Reducing Impacts of Noise from Human Activities on Cetaceans

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ABSTRACT
Cetaceans have evolved to use sound as their primary means for communication, foraging, navigating, and generally perceiving features in the environment around them. Sound from human activities represents unwanted noise to these species. This noise can disrupt their natural activities, induce stress responses, degrade their environment and, in the more extreme cases, lead to permanent hearing damage, or even death. This paper gives a brief overview of the various options available for reducing the human contribution to underwater noise. A number of recommendations that may help reduce underwater noise have been highlighted for managers to take action.

KEY WORDS: COMMUNICATION, STRESS, NOISE, REGULATIONS.

INTRODUCTION

Humans introduce a range of sounds into the marine environment. Some of the greatest attention has been paid to the very loud sounds produced by naval activity (including both the more narrowband sonars and the broadband explosions), the oil and gas industry (broadband seismic survey pulses for detecting deposits under the sea floor), and construction (broadband pile driving pulses). Another source of note is commercial shipping. However, there are numerous other sounds that humans introduce into the marine environment. Industrial activities, such as drilling, dredging, and pipe- or cable-laying, all contribute noise to the environment. Pleasure craft and fishing activities can also be important sources of noise in coastal and remote areas.

There is increasing evidence that the myriad of sound introduced into the oceans by humans is collectively damaging the health and reproductive capabilities of marine mammals and other animals in various ways. There are now a number of solid indications that what is currently known about the severity of the impact of human noise exposure on populations of cetaceans, as well as on individuals, is likely to be only the "tip of the iceberg" (one of two possible options presented by the U.S. National Research Council, NRC, 2005). This is due to the multi-faceted, and often subtle, range of effects that noise can have on the lives of marine animals.

To provide an overview of the merits of the various mechanisms available to managers to address these impacts of noise on marine life, WWF commissioned a report on this topic (Wright, 2014). A summary follows here.

IMPACTS

The aggregated impacts of noise on marine mammals combine with the effects of climate change and other human pressures. For example, marine mammals are exposed to chemical pollutants through their diet and store many of these in their blubber due to the interaction of these chemicals with the fats. This limits circulating levels of the contaminants as well as their total impact on the individual. However, in times of high energy use (e.g., pregnancy) or low energy availability (perhaps due to overfishing or avoidance of a feeding area due to high noise levels) these fat stores are metabolized, thus releasing the chemicals into the blood stream, leading to increased circulating levels at times of vulnerability.

As a consequence of these cumulative impacts, it is becoming increasingly clear that human impacts on the

environment as a whole cannot be managed in isolation. In contrast, it may (in some cases) be possible to reduce the impact of one human activity through the implementation of measures to address another. More generally, the total chronic impacts of combined human activity on marine species can be decreased through reductions in the contributions of each component. As a consequence of this, the resilience of a species to the effects of climate change may increase if its exposure to other pressures, such as underwater noise, can be reduced.

Regarding the impacts of noise exposure on marine mammals, attention has typically focused on hearing damage and behavioural effects. However, the value of using behavioural responses to infer more systemic impacts has become increasingly questioned, as observable reactions are highly context-dependent. Additionally, there are other consequences of noise exposure that must be considered, but which can occur without any outwards indication from the animal affected, such as physiological stress responses and masking.

REGULATIONS

Various international bodies and agreements have issued several specific noise-related resolutions and statements of concern. Many nations are attempting to adapt their various national legislations, and the associated implementing regulations, designed to protect endangered species (e.g., the Canadian *Species at Risk Act*, SARA, 2002; the U.S. *Endangered Species Act*, ESA, 1973). Such environmental legislation typically includes exemptions, exclusions, permitting processes or other authorizations to explicitly consider societal interests. While some of these options are not bound by any findings regarding environmental consequences, others are conditional on demonstrating that some certain maximum impact level, which is to be determined based upon the best available science, has not been exceeded. For example, it may be that society has stated, though environmental laws, that a population should not be prevented from growth through human impacts, or that only a certain proportion of a given population can be exposed to such impacts in any given period (e.g., the ESA).

