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Answer to DG Environment request on scientific information concerning impact of sonar activities on cetacean populations

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The European Commission, DG Environment has requested ICES:

"to undertake a scientific review and evaluation of all relevant information concerning the impact of sonar on cetaceans and fish, to identify the gaps in current understanding and to make recommendations for future investigations/research. The Commission would also be interested in advice on possible mitigation measures to reduce or minimise the impact of sonar on cetaceans and fish."

ICES has commissioned an Ad hoc group to compile the relevant information in the 2004 report of the Ad hoc Group on the Impact of Sonar on Cetaceans and Fish (AGISC) (ICES 2005).

ICES Comments

Scientific review and evaluation of relevant information concerning the impact of sonar on cetaceans

The full effects of sonar on cetaceans are not well known, mostly due to the difficulty of studying the interaction.

The review described a range of sonars that use a range of frequencies and intensities. There is no evidence of harm for sound sources other than high-intensity (>215dB) mid-frequency (1 – 10 kHz) sonar. The use of this sonar has led to the deaths of a number of cetaceans in some places. All incidents that have been investigated have occurred in the North Atlantic or Mediterranean and have related to the use of military sonar. Other stranding incidents have occurred in these and other seas, but their cause is not clear. From relatively limited knowledge, it appears that beaked whales are the most affected species, in particular Cuvier's beaked whale *Ziphius cavirostris*. It is not known whether this species is particularly sensitive or just the most often exposed to the sound. A characteristic of most of the known mortality incidents is that they have been on (or just off) shores near to the shelf break and deep water habitat favoured by these species. It is unclear therefore if further undetected mortality is occurring where the shelf break is further offshore. The precise mechanism causing the animals to beach themselves is unknown – many arrive ashore alive, but obviously distressed. The most consistent deduction from the evidence is that behavioural alteration is more important than the direct effect of the sound on hearing mechanisms. It is unknown how many animals that are affected further out to sea can survive and not strand. Little is known of the sub-lethal effects of sonar on beaked whales or on other cetacean species. The possibilities and consequences of these effects are summarised in Table 1.

Table 1. Summary of likely effects of sonar on beaked whales

Type of effect	**Extent of effect**	**Severity of effect**	**Individuals affected**	**State of knowledge**
Direct death and lethal injury	Very local	Severe	Few/none	Adequate for current purposes
Gas embolism	Medium scale	Severe	Small numbers?	Moderate
Sublethal injury	Medium scale	Unknown	Small numbers?	Poor
Behavioural (avoidance)	Widescale	Mild/long term	Large numbers	Poor

There have been globally about 40 scientifically-verifiable sonar-related deaths among cetaceans (mostly, if not all, beaked whales) over the last 9 years. A recent IWC report indicates that worldwide, fisheries kill several hundred thousand cetaceans as bycatch each year. We do not know of the scale of beaked whale bycatches but 35 fishery-related beaked whale mortalities were observed in the pelagic drift gillnet fishery off the east coast of the USA between 1989 and 1995 and between 1991 and 1995 the total average estimated annual fishery-related mortality of beaked whales in the U.S. EEZ was 9.7 (CV = 0.08). Even accepting that some beaked whales affected by sonar may die uncounted at sea, nevertheless it seems likely that the fishery-related mortality of beaked whales alone is several times higher than that caused by sonar.

Scientific review and evaluation of relevant information concerning the impact of sonar on fish

This review is still in progress and will be reported separately.

Gaps in current understanding and recommendations for future investigations or research.

1. There is insufficient knowledge in European waters of the location and habitats of beaked whales. More reliable information on this topic would enable those wishing to use high intensity sound to avoid those areas. A survey of all shelf-break and adjacent deep-water waters of Europe is required, as is the collation of all current records. Habitat modelling may also improve predictability of beaked whale distribution and help identify critical habitat.

2. Techniques to detect beaked whales more reliably need to be developed with acoustic monitoring, and possibly high-resolution satellite monitoring being promising options for the future.

3. Increased research into the sound transmission properties in the waters near the shelf break may aid in choosing areas to avoid the use of high-intensity sonar.

