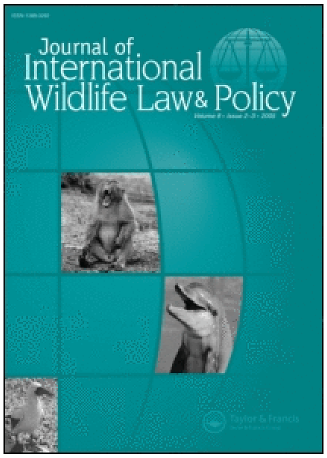


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## The Need for Precaution in the Regulation and Management of Undersea Noise

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# The Need for Precaution in the Regulation and Management of Undersea Noise

LINDA S. WEILGART[1]

Undersea noise has been highlighted as one of the human-caused impacts on cetaceans particularly worthy of precautionary management.[2] The reason for this is primarily that cetaceans are very difficult to study in the wild, spending most of their time underwater. As such, there is a huge dearth of knowledge on the impacts of environmental degradation on them, particularly on the long-term health of their populations. Underwater noise is especially problematic, because the potential spatial scale of impact can be huge, as sound travels very efficiently underwater. These same large potential scales of impact make the study of such impacts even more difficult. How does one begin to assess the environmental damage that may be occurring over 3.9 million sq. km. of ocean[3]—the area over which the U.S. Navy's Low Frequency Active Sonar can be heard at 120 dB,[4] a level shown to produce avoidance in some marine mammals and fish? And how does one attempt to relate the sometimes subtle and short-term changes in whale behavior observable at the surface to a population impact? Links between short-term effects and long-term population consequences cannot usually be made. This is because some reactions may be subtle or not even detectable (e.g., changes in rates of miscarriage or mate finding), yet still be severe in their implications.

Conversely, some short-term effects may be detectable (e.g., changes in dive pattern), yet do not necessarily constitute a long-term impact on the population. Population impacts are the most important ones as these can threaten the health and welfare of cetacean populations, yet these impacts are particularly elusive to determine for cetaceans. This is because population estimates for the vast majority of cetacean species are presently too imprecise

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[2] S. Mayer and M. Simmonds, *Science and Precaution in Cetacean Conservation*, in *The Conservation of Whales and Dolphins*, pp. 391–406. M.P. Simmonds and J.D. Hutchinson, eds., Wiley and Sons, 1996.

[3] J.S. Johnson, SURTASS LFA environmental compliance experience. Presentation at ECOUS (Environmental Consequences of Underwater Sound), May 12–16, 2003, San Antonio, Texas.

[4] This and all other dB levels not otherwise specified are measured re: 1 $\mu$Pa at 1 m.

to allow all but the most dramatic changes in population size to be detected.[5] Indeed, poorly studied species, such as some beaked whales, could easily go extinct without our knowledge.

This level of uncertainty and the fact that, at best, it will take many decades to fill the knowledge gaps necessary to unequivocally prove population impacts, if they exist, underscores the need for precautionary management. While it may be infeasible to ever completely find out how noise impacts the marine environment and its inhabitants, what we do know now should give us cause for concern. The evidence for the negative effects of noise on marine life is mounting, which is hardly surprising given the dependence most marine animals (not just marine mammals) have on sound for many or most of their vital life functions.[6]

Yet regulations used recently in the United States in the management of undersea noise are anything but precautionary. Noise exposure limits are based on a handful of individuals in captive settings representing a handful of species. Short-term behavioral disruptions are routinely classified as having negligible impacts, despite our clear lack of understanding of the long-term population effects of such disruptions. Paradoxically, it appears that the more the evidence of harmful effects of noise accumulates, the less conservative are the noise exposure limits, rising from a received level of 120 dB re 1 $\mu$Pa (SPL, Sound Pressure Level) prior to 1994, to at present, a received level of 195 dB re 1 $\mu Pa^2$-s energy flux density for temporary hearing loss and 215 dB re 1 $\mu Pa^2$-s energy flux density for permanent hearing loss, despite the fact that more noise-induced strandings are being documented.[7]

