Selected Recent Scientific Papers (mainly Spring 2013 onward) Re Noise Impacts on Cetaceans, Particularly Beaked Whales

Lindy Weilgart, Ph.D.
Biology Dept.
Dalhousie University

7 November 2013

1) For the first time, population impacts in beaked whales have been indicated due to noise from naval sonar, based on two separate lines of evidence from a 15-yr. study: 1) lower abundance and fewer births of Blainville's beaked whales on a naval range vs. an area 170 km away in the Bahamas; and 2) an increase in temporary emigration immediately after a beaked whale stranding caused by the single passage of 5 naval vessels using sonar in 2000, suggesting possible displacement. This is especially noteworthy as it was actually Cuvier's beaked whales who stranded in much greater numbers than Blainville's.

Claridge, D.E. 2013. Population ecology of Blainville's beaked whales (*Mesoplodon densirostris*). Ph.D. Thesis, University of St. Andrew's, Fife, Scotland.

2) Most marine mammal strandings coincident with naval sonar exercises have involved Cuvier's beaked whales (*Ziphius cavirostris*). The first direct measurements of Cuvier's behavioral responses to mid-frequency active sonar signals showed a dramatic reaction at very low received levels (RLs; 89–127 dB re 1 μPa). Animals stopped normal swimming, feeding, and vocalizing, moving rapidly and silently away, extending both their dive duration and subsequent non-foraging intervals—a response which lasted 3-4 hrs. This behavior was considered by the authors to elevate the whales' stranding and decompression sickness risk, increase their energetic costs, and reduce their foraging efficiency. The significance here is the very low levels to which Cuvier's dramatically reacted. Previously, the levels were closer to 140 dB. These are 100,000 quieter.

DeRuiter, S.L., Southall, B.L., Calambokidis, J., Zimmer, W.M.X., Sadykova, D., Falcone, E.A., Friedlaender, A.S., Joseph, J.E., Moretti, D., Schorr, G.S., Thomas, L., Tyack, P.L. 2013. First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. Biol. Lett 9: 20130223.
http://dx.doi.org/10.1098/rsbl.2013.0223

3) Blue whales (*Balaenoptera musculus*) in feeding areas in Southern California were exposed to simulated mid-frequency military (1–10 kHz) sonars, and were significantly affected, especially during deep feeding modes. Responses ranged from cessation of deep feeding, increased swimming speed, and directed travel away from the noise. Disruption of feeding and displacement from high-quality prey patches could have significant impacts on baleen whale foraging ecology, individual fitness, and population health. The significance here is that a low

frequency specialist, the blue whale, is responding dramatically to mid frequencies, which is unexpected.

Goldbogen, J.A., Southall, B.L.,DeRuiter, S.L., Calambokidis, J., Friedlaender, A.S., Hazen, E.L., Falcone, E.A., Schorr, G.S., Douglas, A., Moretti, D.J., Kyburg, C., McKenna, M.F., Tyack, P.L. 2013. Blue whales respond to simulated mid-frequency military sonar. Proc. R. Soc. B 280: 20130657. http://dx.doi.org/10.1098/rspb.2013.0657

Evidence of Spatial Restrictions Protecting Beaked Whales From Noise

1) Sowerby's beaked whale showed 21% per year increase in sighting rates over 23 years, likely as a result of less noise disturbance (less loud fishing draggers, seismic surveys, supersonic overflights) since the area became an MPA in 2004.

Whitehead, H. 2013. Trends in cetacean abundance in the Gully submarine canyon, 1988–2011, highlight a 21% per year increase in Sowerby's beaked whales (*Mesoplodon bidens*). Canadian Journal of Zoology 91: 141-148.

2) No mass strandings since Spanish government's moratorium on naval exercises in Canary Islands in 2004.

Fernández, A., Arbelo, M., and Martín, V. 2013. No mass strandings since sonar ban. Nature 497: 317.

Other papers about marine mammal noise impacts

1) Broadband ship noise caused a significant change in beaked whale behavior up to at least 5.2 kilometers away from the vessel. The observed change could potentially correspond to a restriction in the movement of groups, a period of more directional travel, a reduction in the number of individuals clicking within the group, or a response to changes in prey movement.