4. Further research is needed on the apparently non-auditory responses of deep-diving marine mammals to low- and mid-frequency sonars. This could be aimed particularly at trying to understand the sphere of influence of sonar noise on cetaceans. Understanding the mechanisms behind the apparent formation of bubbles in body tissue might help in understanding the causes of death of beaked whales.

It is beyond the remit and the competence of ICES, as an organisation, to make any recommendations concerning the military use of sonar.

Thus, in order for DG Environment to reach a balanced judgement between the requirements for use of high intensity mid-frequency sonar and the need to protect beaked whales, DG Environment should consider commissioning a specialist review and evaluation of the military use of sonar in European waters.

Possible mitigation measures to reduce or minimise the impact of sonar on cetaceans

As described above, the only major effect noted on cetaceans from sonar comes from high intensity mid frequency military sources. This section therefore focuses on this usage, though the principles may be extended more widely.

In order for mitigation to be considered, it is necessary to know

1. the species that might be present,
2. their sensitivity to the noise and hence the area that might be affected;
3. the population density, such that the number of individuals that might be in this affected area can be calculated, and
4. the significance of the effect, or the risk of that effect, on those individuals or their stock.

If the environmental consequences are deemed too great, then use must be made of suitable mitigation measures to reduce the impact to an acceptable level. Note that decisions on whether or not an environmental consequence is too great are societal choices rather than a scientific fact. Examples where the effects of noise might not be acceptable include

1. where species are displaced away from a significant proportion of their feeding grounds;
2. where the species are endangered species, and management is required to apply particularly risk-averse measures;
3. where the noise is in confined waters, on a migratory route, and is of sufficient duration that a significant proportion of a migratory period would be blocked;
4. where the noise has an economic impact, as for instance if whales were displaced from a whale watching area.

In many cases the noise may cause an effect which is of no environmental significance. For instance, a behavioural effect in which cetaceans are simply displaced from the area of the sonar operation to another area of similar habitat for a limited period may well be unimportant.

It is difficult to comment on the practicality of mitigation possibilities without considering military requirements for high intensity low- and mid-frequency sonar, upon which ICES is not qualified to comment. From first principles though, there are three obvious mitigation possibilities, a) limit overall use, b) limit area of use and c) limit season of use. It is assumed that it would not be possible to reduce the source level, as it seems unlikely that this would not be as high as it is unless such power was needed for operational reasons.

Limits on overall use would reduce risk to cetaceans, while limiting the area of use away from those known or thought to be important to beaked whales may be the most efficient way of reducing risk. The difficulty with this is that our knowledge of beaked whale biology and habitat needs is still fairly rudimentary and this species is comparatively difficult to detect in the wild. Acoustic detection may present a way forward, but even here, there is little knowledge of the acoustic behaviour of beaked whales. The calls of Cuvier's beaked whales have been recorded four times. While the three recordings in the presence of Cuvier's beaked whale suggested that they may produce both whistles and pulsed sounds, one identified the vocalizing whale using an acoustic recording tag, and these data only recorded clicks with peak frequencies in the 40-50 kHz range, and little energy in the frequencies humans can hear. Whether these could be specifically separated from the other cetacean species is not known. Cuvier's beaked whales may not click at depths less than 450 m, and they may therefore be more difficult to record at the surface than at depth. One recent solution for this problem would be to use autonomous submersible vehicles to 'sweep' an area, listening for beaked whales, for a period prior to the use of high intensity sonar. Plainly there is an area for great research and development here.

The aim of mitigation is to control and minimise environmental impact, and comprises control of noise at source, mitigation by use of engineering and other methods, and monitoring.

Control at source

Of key importance is the use of the minimum source power to achieve an adequate resolution or range. Mitigation can take the form of reducing the total amount of sound produced, possibly by reducing power, duration and/or by reducing the number of times a system is transmits sound. Where the species of concern has a well-defined hearing sensitivity, it may be possible to operate at frequencies where the animal's hearing is relatively insensitive. We do not know the characteristic(s) of the mid frequency sonar that causes problems for beaked whales – determination of the characteristic(s) and of its precise effect on beaked whales might help in enabling a sonar to be designed that does not affect beaked whales.