Achieving any such legal mandate in terms of noise effects requires an evaluation of the full consequences of all sub injurious impacts to individuals and populations to completely assess the sum of all impacts of noise on marine mammals. An expert panel in the U.S., has noted this fact and stated that injury and behavioural harassment criteria "do not determine the overall level of impact [as] physiological stress and other factors also need to be considered" (Fitch *et al.*, 2011). However, with some specific notable exceptions, current mitigation measures are generally ineffective at reducing the aggregate impact of noise on marine mammals. This is largely because they typically focus on limiting damage to hearing and ignore the more insidious consequences of noise exposure that can arise at lower levels of sound.

DISCUSSION

While numerous options are available for mitigating the impacts of noise on marine mammals, many have limited effectiveness. Operational measures such as safety zones or slow speed requirements can also suffer from compliance issues. Unfortunately, these are currently the best options available for mitigating the impacts of noise on marine mammals. The implications of this are two-fold. Firstly, we must exploit any opportunities for the use of improved planning and protection measures that will help reduce the overlap between marine mammal and human activities. Secondly, and more importantly, we need to pursue any technological developments that will reduce or preferably eliminate the various sources themselves. This can be achieved either through refining or replacing the equipment in question, or by eliminating the demand for the activity entirely.

To that end there are two overarching recommendations that have arisen from this report:

1. Governments and other responsible authorities around the world should phase in increasingly strict noise level standards for all noise-producing activities. This will drive the necessary innovation to reduce noise at the source and take management truly into the realm of addressing the overall impacts of noise, rather than simply focusing concern on the potential for injury. The regulatory pressure on noise levels placed upon companies installing wind farms in Germany led to the necessary innovation to meet these standards (ref?). The result was a reduction in the dangerously high sound levels that are typically mitigated, and the levels of noise at greater

distances. This reduction will also reduce the occurrence and extent of all the various non-injurious impacts of noise.

2. Governments, industry and environmental organizations should seek ways to address and reduce the underlying demand for noise producing activities so that their occurrence can be reduced to the greatest extent possible. Even on the rare occasions when it may not be possible to eliminate a particular source of sound due to its function, suppression of the demand for the result will curtail the activity itself. Consequently, it is recommended that governments take steps to reduce the need for oil, shipping and (where possible) military sonar through improved energy efficiency, support for local over foreign economies, and international agreements. Use of the concept of the Genuine Progress Indicator (GPI) may be of particular importance to these goals and is thus also recommended.

Implementing these recommendations will result in a quieter ocean. However, this will take time. In the meantime, the currently available mitigation measures must continue to be used, although in a more precautionary manner. A visual summary of much of the information contained within the recent report on this topic (Wright, 2014) is presented in Table 1. Specifically, the table includes details of the mitigation options deemed most worthy of use and/or development at this time for several specific sound sources. For example, it is not currently possible to implement safety zones at night with any degree of confidence, so suspension of activities during this period deserves strong consideration. Accordingly, these techniques score a medium to high viability of application, conditional upon the restrictions being put in place to limit the activities in question to hours of daylight.

Similarly, the effectiveness of ramp-up is almost completely unknown, but application to stationary sources can be planned in such a way to allow at least some animals to move away, without risking possible entrapment in unfamiliar coastal features, ice edge environments, or other such areas. Such uncertainties are highlighted in Table 1, which may provide general indications of where more information is needed on the application and effectiveness of these particular management tools for those seeking to fund noise mitigation research. It is very important that any new information on the merits of the various management and mitigation measures be reincorporated into the management process though truly adaptive approaches rather than being excluded from subsequent environmental impact assessments or management decisions. The same is true for details about the potential benefits of new technologies and techniques, or the various impacts of noise sources on marine mammals. It is only through such a mechanism that the quality of management decisions can improve over time.

