Written Testimony of

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Thanks to Chairman Huffman and Ranking Member McClintock for inviting me to testify on the critically important topic of North Atlantic right whale and the potential impacts of noise from seismic airgun surveys on this highly endangered population. I am a biologist and engineer and the founding Director of the Bioacoustics Research Program (BRP) at the Cornell Lab of Ornithology, and the Imogene Johnson Senior Scientist in BRP and Graduate Professor in the Department of Neurobiology & Behavior at Cornell University. I have a long history of successfully working at the interface between science, applied engineering, industry, and regulations; all with the specific objectives of using science to understand the potential impacts of human activities on marine mammals and to inspire and enable the scientific conservation of marine wildlife and habitats. I was the Chief Marine Mammal Scientist for the U. S. Navy's Whales '93 dual-uses program, co-PI for the Low-Frequency Active Scientific Research Program (LFA-SRP), co-PI investigating the impacts of the Navy's mid-frequency active sonar on beaked whales, and lead the development and application of the near-real-time, auto-detection network for North Atlantic right whale acoustic monitoring in Boston shipping lanes (http://admin.nrwbuoys.org/, http://www.listenforwhales.org/). Up until my retirement from Cornell in December 2018, my research areas focus on the potential chronic influence of cumulative man-made noise sources on marine mammal distributions and behaviors. I remain deeply concerned about the continued loss of marine animal acoustic habitats as a result of multiple anthropogenic noise sources operating over large scales for extended periods of time. In collaboration with a small group of experts I am working to develop a new, ecologically based paradigm for evaluating and measuring biological risks from anthropogenic activities at individual and population levels.

Baleen whales are known for their remarkable abilities to sing and produce a wide variety of sounds for basic life function including communicating, foraging, mating, and navigating. Humpback whales were most likely the sirens of the sea whose songs were first heard by ancient mariners through the hulls and masts of their wooden ships. World War II initiated the dramatic development of underwater listening systems motivated by the need to detect, track and identify enemy submarines. Those early efforts at listening to the ocean for rare, but critical acoustic events indicative of a lethal aggressor were accompanied by a deluge of unknown sounds attributed to marine life. Who and what was responsible for all these sounds, and how could we be sure we could know which ones were biological and which were not? That acoustic detection challenge existed beneath a top-secret mantel throughout the period known as the cold war and remains today. However, beginning in the early 1970's, civilian scientists also started listening to the ocean. Today that effort has risen to the point where people outside the military are listening throughout large areas of the world's oceans with all types of recording systems throughout entire years. Furthermore, our technologies for analyzing those large data sets are becoming faster and more and more sophisticated. As a result, it is fair to say that the science of listening to the ocean has entered a period of expansive exploration of and rapid discovery in the bioacoustics of marine acoustic environments.

In 1971, Roger Payne and Scott McVay published a paper first describing humpback whale song compositions based on recordings collected by the US Navy off Bermuda (Payne and McVay 1971). Humpback songs are melodic, complex and primarily composed in a frequency range that we can hear and appreciate. Today scientists are beginning to describe the complex culture of whale communication using humpback songs and how these reveal the global nature of population interactions. In 1971, Roger Payne and Doug Webb also published a paper postulating that prior to the advent of modern shipping, the songs of fin whales could be heard across an ocean basin (Payne and Webb 1971). Fin whale songs are monotonously simple and so low in pitch as to be below our hearing range. The hypothesis that whale voices could be heard across an ocean was almost too grand to believe. Furthermore, the notion that noise from commercial shipping might be interfering with whale communication seemed far-fetched and was essentially forgotten. A point to be made by these recollections is that we (scientists included) can only understand the consequences of something if we can observe it. In the early years of ocean listening, where, when and how we listened were so limited in scope that our understandings of the complexities of sound in the living ocean were based on a few small, disparate pieces. We listened to bays or along short stretches of coastlines for the sounds we wanted to hear and understand (Clark and Clark 1980; Tyack 1983), and usually based on what we already knew was there and what hypothesis we wanted to evaluate.

