less-than-neighborly noise-making behavior. So why should we believe it is acceptable to expose clearly sentient marine animals to noises that compromise their sensory systems?

This is not just sentimentality, because as we understand the interdependence of all life on our planet it is becoming increasingly clear that as we compromise the habitats of other life forms on the planet we are also compromising our own habitat, and that without a healthy and robust natural environment no amount of money or oil will improve the quality of our own civilization or our engagement with the natural world upon which we depend.

Sincerely,

Michael Stocker
Director
Ocean Conservation Research

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September 14, 2015

Amy R. Scholik-Schlomer
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1315 East West Highway
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Re: NOAA-NMFS-2013-0177 Acoustical Guidelines – OCR comments

Dear Amy R. Scholik-Schlomer,

We appreciate this opportunity to review and comment on the revised 2013 Acoustical Guidelines determining Marine Mammal Protection Act (MMPA) Level A exposure guidelines for marine mammals (hereinafter "Guidelines"). We are pleased that this second draft addresses many of the concerns and reflects some of the methodologies we expressed in our February 2014 comments on the first draft of the Guidelines.[1]

But some of our concerns remain, particularly in terms of the paucity of information – too few species, too few actual animals, most animals are captive stock habituated to acoustical operant conditioning regimes, and extrapolations from odontocetes to model mysticetes (addressed below). But these issues have been openly and substantially addressed in the second draft guidelines. The inclusion of Finneran (2015) derivation of weighting functions[2] to fill in the models and substantiate the data gaps is a helpful addition to the Guidelines.

We also find it encouraging that the Guidelines include many open windows to bring in the most current scientific data as it becomes available, although how this data will be incorporated and used to revise the Guidelines in a timely manner remains unarticulated. (Section IV of the Guidelines does not indicate when or how often any new data will be considered, incorporated, and reviewed.) We trust there will be opportunities within the scientific community to determine when new compelling data would warrant review and revision of the Guidelines.

So our overall critique recognizes that while these Guidelines have some shortcomings, they are a significant improvement over the legacy guidelines. And while the more refined

[1] NOAA Draft Acoustic Guidance 2013 OCR Comments. Feb. 2014
[2] Finneran, J.J. 2015. *Auditory weighting functions and TTS/PTS exposure functions for 39 cetaceans and marine carnivores.* July 2015. San Diego: SSC Pacific.

approach of segregating marine mammals into five different hearing regimes will likely lead to lower estimates of "Level A Takes" across all species in future Environmental Impact Statements that use these guidelines, the estimates will more closely represent actual takes. This will provide the added benefit that action proponents will be less likely to be skeptical of adhering to the Guidelines[3] because it reconciles regulatory dissonances with animal behaviors such as dolphins riding the bow waves of seismic airgun survey vessels.

While the improvements are encouraging, from a philosophical standpoint establishing exposure guidelines for impulsive and non-impulsive thresholds for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) presupposes that these thresholds will be met and exceeded. We find the premise of this unconscionable, gruesome, and the nadir of human hubris that suggests there is some value continuum that would allow for the maiming of animals which any marine mammologist knows is not only sentient, but capable of complex value judgements and emotions. i.e. there is no equivalent acoustical guidelines for residential noise ordinances.

Given that the request for this review was not a request for philosophical criticism we submit the foregoing critique in hopes that it further improves the adopted guidelines.

Review: Typographical errors

First - for housekeeping purposes: There seem to be some numerical anomalies that appear to have been generated out of two typographical errors in the Finneran (2015) document. The first inconsistency is found in Table 3 and Table 4 on page 16 of the Finneran paper (p. 75 in the Guidelines) across the Phocid in-water (PW) factors used in the curve-fitting equations wherein the low frequency cutoff parameter F_1 is set to 9510kHz in Table 3 and 4820kHz in Table 4. Additionally (also in the PW factors) the threshold fitting parameter T_0 is anomalously low at -46dB in Table 4. This also appears on Table 3 p.18 of the Guidelines (p. 25 of the pdf) where F_1 is set to 4820kHz. I was unable to find artifacts of the low T_0 in the Guidelines, perhaps because it was caught in the curves at some point, but these factors should be traced back to make sure they don't incorrectly influence the Guidelines.