Pirotta E, Milor R, Quick N, Moretti D, Di Marzio N, et al. (2012) Vessel Noise Affects Beaked Whale Behavior: Results of a Dedicated Acoustic Response
Study. PLoS ONE 7(8): e42535. doi:10.1371/journal.pone.0042535

2) In high noise conditions 20-Hz note duration shortened, bandwidth decreased, centre frequency decreased and peak frequency decreased. Similar results were obtained in 20-Hz song notes recorded during a 10-day seismic survey. During the first 72 h of the survey, a steady decrease in song received levels and bearings to singers indicated that whales moved away from the airgun array source and out of our detection area, and this displacement persisted for a time period well beyond the 10-day duration of seismic airgun activity. This study provides evidence that male fin whales from two different subpopulations modify song characteristics under increased background noise conditions, and that under seismic airgun activity conditions they leave an area for an extended period.

Castellote, M., Clark, C.W., Lammers, M.O. 2012. Acoustic and behavioural changes by fin whales (Balaenoptera physalus) in response to shipping and airgun noise. Biological Conservation 147: 115–122. doi:10.1016/j.jnc.2011.06.005

3) Aberrant behaviour including erratic locomotion was observed in a pantropical spotted dolphin 600 m ahead of an airgun array during 3D seismic explorations off Liberia in March 2009. The dolphin, presumably in acoustic distress, lifted its head and cervical region above the surface in an oblique, strikingly rigid posture during 5 min. Turbulent white-water evidenced a major propulsory thrust. Incremental postural instability and apparent exhaustion progressed to a catatonic-like state of akinesia.

Gray, H., & Van Waerebeek, K. 2011. Postural instability and akinesia in a pantropical spotted dolphin, Stenella attenuata, in proximity to operating airguns of a geophysical seismic vessel. Journal for Nature Conservation, doi:10.1016/j.jnc.2011.06.005

4) In only 2% of cetacean deaths are carcasses recovered

Rob Williams, Shane Gero, Lars Bejder, John Calambokidis, Scott D. Kraus, David Lusseau, Andrew J. Read, & Jooke Robbins. 2011. Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident. Conservation Letters. doi: 10.1111/j.1755-263X.2011.00168.x

5) None of the calves showed hearing loss, but 42% of the subadults had hearing loss. The results of auditory evoked potential measurements from eight species of odontocete cetaceans that were found stranded or severely entangled in fishing gear during the period 2004 through 2009. Approximately 57% of the bottlenose dolphins and 36% of the rough-toothed dolphins had significant hearing deficits with a reduction in sensitivity equivalent to severe (70–90 dB) or profound (>90 dB) hearing loss in humans.

Mann D, Hill-Cook M, Manire C, Greenhow D, Montie E, et al. (2010) Hearing Loss in Stranded Odontocete Dolphins and Whales. PLoS ONE 5(11): e13824. doi:10.1371/journal.pone.0013824

6) As the sound exposure level of the noise was gradually increased to a captive harbor seal, the onset and growth of TTS did not follow the expected pattern. Rather than showing a progressive increase in TTS with increasing sound exposure level, the seal shifted suddenly from a level of no measurable effect to a dramatic threshold shift in excess of 48 dB at a frequency one half-octave above that of the tonal noise exposure. No unusual behavioral response was observed during this noise exposure condition. While hearing recovered rapidly in the hours following this occurrence, recovery was not complete, even after 24 months, resulting in a permanent narrowband hearing loss of approximately 8 to 10 dB.

Reichmuth, C. 2009. Effects of Noise and Tonal Stimuli on Hearing in Pinnipeds. Rpt. To Navy. Noise-induced permanent threshold shift in a harbor seal.

Kastak, D., Mulsow, J., Ghoul, A., and Reichmuth, C. 2008. Noise-induced permanent threshold shift in a harbor seal. J. Acoust. Soc. Am., Vol. 123, No. 5, Pt. 2: 2986.