In 1993, after the collapse of the Soviet Union, along with a handful of other scientists, I was given access to the US Navy's Sound Surveillance System (SOSUS). In those first days after my introduction to SOSUS, a Navy Commander helped me locate, track and record a singing blue whale out to distances of over a thousand miles. This memorable observation proved to me that the far-fetched Payne and Webb (1971) hypothesis was true: whales could be heard across an ocean basin. Commander Gagnon and I later published a paper on an extensive set of SOSUS observations on singing blue, fin, humpback and minke whales in the North Atlantic (Clark and Gagnon 2004). The SOSUS observation system that worked on ocean basin and decadal scales totally changed my comprehension of sound in the ocean. It expanded my experiential knowledge about whale acoustic behaviors from the traditional small scales of tens of miles and a few weeks into the much larger scales of many thousands of miles and years. I have often remarked that my ocean listening experiences using old technology vs the modern SOSUS technology, was like the difference between looking at the night sky with a toy telescope and the Hubble telescope. There were many important insights from those early SOSUS experiences, three of which stand out as monumental. One, I observed the immense distances over which sounds of different frequencies (i.e. pitches) traveled through the ocean's complex, refractive medium (Jensen et al. 1994). Two, I participated in a nearly continuous flow of discoveries that contradicted current thinking about where and when whales should occur in the ocean. Three, I witnessed the ubiquitous occurrence of human noises from commercial shipping and seismic explorations throughout enormous ocean regions. These experiences clearly demonstrated that our limited technologies and analysis tools, had significantly limited our abilities to observe the movements and behaviors of whales throughout their actual ocean-scale ranges. At the same time as I was having these incredible experiences listening at ocean basin scales, I started working with some of the world's best acoustic oceanographers as part of the Acoustic Thermometry of Ocean Climate (The ATOC Consortium 1998), which gave me the experience of learning about the intricacies of how, why and when low-frequency sound travels so efficiently through the ocean.

Those expansive insights occurred in the mid 1990's. Today, there is a growing community of scientists recording along the east coast of North America, from the Gulf of Mexico to the Grand Banks of Canada, and much of this effort is dedicated to documenting the acoustic occurrence of right whales (e.g. Davis et al. 2017) throughout a significant portion of their home range. A significant increase in this acoustic effort along the east coast has come from NOAA's scientific community that recognized that anthropogenic noises are affecting marine acoustic environments (Hatch et al. 2016) as well as the value of applied bioacoustics for monitoring, mitigation and management actions in support of the North Atlantic right whale population recovery. This NOAA scientific effort is complemented by a rising global awareness that anthropogenic noises are influencing acoustic environments, in general (Merchant et al. 2018 and impacting the acoustic habitats of specific populations (Williams et al. 2013), and must be included in assessments of cumulative impacts on marine wildlife (Williams et al. 2016, Lacy 2017).

Why is there so much concern about the potential influences of anthropogenic noise on marine mammals in general and the effects of seismic airgun array surveys on baleen whales specifically? There are two basic reasons. Firstly, it has been known since the time of Aristotle, and repeatedly confirmed by scientific study that marine mammals depend on sound to survive. In particular, there is compelling evidence that baleen whales (like right whale) have acute very-low-frequency (< 100 Hz) and infrasonic hearing (< 20 Hz; Ketten 1994). In particular, right whales are specifically well-adapted to and dependent upon listening to sounds in the low-frequency register (Ketten 1997, Parks 2007) for critical life functions such as communicating, navigating, mating, and maintaining social bonds (e.g. between mothers and calves).. Secondly, the very-low-frequency band (10-100 Hz) used by baleen whales overlaps substantially with the frequency bands in which seismic airgun energy is concentrated. In short, there are significant overlaps between whale sounds and the explosive noise produced by seismic airguns.

The occurrences of seismic airgun explosions from surveys throughout the North Atlantic have been well documented (Nieukirk et al. 2004) and are essentially unavoidable. This is true for recorders operating along the east coast of the United States and Canada, even recorders on the continental shelf in relatively shallow water (< 100m) (pers. Obs). All of these seismic surveys were conducted far, far away from the recorders; for example, off the Scotian shelf of Canada (1200 km), on and off the shelf of Surinam and French Guiana (3800 km), and on and off the shelf of western Ireland (5000 km). The coincident occurrence of acoustically active baleen whales and seismic airgun surveys has been observed in multiple oceans in very remote parts of the world (e.g., Nieukirk et al. 2012). These types of surveys have been happening throughout the last 20 years. To my knowledge there is no complete and reliable inventory of the possible hundreds of surveys conducted during this period.