Additionally in Table ES 1 p.2 (p.6 in the pdf) and E1 p. 136 (143 of pdf) Otariid Pinnipeds PTS Underwater Exposure threshold for SEL_{CUM} seems high at 218dB.The differences between other peak and cumulative PTS exposure values in all other cases run around 30dB, this one value difference of 12dB seems anomalous and should be verified.

[3] William Yancy Brown *BOEM Science Notes* http://www.boem.gov/BOEM-Science-Note-August-2014/

Review: Critique

As mentioned above, we remain concerned that so much marine mammal protection is resting on data from so few animals and so few species. This is particularly the case with determining the weighting curves for the Low Frequency cetaceans – which is based on some informed but speculative understanding of the hearing physiology of mysticetes (based on peer-reviewed models,[4] non-peer-reviewed models,[5] and peer-reviewed predictions[6]), vocalizations, and according to the Guidelines Section II:2.1 "taxonomy and behavioral responses to sound" taken from a white paper review[7] of a 1990 paper.[8]

As much more verifiable behavioral data are available on mysticete responses to sound it is possible that more accurate correlations might be made to derive TTS and thus PTS thresholds for LF cetaceans based on these data.[9]

The guidelines do make a useful distinction and thus different exposure thresholds for impulsive and non-impulsive noise (see Appendix 1.0), these qualities do not accurately represent other characteristics such as signal kurtosis which have greater bearing on physical assault/damage to hearing and body tissues.[10]

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[4] Cranford, T.W. and P. Krysl. (2015) Fin whale sound reception mechanisms: *Skull vibration enables low frequency hearing.* PLoS ONE 10:1-17.

[5] e.g. Ketten, D.R., and D.C. Mountain. 2014. *Inner ear frequency maps: First stage audiograms of low to infrasonic hearing in mysticetes.* Presentation at ESOMM 2014, Amsterdam, Netherlands, and Ketten D.R., J.J. Arruda, S.R. Cramer, A.L. Zosuls, and D.C. Mountain. 2013. *Biomechanical evidence of low to infrasonic hearing in mysticetes: Implications for impacts* (poster). 30th International workshop cetacean echolocation and outer space neutrinos: Ethology and physics for an interdisciplinary approach to underwater bioacoustics and astrophysical particles detection.

[6] Parks, S., D.R. Ketten, J.T. O'Malley, and J. Arruda.2007. *Anatomical Predictions of Hearing in the North Atlantic Right Whale.* The Anatomical Record 290:734-744

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[9] e.g.: Goldbogen JA, Southall BL, DeRuiter SL, Calambokidis J, Friedlaender AS, Hazen EL, Falcone EA, Schorr GS, Douglas A, Moretti DJ, Kyburg C, McKenna MF, Tyack PL.2013 *Blue whales respond to simulated mid-frequency military sonar.* Proc R Soc B 280: 20130657. Blackwell SB, Nations CS, McDonald TL, Thode AM, Mathias D, Kim KH, et al. (2015) *Effects of Airgun Sounds on Bowhead Whale Calling Rates: Evidence for Two Behavioral Thresholds.* PLoS ONE 10(6): e0125720. Lucia Di Iorio, Christopher W. Clark *Exposure to seismic survey alters blue whale acoustic communication*. Biol. Lett. (2010) 6, 51–54. Manuel Castellote, Christopher W. Clark, Marc O. Lammers 2012 *Acoustic and behavioral changes by fin whales (Balaenoptera physalus) in response to shipping and airgun noise.* Biological Conservation 147 (2012) 115–122. Cerchio S, Strindberg S, Collins T, Bennett C, Rosenbaum H, (2014) *Seismic Surveys Negatively Affect Humpback Whale Singing Activity off Northern Angola.* PLoS ONE 9(3): e86464

[10] Dolan, T. R., Murphy, R. J., and Ades, H. W. (1976). "A comparison of the permanent deleterious effects of intense noise on the chinchilla resulting from either continuous or intermittent exposure," in Effects of Noise on Hearing, edited by Henderson, D. Hamernik, R. P. Dosanjh, and D. S. Mills (Raven, New York), pp. 327–340

Quantifiable sound "qualities" (Frequency, Duration, Cumulative Exposure) identified in Table 9 p.30 are useful, but again Kurtosis as a quantifiable quality is not identified. It is mentioned (and dismissed) in Appendix B particularly around the discussion of peak pressure to pulse duration and rise times and "not being practical to implement" without giving an explanation as to why they are impractical.