(Energy flux density (EL) is a measure which incorporates duration of exposure. For a sound of 1 sec duration, 195 dB is more than 10 million times more intense than 120 dB, as the decibel scale is logarithmic. For a 10 sec exposure duration, the allowable exposure level would be 185 dB re 1 $\mu Pa^2$-s for temporary hearing loss, and for 100 sec, it would be 175 re 1 $\mu Pa^2$-s energy flux density. Exposure levels would only reach 120 dB re 1 $\mu Pa^2$-s after 31 million sec or about one year). Unless there is incontrovert-

[5] H. Whitehead, R.R. Reeves, and P.L. Tyack, *Science and the Conservation, Protection, and Management of Wild Cetaceans, in* Cetacean Societies, pp. 308–332 (Mann, J., Connor, R.C., Tyack, P.L., and Whitehead, H., eds., University of Chicago Press, 2000). B.L. Taylor, M. Martinez, T. Gerrodette, J. Barlow, and Y.N. Hrovat, *Lessons from Monitoring Trends in Abundance of Marine Mammals*. Mar. Mamm. Sci. 23: 157–175.

[6] W.J. Richardson, C.R Greene, Jr., C.I. Malme, and D.H. Thomson, Marine Mammals and Noise.(Academic Press, 1995)., A.N. Popper, *The Effects of Anthropogenic Sounds on Fishes*. Fisheries 28(10): 24–31 (2001).

[7] For example, P.D. Jepson, M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herraez, A.M. Pocknell, F. Rodriguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham, and A. Fernandez, *Gas-Bubble Lesions in Stranded Cetaceans*. Nature 425: 575–576 (2003); J.A. Hildebrand, *Impacts of Anthropogenic Sound*, *in* Marine Mammal Research: Conservation Beyond Crisis, pp. 101–124 (J.E. Reynolds, III, W.F. Perrin, R.R. Reeves, S. Montgomery, and T.J. Ragen, eds., Johns Hopkins University Press, 2005).

ible proof of population declines solely from undersea noise (in the absence of other confounding factors), regulators seem largely unwilling to aggressively limit noise producers.

Moreover, cumulative (additive) and synergistic effects (those that interact and thus are greater or less than the sum of their parts) do not seem to be seriously taken into consideration, even though human impacts such as fisheries by-catch, habitat degradation, chemical pollution, whaling, vessel strikes, global warming, etc., do not occur in isolation. We already know that human impacts on marine ecosystems such as over-fishing, eutrophication, climate change, and ultraviolet radiation interact to produce a magnified effect.[8] Noise or noise-induced hearing loss could similarly interact with marine mammal by-catch or ship collisions, preventing animals from sensing fishing gear or oncoming vessels, as evidence seems to indicate.[9]

While research and resources could help refine management and improve our understanding of the effects of noise, it is necessary to proceed expeditiously with sensible mitigation measures (such as avoiding biologically important or critical areas and reducing noise output) without waiting for scientific certainty. In animals that are as slowly reproducing as many whale species, with maximum rates of increase of $<1\%$ (giving birth to only one calf every five years or more and reaching maturity in their late 20s), a delay may mean that remedial action could come too late to prevent a species from tipping into decline and eventual extinction. As such, precautionary management is required to address the problem of noise impacts on marine mammals.

Precaution is not furthered by research in which statistical hypothesis testing is used to determine whether or not a significant effect has occurred, since such testing is weighted toward not "crying wolf" (concluding an effect that isn't really there) rather than being precautionary (missing an effect with possibly disastrous consequences).[10] Science is supposed to be "conservative," that is, it is supposed to be more difficult to find an effect, but this has grave implications for management, since it is the opposite of being precautionary. The likelihood of making errors is reduced with increasing sample size. However, with sample sizes typically available for studies of acoustic impacts on marine mammals, it is difficult to detect an effect even when one exists, a situation which, again, is weighted against precaution.