Explosions from seismic airgun surveys have been recorded throughout the oceans, which is not surprising because the acoustic energy is so high and the frequency content so low. As scientists we are still in the process of understanding the long-term, large-scale, chronic, biological consequences of these surveys. Because these surveys occur offshore in distant places and influence the ocean's acoustic environment over such enormous spatial areas (> 200,000 km^2) and temporal scales (> 60-180 days), assessing the full scale of a sub-lethal impact is challenging. Lack of data is not evidence of lack of impact, especially when the space and time scales of existing observational schemes do not match to the scales of the seismic airgun noise. Papers reporting responses to distant seismic airgun noise by a species closely related to right whales are sobering.

This critical piece of evidence that raises my deep concern about seismic survey impacts on right whales comes from responses of bowhead whales (a species closely related to right whales) to seismic surveys (Blackwell et al. 2015). In that paper, the authors show that bowhead whale calling rates differ depending on the received level of airgun sounds from distant seismic surveys. Calling rates increased as soon as airgun pulses were detectable, then plateaued at increased received levels, began decreasing as received levels continued to rise, and then ceased entirely at levels that have been assumed to be approaching some sort of auditory harm. In other words, the whales have some capacity to first compensate for rising relative levels of noise exposure, but these levels are far below levels that have ever been of concern. They continue to have the significant response of decreasing calling rates at received levels that have only been of minor concern. In my opinion, these kinds of significant and consistent responses by an endangered species to seismic airgun sounds are alarming. Furthermore, there is nothing in any of the proposed monitoring or mitigation actions that could determine whether or not right whales modify their calling behavior in the face of noise from proposed seismic surveys. The inability to observe a likely response and therefore no data is not evidence of no response.

What do I know about right whale acoustic communication that leads me to be extremely concerned about North Atlantic right whales exposures to seismic airgun surveys?

For my PhD research, I conducted research on a population of southern right whales lived in the Golfo San Jose in southern Argentina. We simultaneously observed and listened to the whales every day for eighteen months, for two full seasons in great detail. I designed, built and installed an array of bottom hydrophones (underwater microphones) that allowed us to know which whales made which sounds. We learned to associate certain types of sounds with different behaviors, and built a very simple form of a sound dictionary. Of particular importance, we observed that the whales produced a distinctive class of calls as a means of maintaining contact and coming together into social groups. We referred to these sounds as "contact calls", and we validated the biological importance of contact calls by conducting experiments in which we used an underwater loudspeaker to play back different types of sounds. In response to play back of contact calls, distant whales called back, and many of those whales swam to the location of our underwater loudspeaker. I referred to this as counter-calling. From watching and listening to the whales, and learning the personalities of the different individuals, I determine that right whales are highly dependent upon sound to maintain social contact. This includes mothers and young calves that must maintain close proximity in order for the calf to nurse and increase the chances of the mother being able to protect her calf from killer whales. This dependence is ultimately dependent on listening for sounds under naturally quiet conditions.

In 2001, I initiated an acoustic research project on North Atlantic Right Whales in Cape Cod Bay, MA for which our team from Cornell deployed arrays of bottom recorders that we could use to detect, locate and track calling whales (Urazghildiiev & Clark 2009). I did this in part because other right whale scientists had been studying right whales there for some time (e.g. Hamilton and Mayo 1990, Ganley et al. 2018). Early on we discovered that on days when only a few right whales were acoustically present in the bay, aerial surveys did not see any whales (Clark et al. 2010). Continued research on right whale acoustics by a growing number of scientists has shown that North Atlantic right whales produce contact calls and counter call (Parks et al). In Cape cod Bay, I have observed cessation of right whale calling under high noise conditions as a result of both winter storms and shipping traffic. Calling right whales are detected throughout the year in regions and at times of year when they were not expected to occur (Hodge et al. 2015). Calling right whales are also detected far offshore where they were not expected to occur (Muirhead et al. 2018). What has happened over the last several decades is that the level of effort for acoustically observing right whales has expanded to include places along the entire east coast, many as far out as the continental shelf break.