It is true that using Kurtosis in the time domain – particularly evaluating single impulses, or a series of single impulses along a pulse stream is not very practical. But this can be easily remedied by looking at kurtosis in the frequency domain (frequency = time^{-1}) where the metric can be useful in impulse, non-impulse, and continuous noise sources.

A repeatable metric can be easily derived by evaluating any broadband the impulse signal through Fast Fourier Transform (FFT) frequency analysis and evaluating the filter outputs for amplitude variability across the filter bins. In this setting higher frequency components of an impulse signal would indicate faster rise times.

The kurtosis of non- impulse or continuous signals can be further quantified evaluating the amplitude variability of each FFT filter bin over time and across all of the filter bins. Placing the output of each FFT frequency bin into a frequency/amplitude array will yield a distribution that will express rise-time and peak to duration value set that would directly correlate with kurtosis inasmuch as a high peak-to-duration ratio would equate to high kurtosis, and a low peak-to-duration ratio would equate to lower kurtosis.

For continuous signals the FFT bin outputs can be evaluated in a three-dimensional array (frequency, amplitude, and time) and evaluating the variability of amplitudes in each bin over time. (see Appendix 1.1) In this manner the high kurtosis of highly variable or "peaky" signals associated with antagonistic[11] and harmful sounds[12] can be numerically identified. This would yield a numeric that could be associated with damaging characteristics of sound – similar to the proposed "Peak Amplitude to Pulse Duration metric," but without the need to "bring out the calipers."

Regardless of how these characteristics are expressed it is useful that sound qualities are being identified as an indicator of potential damage. Although it remains to be seen how these metrics will be incorporated into regulatory thresholds, the appearance of this discussion is promising.

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[11] Sukhbinder Kumar, Helen M. Forster, Peter Bailey and Timothy D. Griffiths (2008) *Mapping unpleasantness of sounds to their auditory representation* J. Acoust. Soc. Am. 124:6

[12] Hamernik, R.P., W. Qiu, and B. Davis. 2003. *The effects of the amplitude distribution of 4 equal energy exposures on noise-induced hearing loss: The kurtosis metric.* Journal 5 of the Acoustical Society of America 114:386-395.

In section 2.3.3.1 “Cumulative Sound Exposure Level (SEL_{CUM}) Metric, per our original concerns expressed on the Draft Acoustic Guidelines remain. Using a 24 hour accumulation window is only a convenience which only has meaning in terms of how we set our watches; exposed animals do not “clear the stack” after 24 hours and start anew. Accumulation of sound for the purposes of SEL_{CUM} should continue as long as the sound continues if the noise generated is above the “Effective Quiet” described in the Guidelines.[13] The question of “how much above” is a matter for further research, but if hearing acuity is continuously compromised by a relentless noise source in an animal’s usual habitat, the distinction of whether the noise is “masking” or their hearing is neuro-mechanically compromised may only be academic.

This is particularly germane as the noises we are deploying in the ocean are increasingly becoming continuous – from the “around the clock” seismic surveys, the expanding fleet of acoustically-controlled autonomous vehicles, seafloor mounted processing equipment, and continuously operating communication and navigation beacons. Cumulative sound exposure in the Guidelines Section 2.3.3.1 are limited to evaluating single sounds sources – a point that is recognized in the section. But it is becoming increasingly germane that the noise levels of entire soundscapes be incorporated into a cumulative exposure metric because offshore industrial operations are typically deploying arrays of devices and fields of equipment all of which continuously generate noise.

For example a common positioning beacon generates streams of navigation data at 205dB centered around 22kHz (e.g. Kongsberg positioning beacons[14]). At these frequencies a single beacon would only induce an MMPA Level A take within 12-15 meters of the device, but as these and other complimentary devices are being deployed in synchronized arrays of four to six units and are operating continuously with a designed effective range of 10km, the entire array of devices needs to be evaluated as a continuous source of noise, not as a four to six separate noise sources. This same would hold true for seafloor mounted processing equipment used in extraction industries (such as materials separators, reinjection pumps, and manifolds) which operate as a complimentary set of equipment, not an assortment of discrete pieces of gear.