Table 1. An indication of the relative merits of the different management and mitigation options. The metrics are defined as follows: Viability is the likely applicability of the management option to the source; Effectiveness is the likely extent to which the management option can be expected to reduce noise; and Availability is an indication of the likely time before the tool becomes available to managers for use. N=None; L=Low; M=Medium; H=High; VH=Very High; I=Immediate; S=Soon; F=Further into the Future; N/A=Not Applicable; ?=Unknown or uncertain; and *=Indicates situations where Mitigation sources are linked to Ramp-ups, or vice versa. Colouring indicates overall preference based mainly on Effectiveness and Viability in the descending order: Green; Yellow; Orange; and Red. These assignments are determined as follows: Green required a high or very high Effectiveness and a high Viability score; Red required a low Effectiveness value; Yellow and Orange were separated based on the remaining balance of scores in both Effectiveness or Viability and the general uncertainty across all categories. Specific case-by-case complexities, such as (but not limited to) the presence of particularly sensitive species or specific topography thought to increase likelihood of impact are not considered here.

Source Type	Metric	Demand reduction	Alternative technology	Modify existing gear	MPAs and similar	Early planning options	Safety zones & shut-downs	Ramp-up	Mitigation sources	Isolation techniques	Operational measures
Seismic survey airguns	Viability	H	H	H	M-H	M-H	M-H	H	H	L	H
	Effectiveness	VH	M-H	L-M	M	M	(L-M)?	?	L?	L	L-M
	Availability	S-F	I-S	I	I	I	I	I	I	S	I
Navy sonar	Viability	L-M	?	M-H	M	M-H	M-H	H	M-H*	N	M
	Effectiveness	VH	?	H?	H?	H?	(L-M)?	?	?	N/A	M
	Availability	S?	F?	S?	I	I	I	I	I	N/A	I
Piledriving	Viability	?	M	H	M-H	M-H	M-H	H	L	H	N
	Effectiveness	VH	H	M-H	M	M	(L-M)?	M?	?	H	N/A
	Availability	?	I-S	I	I	I	I	I	I	I	N/A
Shipping	Viability	M	N	M-H	M	M	N	N	N	H	H
	Effectiveness	M-H	N/A	H	M	M	N/A	N/A	N/A	?	L-M
	Availability	I-S	N/A	I-S	I	I	N/A	N/A	N/A	S	I
Explosions	Viability	L?	?	N	H	H	H	H*	H*	V	N
	Effectiveness	VH	?	N/A	H	H	M-H	M?	M?	?	N/A
	Availability	I	?	N/A	I	I	I	I	I	I-S	N/A
Pleasure craft propellers	Viability	H?	M-H	N	H	N	N	N	N	N	M
	Effectiveness	L	H	N/A	H	N/A	N/A	N/A	N/A	N/A	(L-M)?
	Availability	I	S	N/A	I	N/A	N/A	N/A	N/A	N/A	I
Echo-sounders	Viability	H	N	N	H	N	N	N	N	N	L
	Effectiveness	VH	N/A	N/A	H	N/A	N/A	N/A	N/A	N/A	L
	Availability	I	N/A	N/A	I	N/A	N/A	N/A	N/A	N/A	I
Multi-beam sonar	Viability	?	?	?	H	H	M-H	H	H	N	L
	Effectiveness	VH	?	?	H	H	(L-M)?	?	L?	N/A	L
	Availability	?	?	?	I	I	I	I	I	N/A	I

It is extremely important to note that the content of Table 1 cannot reflect any special considerations required of specific locations or likely impacted species. For instance, source levels of near-coast operations need to be very carefully controlled to avoid unreasonably high exposures when animals are unable to move away, even in situations where entrapment is unlikely. Conditions in the Arctic, such as, but not limited to, prevalence of sea ice and hours of sunlight, also require special considerations. Similarly, small populations with limited ranges may simply not be able to avoid noise sources introduced into their habitats. Furthermore, the assessments of mitigation effectiveness in Table 1 are based primarily on the best possible implementation of the tools. Accordingly, a lack of compliance or (where appropriate) the use of untrained personnel has not been factored into any category, with the explicit exception of "Operational measures". The lack of compliance considered here is not regarded as malicious, but as a consequence of unclear regulations or uninformed or poorly-trained participants.

RECOMMENDATIONS

In addition to the above-mentioned over-arching recommendations, and the very general guidance in Table 1, a number of more detailed recommendations for regulators, managers, industry, environmental organizations, and other interested parties follow.