Consider this as evidence for concern: All right whale populations in the Southern Hemisphere for which there are population data are increasing, while the North Atlantic population is not (Corkeron et al. 2018). There are now years in which more calves are born into the population of right whales off the western South Atlantic than there are in the total population of right whales in the North Atlantic Ocean. One very obvious difference between the regions in which these two populations occur is the level of commercial activities that influence the very-low-frequency marine acoustic environment; namely, the levels of anthropogenic noise from shipping traffic and seismic airgun surveys.

Finale: Right whales, as well as many marine animals (e.g. shrimp and commercial fishes), are highly dependent upon a naturally quiet ocean for basic life functions. Seismic airgun surveys off the east coast will significantly change the natural dynamics of that acoustic ecosystem. We know that the sounds from seismic airgun arrays propagate and change the acoustic environment throughout enormous areas. We know that a close species relative of the right whale, the bowhead whale starts to react to seismic noise at extraordinarily low received levels and continues reacting until it totally stops communicating. The present level of seismic airgun activity authorized by NMFS, both in terms of the area covered by a single survey and especially in terms of multiple surveys, is incredibly irresponsible and has a legitimate likelihood of causing significant impacts on right whale acoustic behavior. For right whales, such changes will increase the likelihood of mother-calf separations, decrease the likelihood of acoustic communications between whales, and impact all those acoustic behaviors that are essential for maintaining the population’s social cohesion and integrity. This is not about acute, physical harm to an individual. Rather, this is about the cost to a marginally surviving population as a result of aggregate chronic noise from seismic airgun surveys throughout large portions of the population's range throughout significant periods of the year.

References Cited

Payne, R. S., McVay, S. 1971 Songs of humpback whales. *Science* 173,: 585-597. (10.1126/science.173.3997.585)

Payne, R. and Webb, D. 1971. Orientation by means of long-range acoustic signaling in baleen whales. *Ann NY Acad Sci* 188:110-141.

Clark, C. W., Clark, J. M. 1980 Sound playback experiments with southern right whales (*Eubalaena australis*). *Science* 207: 663-665. (10.1126/science.207.4431.663)

Tyack, P. 1983 Differential response of humpback whales (*Megaptera novaeangliae*) to playback of song or social sounds. *Behav. Ecol. Sociobiology* 13: 49-55. (10.1007/BF00295075)

Clark, C. W., Gagnon, G. C. 2004 Low-frequency vocal behaviors of baleen whales in the North Atlantic: Insights from IUSS detections, locations and tracking from 1992 to 1996. *Journal of Underwater Acoust* 52:609-640.

Jensen, F.B., Kuperman, W.A., Porter, M.B., Schmidt, H. 1994. Computational Ocean Acoustics. New York: American Institute of Physics.

The ATOC Consortium. 1998. Ocean Climate Change: Comparison of Acoustic Tomography, Satellite Altimetry, and Modeling. *Science* 281: 1327-1332

Davis, G.E., Baumgartner, M.F., Bonnell, J.M., Bell, J., Berchok, C., Thornton, J.B., Brault, S., Buchanan, G., Charif, R.A., Cholewiak, D., Clark, C.W., Corkeron, P., Delarue, J., Dudzinski, K., Hatch, L., Hildebrand, J., Hodge, L., Klinck, H., Kraus, S., Martin, B., Mellinger, D.K., Moors-Murphy, H., Nieukirk, S., Nowacek, D., Parks, S., Read, A., Rice, A.N., Risch, D., Širović, A., Soldevilla, M., Stafford, K., Stanistreet, J., Summers, E., Todd, S., Warde, A., Van Parijs, S.M. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. *Scientific Reports* 7, No/ 13460, doi:10.1038/s41598-017-13359-3.