This argument on cumulative exposure intersects section 3.2.2 “Stationary Sources” description in the Guidelines under two conditions. The first condition is when the exposed animal may deliberately come within the “24-h Accumulated Isopleth” such as when pinnipeds remain in auditory “harm’s way” if their incentive is feeding.[15] The cited situation

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[13] Guidelines Appendix C Section I:1.11

[14] Kongsberg Acoustic underwater positioning and navigation systems HiPAP and HPR

[15] Olesiuk, P. E., Nichol, L.M., Sowden, M. J., and Ford, J. K. B. (1995). *Effect of sounds generated by acoustic deterrent device on the abundance and distribution of harbor porpoise (Phocoena phocoena) in Retreat Passage, British Columbia*. Dept. of Fisheries and Oceans Canada, Pacific Biological Station,

refers to the “dinner bell” effect of acoustic harassment devices which are specifically designed to repel animals preying on fishing and aquaculture operations and thus subject to a different ethic than unintentional exposures. But this needs to be considered when an action proponent applies for a harassment authorization. The context of Acoustic Harassment Devices (AHDs) introduces the second condition where stationary sources that would otherwise subject animals to Level A takes but due to avoidance of the sources, the noises end up colonizing habitat and displacing animals that would otherwise inhabit the area.[16] While avoidance response falls under Level B “behavioral” takes, if a noise source is continuous and displaces an animal from critical feeding habitat it would also compromise survival success[17] which puts the noise along a continuum between Level A and Level B takes.

Appendix C section on research needed is useful guidance. Sound exposure in more realistic conditions and using actual sounds encountered will help refine actual impacts, but missing is a quantitative evaluation of noise characteristics associated with hearing damage or compromise. A metric correlating sound qualities with known impacts would be extremely useful in further tailoring the acoustic guidelines to actual impacts and modifying the noises of human enterprise to be less impactive.

We find the alternative threshold instructions practical and workable, and will save much effort on the part of action proponents who do not have the assets to bring the more tailored M-derived exposure thresholds to their impact assessments. I suspect that once the new acoustic guidelines are implemented that tools will be designed and implemented to facilitate their use.

Summary

We find that the guidelines are a definite improvement over the legacy guidelines and applaud the significant effort to both craft the premise of “M-derived” curves and provide a simpler “alternative” thresholds should they be useful. We also appreciate the efforts to incorporate our comments and concerns, and the comments of others from the first draft. It is also encouraging that there are repeated references to incorporating new scientific data into the Guidelines as they become available. The key points in our critique above are:

Nanaimo BC V9R 5K6 Canada. 47pp. and Carretta, James V.; Barlow, Jay Source *Long-Term Effectiveness, Failure Rates, and “Dinner Bell” Properties of Acoustic Pingers in a Gillnet Fishery*: Marine Technology Society Journal, Volume 45, Number 5, September/October 2011, pp. 7-19(13)

[16] Alexandra B. Morton and Helena K. Symonds (2002) *Displacement of Orcinus orca (L.) by high amplitude sound in British Columbia, Canada* ICES Journal of Marine Science, 59: 71–80. doi:10.1006/jmsc.2001.1136

[17] Clinton D Francis, Catherine P Ortega, Alexander Cruz (2009) *Noise pollution changes avian communities and species interactions* J. Current Biology v. 19:6

- Weighting curves of LF cetaceans should be updated and revised predicated on most current behavioral responses (e.g. avoidance behavior) to actual sounds in the field.
- Identifying sound qualities as an impact predictor is encouraging and should be further developed.
- We suggest incorporating signal kurtosis as a metric to quantify sound qualities
- Using the 24hr cumulative exposure method does not accurately express the impacts of increasingly louder continuous noises being introduced into the sea. More work needs to be done on this.
- Cumulative sound exposure needs to accommodate for entire “soundscapes” as noise sources as well as individual pieces of equipment.
- Stationary, continuous sources of noise capable of inflicting Level A impacts need to be considered in terms of the population impacts of habitat displacement, not just in terms of the probability of inflicting a Level A exposure.

