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September 14, 2015

Amy R. Scholik-Schlomer
NMFS Protected Resources Acoustic Coordinator
1315 East West Highway
Silver Spring, MD 20910

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.

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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

[7] Reichmuth, C. 2007. Assessing the hearing capabilities of mysticete whales. A proposed 15 research strategy for the Joint Industry Programme on Sound and Marine Life (JIP link not available).

[8] Dahlheim, M.E., and D.K. Ljungblad. 1990. *Preliminary hearing study on gray whales 42 (Eschrichtius robustus) in the field*. Pages 335-346 in J. Thomas and R. Kastelein, eds. *Sensory Abilities of Cetaceans*. New York: Plenum Press.

[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

[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

Delice Calcote
Executive Director
Alaska Inter-Tribal Council

Hamilton Davis
Energy Program Director
Coastal Conservation League
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Emily E. Stolarcyk
Program Manager
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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 $\beta(t)$