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[8] B. Worm, H.K. Lotze, H. Hillebrand, and U. Sommer, *Consumer Versus Resource Control of Species Diversity and Ecosystem Functioning*. Nature 417: 848–851 (2002). H.K. Lotze and B. Worm, *Complex Interactions of Climatic and Ecological Controls on Macroalgal Recruitment*. Limnol. Oceanogr. 47: 1734–1741 (2002).

[9] M. Andre, C. Kumminga, and D. Ketten, *Are Low-Frequency Sounds a Marine Hazard: A Case Study in the Canary Islands*. Underwater Bio-sonar and Bioacoustics Symposium, Loughborough University, 1997. S. Todd, P. Stevick, J. Lein, F. Marques, and D. Ketten, *Behavioural Effects of Exposure to Underwater Explosions in Humpback Whales* (Megaptera novaeangliae). Can. J. Zoo. 74: 1661–1672 (1996).

[10] D.H. Johnson, *The Insignificance of Statistical Significance Testing*. J. Wildlife Management 63(3): 763–772 (1999).

## 1. BEAKED WHALE STRANDINGS AND POPULATION IMPACTS

Some have attempted to downplay the importance of acoustically induced strandings, often involving the family of beaked whales, stating that they only affect a few individuals and not populations. Such conclusions are scientifically indefensible because:

1) The majority of strandings likely go undocumented or unreported, especially in remote areas.
2) Strandings, even if reported, may not be able to be linked to noise events because the noise events are undocumented or unknown.
3) The animals that end up on the beach may be a small fraction of those killed at sea or displaced.
4) Beaked whales are the most elusive and poorly studied of all whales, thus limiting our ability to assess their population health in most cases.

The population consequences of acoustically induced strandings are uncertain, but what is known should raise concern. The few long-term studies of beaked whale populations that exist indicate that these animals are found in small local populations that occupy the same area all year round.[11] Cuvier's beaked whales also show a high degree of genetic isolation among oceanic, and in some cases, regional populations.[12] Species with this kind of population structuring are particularly vulnerable to impacts, and even transient and localized acoustic events could have prolonged and serious consequences.

In the case of the Bahamas 2000 event, the only stranding event for which almost a decade of baseline survey data on beaked whales are available, there were no sightings of Cuvier's beaked whales for a 20 mo. period (May 2000–Feb. 2002) following the stranding, despite increased sighting effort in 2000 and 2001.[13] In the Bahamas, only one of the Cuvier's beaked whales that were previously photo-identified has been resighted since the stranding. This indicates that the affected local population of Cuvier's beaked whales may be isolated from a larger population, implying that a population-level effect may have resulted, directly or indirectly, from the single, brief sonar

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[11] T. Wimmer and H. Whitehead, *Movements and Distribution of Northern Bottlenose Whales,* Hyperoodon ampullatus*, on the Scotian Slope and in Adjacent Waters*. Can. J. Zool. 82: 1782–1794 (2004); K.C. Balcomb and D.E. Claridge, *A Mass Stranding of Cetaceans Caused by Naval Sonar in the Bahamas*. Bahamas J. Sci. 8(2): 1–12 (2001). D.J. McSweeney, R.W. Baird, and S.D. Mahaffy, *Site Fidelity, Associations, and Movements of Cuvier's* (Ziphius cavirostris) *and Blainville's* (Mesoplodon densirostris) *Beaked Whales of the Island of Hawaii*. Mar. Mamm. Sci. 23(3): 666–687 (2007).

[12] M.L. Dalebout, K.M. Robertson, A. Frantzis, D. Engelhaupt, A.A. Mignucci-Giannoni, R.J. Rosario-Delestre, and C.S. Baker, *Worldwide Structure of MtDNA Diversity Among Cuvier's Beaked Whales* (Ziphius cavirostris): *Implications for Threatened Populations*. Mol. Ecol. 14(11): 3353–3371 (2005).