As the Guidelines have provisions for updating and revising as more data become available we endorse the implementation of these guideline forthwith

Sincerely,

Michael Stocker
Director,
Ocean Conservation Research

These comments are endorsed by the following individuals and organizations:

Richard Charter
Coastal Coordination Program
The Ocean Foundation

Hamilton Davis
Energy Program Director
Coastal Conservation League
Charleston, SC

Delice Calcote
Executive Director
Alaska Inter-Tribal Council

Emily E. Stolarcyk
Program Manager
Eyak Preservation Council

APPENDIX

1.0 Kurtosis Metric

Kurtosis (β) describes the shape of a probability distribution on an x-y graph. It is equated with the "peakedness" of the curve as a product of the distribution of observed data around the mean.

$$\beta = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{X_i - \bar{X}}{S}\right)^4$$

Where:

> n = the number of elements in the distribution.
> S = Standard deviation
> X= are the discrete peaks in data stream (for sound, the pressure/time waveform) over some interval of time.

Kurtosis then is an expression whether the data are peaked or flat relative to a Gaussian distribution. Datasets with a high kurtosis (β >3) tend to have a distinct peak near the mean, declining rapidly below and above the mean (leptokurtic). Data with low kurtosis (β <3) tend to have a low rise around the mean (platykurtic). Gaussian distribution β = 3 (mesokurtic).

Kurtosis then is correlated to a high degree of variability in either a static or streaming dataset. If an acoustical input is used as a streaming data set then a 1kHz sinusoid would be platykurtic, band-limited pink noise or would be mesokurtic, and grinding brakes would be leptokurtic. Other leptokurtic sounds would include babies screaming, earthquakes and avalanches, or fire alarms.

1.1 Using FFT to derive signal kurtosis:

Fast Fourier Transform (FFT) is a method used to break down complex signals into their component parts in the frequency domain. In practice a signal is placed in an array of frequency-centered filters of a defined bandwidth across the entire bandwidth of the signal of interest. The amplitude output of these filter "bins" yields the amplitude of each frequency component of the input signal. The amplitude values of the bins can then be statistically evaluated to yield a kurtosis metric by the following methodology:

The amplitude numeric of each filter bin is placed into an averaging array so that each bin average can be analyzed over a time interval *i* across the bin query frequency f_Q - which is related to the bin center frequency "f" by:

$$f_Q = \left(\frac{1}{n}\sum_{i=1/f}^{n} f\right)$$

The sample time t_s of the analysis is associated with the low frequency cutoff f_L of the system bandwidth by being higher than twice the lowest required frequency. The sampling frequency f_s of the system is greater than twice the highest required signal frequency f_H so that the bandwidth of the system is defined by:

$$t_s > 2 * f_L \text{ and } f_s > 2 * f_\mathrm{H}$$

The average output of each bin is sent to an array and analyzed over the cumulative time window “T” typically one second to yield signal kurtosis in the time domain $\beta(t)$

OCEAN CONSERVATION RESEARCH
Science and technology serving the sea

March 28, 2016

Ms. Nicole LeBoeuf, Chief
Marine Mammal and Sea Turtle Conservation Division
Office of Protected Resources
National Marine Fisheries Service
Attn: Acoustic Guidance
1315 East-West Highway
Silver Spring, MD 20910-3226

Re: NOAA-NMFS-2013-0177 Comments on proposed changes to the Draft Guidance For Assessing The Effects Of Anthropogenic Sound On Marine Mammal Hearing

Dear Ms. LeBoeuf,

We appreciate being given an opportunity to review the proposed changes on the NMFS-OPR Draft Acoustical Guidelines (hereinafter "Guidelines") although we were a bit chagrinned to find the format of the "Proposed Changes" document to be in a narrative, ancillary document rather than a revised and annotated version of the actual draft. This necessitated our doing your work by jumping between the July 2015 Draft and the proposed changes. As "homework" goes this would be awarded an "incomplete."

This format also does not allow us to make sure that the typographical errors we indicated in our September 22, 2015 critique (of which there were many) have been properly addressed. This may not have been so annoying had we been afforded more than fourteen days to review the proposed changes, but having to review across and between these documents was unnecessarily time consuming.

I assume that if they did not show up in the proposed changes, the many concerns we expressed in our critique had no bearing on the revisions. This is unfortunate because our proposals were both modest, and reflect the best and most current available science on the impacts of noise – particularly noise characteristics on marine mammals. So while the guidelines are an improvement over the legacy guidelines, they still fall short of where the science sits on noise characteristics and hearing compromise. It would be useful to

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know that the efforts we put into our September 22 critique were at least reviewed and addressed.