1. It is clear from existing research that ocean noise is a conservation threat to many marine species. We do not need more research before acting to reduce impacts and reduce noise at source. However, further research on technologies to reduce noise created by oil exploration, commercial shipping, and pile driving is needed.
2. Making certain areas of the marine environment unavailable to industry, at least during sensitive periods, represents one of the most effective methods for reducing impacts of noise on marine mammals. Consequently, noise-producing activities should be avoided in vulnerable areas where vulnerable species are located, particularly in areas that are stressed by existing noise levels and/or are ecologically important. Management agencies should implement proactive area-based management efforts such as establishing marine protected areas (MPAs) or time-area closures that restrict noise-producing activities, and implement buffer zones around protected areas to ensure that levels of noise within are not raised beyond acceptable levels.
3. Where avoidance is not possible, mitigation measures should be taken (i) that reduce loud sounds in areas where vulnerable species may be present and (ii) that reduce the amount of noise pollution at the source. In the case of shipping, the *Guidelines for the Reduction of Underwater Noise from*

Commercial Shipping to address Adverse Impacts on Marine Life[1], recently adopted by the International Maritime Organization (IMO), need to be swiftly and effectively implemented by the industry and formalized as regulations.

4. Transit areas that require lower speed to avoid cetaceans should be encouraged as part of marine spatial planning/voyage planning. The slow steaming initiative that saves fuel and additionally reduces emissions as well as other environmental impacts needs to be maintained. This initiative is believed to have also resulted in a substantial decrease in noise levels (and a reduced collision risk for whales).
5. As recommended by the IMO Subcommittee on Design and Equipment, the IMO's Marine Environmental Protection Committee (MEPC) should consider the proposals for further work on the reduction of underwater noise from commercial shipping, listed as 'out of scope' of the above IMO Guidelines, by developing future guidelines and regulatory policies that include a global noise reduction target and the inclusion of environmentally sensitive areas on marine charts.
6. The proposed High Seas Biodiversity Agreement under discussion via the UN should address underwater noise including through the designation of acoustic refuges for cetaceans, which might be addressed through high seas MPAs or other measures.
7. Limits on pile driving noise have been put in place by Germany. Such noise may be limited by using techniques such as bubble curtains and coffer dams which prevent much of the source noise travelling beyond them and into the wider ocean environment. The development and use of these technologies to their current states was a direct result of the German regulations. The noise limits developed by Germany and the reduction methods employed there should be implemented elsewhere.
8. Seismic surveys using airguns are extremely noisy. Much of the frequency spectrum of the noise created by the airgun explosions is not required for seabed analysis and surveys may be repeated over the same areas of seabed. Other techniques for oil exploration are available (such as Vibroseis, which uses a vibrating device on the sea floor). Every effort should be made to limit the extent of seismic surveys and the further development and use of less noisy technologies should be encouraged.
9. High-intensity sonars used by the military for training exercises need to be used less and great care taken in terms of where and when they are used in order to avoid impacts on marine life.
10. Marine management and spatial plans should specify noise objectives, and set cumulative noise caps.
11. To facilitate a more holistic approach to the management of noise exposures, management agencies and regulators should improve cumulative impact assessment procedures; make wider use of strategic or regional environmental assessments, especially in areas experiencing rapid growth; and adopt protocols that encourage industry cooperation in the preparation of assessments, such as the joint noise exposure model required from companies wishing to conduct seismic surveys in Greenland.
12. Governments and regulators are recommended to implement scientifically based noise limits for oil and gas activities, including, but not limited to, exploration, extraction and decommissioning, that can be phased in over a period of not more than 10 years.
13. Port authorities are strongly encouraged to develop regional port partnerships and adopt noise-related green certification standards, and certification programs are recommended to include noise-related criteria in their standards.
14. Regulators should develop public and industry education programs about the impacts of ocean noise on marine life, and possible reduction measures.

REFERENCES

Wright, A.J. 2014. Reducing Impacts of Human Ocean Noise on Cetaceans: Knowledge Gap Analysis and Recommendations. WWF Global Arctic Programme, Ottawa, Canada (online @ wwf.panda.org/oceannoise)

[1] IMO MEPC.1/Circ.833 7 April 2014 (https://www.bimco.org/~/media/marine/news/2014/mepc.1-circ.833.ashx downloaded May 5th, 2014)