[13] D.E. Claridge, *Fine-Scale Distribution and Habitat Selection of Beaked Males*. M.S.c. Thesis, Department of Zoology, University of Aberdeen, Scotland, UK (2006).

transit.[14] Most, if not all, of the local population of the species may have been killed, or at minimum, may have significantly abandoned their former habitat. For species like beaked whales whose rates of increase are low, even relatively small effects may cause population declines.[15]

## 2. OTHER POPULATION IMPACTS FROM NOISE

While strandings brought public attention to the issue of undersea noise impacts on marine mammals, they are not the only cause for concern. Anything that interferes with a marine mammal's ability to detect biologically important sounds could have a negative effect on its survival and the health of its population. Underwater noise can prevent marine mammals and fish from hearing their prey or predators, from avoiding dangers, from navigating or orienting toward important habitat, from finding mates that are often widely dispersed, from staying in acoustic contact with their young or group members, and can cause them to leave important feeding and breeding habitat. Marine mammal calls can be drowned out or "masked" by noise. While some of these effects are not immediately lethal, as strandings can be, they nevertheless can be as serious. Sublethal effects, causing animals to be so compromised as to make their survival dubious, may be harder to detect, yet may ultimately affect more individuals. With ocean background noise levels doubling every decade for the last six decades in some areas,[16] the problem of ocean noise will not diminish.

Moreover, we have no idea what the effects of undersea noise are on the entire marine ecosystem. We do know that most marine animals, and certainly fish, rely on sound for most aspects of their life, including reproduction, feeding, and predator avoidance.[17] The various species that make up the marine ecosystem are more interrelated than those on land, which means that the potential for broad ecological effects ('domino effects') is greater than for terrestrial ecosystems.[18] As such, the effects of undersea noise could be far-ranging and severe. Noise has killed and deafened marine animals,[19] caused

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[14] Balcomb and Claridge (2001), International Whaling Commission Scientific Committee (IWC/SC). Annex K: Report of the Standing Working Group on Environmental Concerns. Annual IWC meeting, Sorrento, Italy, 29 June–10 July 2004.

[15] Whitehead *et al*. (2000).

[16] IWC/SC (2004).

[17] For example, A.N. Popper (2001).

[18] K.T. Frank, B. Petrie, J.S. Choi, and W.C. Leggett, *Trophic Cascades in a Formerly Cod-Dominated Ecosystem*. Science 308: 1621–1623 (2005); J.B. Shurin, E.T. Borer, E.W. Seabloom, K. Anderson, C.A. Blanchette, B. Broitman, S.D. Cooper, and B.S. Halpern, *A Cross-Ecosystem Comparison of the Strength of Trophic Cascades*. Ecol. Lett. 5: 785–791 (2002).

[19] For example, Jepson *et al*. (2003); R.D. McCauley, J. Fewtrell, and A.N. Popper, *High Intensity Anthropogenic Sound Damages Fish Ears*. J. Acoust. Soc. Am. 113(1): 638–642 (2003).

them to move away from important breeding and feeding areas,[20] and produced declines in fisheries' catch rates.[21]

The IWC's Scientific Committee noted, "...repeated and persistent acoustic insults [over] a large area...should be considered enough to cause population level impacts."[22] Noise has been thought to at least contribute to several whale species' decline or lack of recovery.[23] However, population declines as a result of noise will generally be difficult to document because:

1. As mentioned, population declines are likely only detectable in a handful of cetacean species, since our population estimates for most species are too imprecise.[24]
2. Population declines, should we be able to detect them, will be hard to link solely with noise.
3. Most cetacean population declines that we know about are not tied to any one effect. Some rare examples of population declines known to be primarily caused by one effect are: the vaquita and by-catch; the Eastern Tropical dolphin declines and tuna nets; and Aleutian sea otters and orca predation.[25]
4. Even contaminants known to be toxic have not produced proven marine mammal population declines, with the exception of sea otters and oil,[26] again, at least partially, because population declines are hard to document.