We continue to be concerned on how the LF Cetacean audiograms are derived. While the revised exposure threshold curves are more conservation-minded than the curves originally proposed in the July 2015 Guidelines, they are still more a product of assumptions and conventions than of any substantiating research or evidence. For example; given that a preponderance of blue whale vocalization occur below 19Hz[1] and humpback whales also vocalize below the f_1 of 200Hz,[2] there is no reason that the LF weighting function should roll off at 200Hz.[3] In the absence of any other compelling evidence, logic (and precaution) would dictate that the LF weighting function would not roll off at all in the low frequency end of the weighting curve.

We remain concerned that our critique for the Guidelines section 2.3.3.1 "Cumulative Sound Exposure Level" (SEL_{CUM}) Metric has not been addressed in the proposed revisions. Reiterating our concern; using a 24 hour accumulation window is only a convenience which only has meaning in terms of how we set our watches; exposed animals do not "clear the stack" after 24 hours and start anew. Accumulation of sound for the purposes of SEL_{CUM} should continue as long as the sound continues if the noise generated is above the "Effective Quiet" described in the Guidelines.[4] The question of "how much above" is a matter for further research, but if hearing acuity is continuously compromised by a relentless noise source in an animal's usual habitat, the distinction of whether the noise is "masking" or their hearing is neuro-mechanically compromised may only be academic.

This is particularly germane as the noises we are deploying in the ocean are increasingly becoming continuous – from the "around the clock" seismic surveys, the expanding fleet of acoustically-controlled autonomous vehicles, seafloor mounted processing equipment, and continuously operating communication and navigation beacons. Cumulative sound exposure in the Guidelines Section 2.3.3.1 are limited to evaluating single sounds sources – a point that is recognized in the section. But it is becoming increasingly germane that the noise levels of entire soundscapes be incorporated into a cumulative exposure metric because offshore industrial operations are typically deploying arrays of devices and fields of equipment all of which continuously generate noise.

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[1] David K. Mellinger, Christopher W. Clark, *Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic* J. . Acoust. Soc. Am., Vol. 114, No. 2, August 2003

[2] James D. Darling *Low frequency, ca. 40 Hz, pulse trains recorded in the humpback whale assembly in Hawaii* J. Acoust. Soc. Am. 138 (5), November 2015

[3] Guidelines Table PC3 and Fig. PC3: *Summary of updated weighting function parameters (updates Main Document: Table 7; Appendix A: Table 8 from NOAA 2015a.*

[4] Guidelines Appendix C Section I:1.11

For example a common positioning beacon generates streams of navigation data at 205dB centered around 22kHz (e.g. Kongsberg positioning beacons[5]). At these frequencies a single beacon would only induce an MMPA Level A take within 12-15 meters of the device, but as these and other complimentary devices are being deployed in synchronized arrays of four to six units and are operating continuously with a designed effective range of 10km, the entire array of devices needs to be evaluated as a continuous source of noise, not as a four to six separate noise sources. This same would hold true for seafloor mounted processing equipment used in extraction industries (such as materials separators, reinjection pumps, and manifolds) which operate as a complimentary set of equipment, not an assortment of discrete pieces of gear.

This argument on cumulative exposure intersects section 3.2.2 "Stationary Sources" description in the Guidelines under two conditions. The first condition is when the exposed animal may deliberately come within the "24-h Accumulated Isopleth" such as when pinnipeds remain in auditory "harm's way" if their incentive is feeding.[6] The cited situation refers to the "dinner bell" effect of acoustic harassment devices which are specifically designed to repel animals preying on fishing and aquaculture operations and thus subject to a different ethic than unintentional exposures. But this needs to be considered when an action proponent applies for a harassment authorization. The context of Acoustic Harassment Devices (AHDs) introduces the second condition where stationary sources that would otherwise subject animals to Level A takes but due to avoidance of the sources, the noises end up colonizing habitat and displacing animals that would otherwise inhabit the area.[7] While avoidance response falls under Level B "behavioral" takes, if a noise source is continuous and displaces an animal from critical feeding habitat it would also compromise survival success[8] which puts the noise along a continuum between Level A and Level B takes.