Hatch, L.T.,, Charles M. Wahle, C.M., Gedamke, J, Harrison, J., Laws, B., Moore, S.E., Stadler, J.H., Van Parijs, S.M. 2016. Can you hear me here? Managing acoustic habitat in US waters. *Endangered Species Research* 30: 171-186. doi: 10.3354/esr00722

Williams, R., Clark, C. W., Ponirakis, D. and Ashe, E. 2013. Acoustic quality of critical habitats for three threatened whale populations. *Anim. Cons.*, Zool. Soc. London. Pp. 12.

Williams, R., Thomas, L., Ashe, E., Clark, C. W., and Hammond. 2016. Gauging allowable harm limits to cumulative, sub-lethal effects of human activities on wildlife: A case-study approach using two whale populations. *Journal of Marine Policy*. Online.

Lacy, R.C., Williams, R., Ashe, E., Balcomb III, K.C., Brent, L.J.N., Clark, C.W., Croft, D.P., Giles, D.A., MacDuffee, M., Paquet, P. 2017. Evaluating anthropogenic threats to endangered killer whales to inform effective recovery plans. *Scientific Reports* 17, 14567, doi:10.1038/s41598-017-14471-0.

Ketten, D.R. 1994. Functional Analyses of Whale Ears: Adaptations for Underwater Hearing, *I.E.E.E Underwater Acoustics* vol. 1, pp. 264 - 270

Ketten, D.R. 1997. Structure and Function in Whale Ears. *Bioacoustics* 8: 103-136.

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

Nieukirk, S. L., Stafford, K. M., Mellinger, D. K., Dziak, R. P., and Fox, C. G. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. *Journal of the Acoustic Society of America* 115, 1832–1843.

Nieukirk, S. L., Mellinger, D. K., Moore, S. E., Klinck, K., Dziak, R. P., Goslin, J. 2012 Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999-2009. *Journal of the Acoustic Society of America* 131, 1102-1112. (10.1121/1.3672648)

Blackwell, S.B., C.S. Nations, T.L. McDonald, A.M. Thode, D. Mathias, K.H. Kim, C.R. Greene, Jr., and A.M. Macrander. 2015. Effects of airgun sounds on bowhead whale calling rates: Evidence for two behavioral thresholds. 10(6) *PLoS ONE* e0125720.doi:10.1371/ journal.pone.0125720.

Urazghildiiev, I. R., Clark, C. W., Krein T. P. and Parks, S. E. 2009. Detection and recognition of North Atlantic right whale contact calls in the presence of ambient noise. *IEEE J. Ocean Engineering* 34: 358-368.

Hamilton PK, Mayo CA (1990) Population characteristics of right whales (Eubalaena glacialis) observed in Cape Cod and Massachusetts Bays, 1978–1986. Rep *Int Whal Comm Spec Issue* 12: 203−208,

Ganley, L.C., Brault, S., Mayo, C.A. 2019. What we see is not what there is: estimating North Atlantic right whale Eubalaena glacialis local abundance. *Endangered Species Research* 38:101-113. https://doi.org/10.3354/esr00938

Clark, C. W., Brown, M. W. and Corkeron, P. 2010. Visual and acoustic surveys for North Atlantic right whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts, 2001-2005: Management implications. *Marine Mammal Science* 26: 837-854.

Hodge, K.B., C.A. Muirhead, J.L. Morano, C.W. Clark, and A.N. Rice. 2015. North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: implications for management. *Endangered Species Research* 28: 225-234.

Muirhead, C.A., Warde, A.M., Biedron, I.S., Mihnovets, N., Clark, C.W., and Rice, A.R. 2018. Seasonal Acoustic Occurrence of Blue, Fin, and North Atlantic Right Whales in the New York Bight. *Aquatic Conservation* 1-10. doi.org/10.1002/aqc.2874

Corkeron, P., P. Hamilton, J. Bannister, P. Best, C. Charlton, K.R. Groch, K. Findlay, V. Rowntree, E. Vermeulen, and R.M. Pace III. 2018. The recovery of North Atlantic right whales, *Eubalaena glacialis*, has been constrained by human-caused mortality. *Royal Society of Open Science* 5: 180892.