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[20] P.J. Bryant, C.M. Lafferty, and S.K. Lafferty, *Reoccupation of Laguna Guerrero Negro Baja California, Mexico, by Gray Whales. in* The Gray Whale *Eschrictius robustus,* pp. 375–386.(M.L. Jones, S.L. Swartz, and S. Leatherwood, eds., Academic Press, 1984). D.W. Weller, S.H., Rickards, A.L., Bradford, A.M., Burdin, and R.L., Brownell, Jr., *The Influence Of 1997 Seismic Surveys on the Behavior Of Western Gray Whales Off Sakhalin Island, Russia*. International Whaling Commission SC/58/E4. (2006a). Available from the Office of the Journal of Cetacean Research and Management; D.W. Weller, G.A. Tsidulko, Y.V. Ivashchenko, A.M. Burdin, and R.L. Brownell, Jr. A Re-Evaluation of *The Influence of 2001 Seismic Surveys on Western Gray Whales off Sakhalin Island, Russia*. International Whaling Commission SC/58/E5 (2006b). Available from the Office of the Journal of Cetacean Research and Management.

[21] A. Engås, S. Løkkeborg, E. Ona, and A.V. Soldal, *Effects of Seismic Shooting on Local Abundance and Catch Rates of Cod (*Gadus morhua) *and Haddock* (Melanogrammus aeglefinus). Can. J. Aquat. Sci. 53: 2238–2249 (1996); J.R. Skalski, W.H. Pearson, and C.I. Malme*, Effects of Sounds from a Geophysical Survey Device on Catch-Per-Unit-Effort in a Hook-and-Line Fishery for Rockfish* (*Sebastes* spp.). Can. J. Fish. Aquat. Sci. 49: 1357–1365 (1992).

[22] IWC/SC (2004).

[23] National Marine Fisheries Service (NMFS), *Status Review under the Endangered Species Act: Southern Resident Killer Whales* (Orcinus orca). National Oceanic and Atmospheric Administration Technical Memorandum NMFS NWFSC-54, Seattle, WA (2002); Weller *et al*. (2006a,b).

[24] Whitehead *et al*. (2000). Taylor et al. (2007).

[25] W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals (Academic Press, 2002).

[26] J.R. Twiss, Jr. and R.R. Reeves (eds.), Conservation and Management of Marine Mammals (Smithsonian Institution Press, 1999.)

Indeed, to date there have been no studies attempting to document population declines with noise. The fact that it has taken us 40 years to discover the link between military maneuvers involving naval sonars and beaked whale strandings underscores how easy it is to miss such impacts from human activities, even for such relatively obvious events such as strandings.

This should give us pause and encourage us to pursue more precautionary management, such as distancing noise sources and events from critical habitat, reducing our "acoustic footprint" by reducing overall ocean noise levels, making noise safer through technological innovations (e.g., by eliminating the unnecessary high frequencies in seismic airguns), and avoiding the unnecessary duplication of noise events (e.g., by sharing seismic survey data). Marine Protected Areas should be established around critical habitat and these should be kept noise-free, to the greatest extent possible. Noise producers should also be required to justify their acoustic intrusions and shoulder the burden of proof. Rather than demanding that poorly funded regulatory agencies and environmental groups prove that noise is harmful before real mitigation is undertaken, noise producers should have to clearly demonstrate that their noise will not have an impact on the marine ecosystem. If this cannot be proven, then at least such activities should be moved to areas where the potential for damage is small. Failing that, the activity may need to be halted outright. This would be truly precautionary and would go furthest in safeguarding the marine environment for future generations.