We remain concerned that given what is known about the greater impacts of high kurtosis signals with equal energy of low kurtosis signals that there is still no consideration for

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[5] Kongsberg Acoustic underwater positioning and navigation systems HiPAP and HPR

[6] Olesiuk, P. E., Nichol, L.M., Sowden, M. J., and Ford, J. K. B. (1995). *Effect of sounds generated by acoustic deterrent device on the abundance and distribution of harbor porpoise (Phocoena phocoena) in Retreat Passage, British Columbia*. Dept. of Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo BC V9R 5K6 Canada. 47pp. and Carretta, James V.; Barlow, Jay Source *Long-Term Effectiveness, Failure Rates, and "Dinner Bell" Properties of Acoustic Pingers in a Gillnet Fishery*: Marine Technology Society Journal, Volume 45, Number 5, September/October 2011, pp. 7-19(13)

[7] Alexandra B. Morton and Helena K. Symonds (2002) *Displacement of Orcinus orca (L.) by high amplitude sound in British Columbia, Canada* ICES Journal of Marine Science, 59: 71–80. doi:10.1006/jmsc.2001.1136

[8] Clinton D Francis, Catherine P Ortega, Alexander Cruz (2009) *Noise pollution changes avian communities and species interactions* J. Current Biology v. 19:6

this fact.[9] Perhaps this is where terminology is seeking a numeric standard. Hopefully the provisions in the guidelines for more frequent review and updating will accommodate this metric and this standard as it becomes codified in the literature.

Regarding some of the systematic changes in the revision document: we concur that the white-beaked dolphins are best moved from the MF cetacean to the high-frequency (HF) cetacean functional hearing group (Section 2 in the proposed changes) and that recent harbor porpoise data should be included in the HF cetacean audiograms (Section 3 in the proposed changes). It also makes sense that non-representative animals such as hearing compromised pinnipeds should be removed from the datasets (Section 4 in the proposed changes), although this does little to assuage our concerns that so few animals –all captive, are being used as a proxy for many more species of non-captive animals living in an unbounded acoustical environment.

We do concur that peak (PK) metrics are not relevant to continuous or non-impulsive sounds (Section 5 in the proposed changes).

While these new guidelines and proposed revisions are an improvement over the legacy guidelines, there remains room for improvement. We understand that the Kurtosis Exposure Metric has not been standardized yet, but given that NOAA has taken liberties in defining a SEL_{CUM} metric with a "reset" after 24 hours,[10] it would not be much of a reach to extend the Equal Energy Hypothesis used in the guidelines[11] to include a consideration for signal kurtosis using published – albeit not standardized kurtosis metric.[12]

In light of what is likely and possible at this juncture, our dominant recommendation would be to revise the LF low frequency weighting curve to extend flat to 0Hz to assure that low frequency noises from shipping, industry, seismic surveys, acoustic tomography, and any future anthropogenic communication or navigation signals does not compromise the low frequency communications, biological, or geological signals that LF cetaceans may need to survive and thrive.

It would be helpful in the final analysis to have an opportunity to review the actual document with the proposed changes integrated into the guidelines before adopting them. Even in light of the provisions for more frequent scientific review and updating we

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[9] Hamernik, R.P., W. Qiu, and B. Davis. 2003. *The effects of the amplitude distribution of equal energy exposures on noise-induced hearing loss: The kurtosis metric.* J. of the Acoustical Society of America V.114:386-395.
[10] Guidelines: 2.3.3.1 Cumulative Sound Exposure Level (SEL_{cum}) Metric
[11] Ibid. *Equal Energy Hypothesis*
[12] Wei Qiu,a) Roger P. Hamernik, and Robert I. Davis. *The value of a kurtosis metric in estimating the hazard to hearing of complex industrial noise exposures* J. Acoust. Soc. Am. 133 (5), May 2013

suspect that future modifications run the risk of getting bogged down (as these very guidelines and revisions seemed to have suffered). Any typographical errors, oversights, or omissions may have a longer shelf life than would be desirable. Reviewing the final document, rather than having to cross-reference to a narrative, ancillary document would give us the assurance that at least for now we have a correct document representative of the most practicable acoustical exposure guidelines for “Level A Takes.”

Sincerely,

Michael Stocker
Director