7) A highly unusual event involving the long-term displacement and mass stranding of approximately 100 melon-headed whales (Peponocephala electra) occurred in May-June 2008 in the Loza Lagoon system in northwest Madagascar. At least 75 mortalities resulted over the following weeks. High-power 12 kHz multi-beam echosounder system (MBES) operated intermittently by a survey vessel moving in a directed manner down the shelf-break the day before the event, to an area ~65 km offshore from the first known stranding location. The ISRP deemed this MBES use to be the most plausible and likely behavioral trigger for the animals initially entering the lagoon system. This is the first known such marine mammal mass stranding event closely associated with relatively high-frequency mapping sonar systems. It is important to note the relatively lower output frequency, higher output power, and complex nature (100+ directional but overlapping sound beams) of the MBES used here relative to most conventional lower-power and often much higher-frequency fish-finding or shallow-water bathymetric mapping systems. Similar MBES systems to the 12 kHz source used in this case are in fact commonly used in hydrographic surveys around the world over large areas without such events being previously documented. It is important to note that, especially for odontocete cetaceans that hear well in the 10-100 kHz range where ambient noise is typically quite low, high-power active sonars operating in this range may in fact be more easily audible and have potential effects over larger areas than lower-frequency systems that have more typically been considered in terms of anthropogenic noise threats. The potential for behavioral responses and indirect injury or mortality from the use of similar MBES systems should be considered in future environmental assessments, operational planning, and regulatory decisions.

Southall, B.L., Rowles, T., Gulland, F., Baird, R. W., and Jepson, P.D. 2013. Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (Peponocephala electra) in Antsohihy, Madagascar. http://iwc.int/index.php?cID=454&cType=html

Fish and invertebrates

1) Shore crab (Carcinus maenas), is affected by both single and repeated exposure to ship-noise playback. Crabs experiencing ship-noise playback consumed more oxygen, indicating a higher metabolic rate and potentially greater stress, than those exposed to ambient-noise playback. The response to single ship-noise playback was size-dependent, with heavier crabs showing a stronger response than lighter individuals.

Wale MA, Simpson SD, Radford AN. 2013 Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. Biol Lett 9: 20121194. http://dx.doi.org/10.1098/rsbl.2012.1194

2) Evidence that noise exposure during larval development produces body malformations in marine invertebrates. Scallop larvae exposed to playbacks of seismic pulses showed significant developmental delays and 46% developed body abnormalities. Similar effects were observed in

all independent samples exposed to noise while no malformations were found in the control groups (4881 larvae examined). Such strong impacts suggest that abnormalities and growth delays may also result from lower sound levels or discrete exposures during the D-stage, increasing the potential for routinely-occurring anthropogenic noise sources to affect recruitment of wild scallop larvae in natural stocks.

Aguilar de Soto, N., Delorme, N., Atkins, J., Howard, S., Williams, J. and Johnson, M. 2013. Anthropogenic noise causes body malformations and delays development in marine larvae. Scientific Reports 3: 2831 DOI: 10.1038/srep02831

3) Large steelhulled vessels are known to be a major source of underwater sound in the marine environment. The possibility that underwater sound from vessels may promote biofouling of hulls through triggering natural larval settlement cues was investigated for the mussel, Perna canaliculus. The mussel larvae showed significantly faster settlement when exposed to the underwater noise produced by a 125-m long steel-hulled passenger and freight ferry. Median time to attachment on the substrata (ie settlement) was reduced by 22% and the time taken for all experimental larvae to settle was reduced by 40% relative to a silent control. The decrease in settlement time of the mussel larvae appeared to correlate with the intensity of the vessel sound, suggesting that underwater sound emanating from vessels may be an important factor in exacerbating hull fouling by mussels.

S.L. Wilkens, J.A. Stanley & A.G. Jeffs (2012): Induction of settlement in mussel (Perna canaliculus) larvae by vessel noise, Biofouling: The Journal of Bioadhesion and Biofilm Research, 28:1, 65-72

4) Exposed captive three-spined sticklebacks (Gasterosteus aculeatus) to brief and prolonged noise to investigate how foraging performance is affected by the addition of acoustic noise to an otherwise quiet environment. The addition of noise induced only mild fear-related behaviours - there was an increase in startle responses, but no change in the time spent freezing or hiding compared to a silent control - and thus had no significant impact on the total amount of food eaten. However, there was strong evidence that the addition of noise increased food-handling errors and reduced discrimination between food and non-food items, results that are consistent with a shift in attention. Consequently, noise resulted in decreased foraging efficiency, with more attacks needed to consume the same number of prey items.

Purser J, Radford AN (2011) Acoustic Noise Induces Attention Shifts and Reduces Foraging Performance in Three-Spined Sticklebacks (Gasterosteus aculeatus). PLoS ONE 6(2): e17478. doi:10.1371/journal.pone.0017478