Mitigation of death and injury caused by the direct effects of sound

The range at which death or injury due to the direct effect of sound levels (as opposed to behavioural alteration that may lead to death) can occur is limited. Hence the likelihood of a marine mammal straying into the area prior to the commencement of a sonar transmission is relatively low unless there is a large degree of overlap between important or critical beaked whale habitat and areas of sonar usage. Since the range of the effect is small, there are several mitigation measures that might be effective in preventing injury through the direct effects of sound. A first mitigation measure might therefore be to avoid areas of known beaked whale abundance. Second, it might be possible to regulate the use of sound if marine mammals are detected close to the source. Such detection could occur in two main ways:

Marine Mammal Observers (MMOs) MMOs are trained observers who aim to visually detect and identify marine mammals, at distances of up to 500 m during daylight hours. Their use is mandatory during UK and some other nation's offshore seismic surveys. It may be possible to watch for whales prior to commencing sonar operation and not start transmitting sound if whales are seen or to cease operations if whales enter the area during transmission. However, beaked whales in particular are very difficult to detect and spend a long time under water; in addition the approach does not work in poor visibility or at night. The efficiency of this mitigation measure is low under many conditions likely to be encountered in naval sonar operation.

Passive Acoustic Monitoring (PAM) or Active Acoustic Monitoring (AAM) Both passive and active acoustic monitoring may be used to detect marine mammals. Passive acoustic monitoring is the term used for listening passively to sources of sound, while active acoustic monitoring is the term used for producing sounds and listening for echoes from nearby objects. Active acoustic monitoring is thus a form of sonar and offers several potential advantages compared to passive. Unlike passive acoustic monitoring, which can only detect animals when they vocalize, active acoustic monitoring can detect non-vocalizing animals such as marine mammals or fish. Active acoustic monitoring can estimate the range of targets more easily than can passive monitoring. In spite of these advantages, active acoustic monitoring is relatively undeveloped compared to passive acoustic monitoring for detecting marine mammals. Both systems might be installed on remotely operated or autonomous vehicles to provide a sweep of a wider area or a longer time period than would be possible from one ship at one time.

Passive or active acoustic monitoring offers one way that a wider area might be surveyed for beaked whales. If the lethal effects observed in beaked whales are due to behavioural alteration caused by sound and not to the direct effects of the sound, then such wider area surveys are needed if sonar deployment is to be avoided near beaked whales. This though would be challenging to accomplish, as little is known of beaked whale vocalisations and suitable technology has yet to be developed.

Other control methods

Two other measures can be taken that would reduce the risk of exposure of marine mammals to loud sound (though as noted earlier, not necessarily risk to behavioural change):

Scheduling Sonar transmissions may be timed for periods when the species are not in the area, for instance by avoiding migratory periods or periods where local breeding or calf-rearing grounds are used. However, as noted in earlier sections, this information is largely absent for beaked whales, so it is difficult to apply this measure without further research on the use that beaked whales make of certain areas of the sea.

Warning signals. It has been suggested that warning signals for marine mammals could be developed – these are sounds that would make marine mammals move away from dangers such as explosions, fast ships, or intense sound sources such as sonars. There has been little development and testing of warning signals, but it is known that even though right whales do not respond to vessel noise, they do show strong responses to signals designed to alert them. In the absence of information on what sounds cause avoidance reactions, regulators have required some intense sound sources (seismic sources) to be increased in level slowly. In principle, such a 'soft start' might offer animals a chance to move out of the danger zone, but this seemingly reasonable technique is unproven. Soft start should be viewed as a type of warning signal, one selected because the sound source is already there, not because it is necessarily effective. In most cases, it is more likely that warning signals specially designed to elicit the appropriate avoidance safely would be more successful than soft start. Since it is not known what levels of sonar sounds are safe for beaked whales, warning signals other than sonar sounds would likely pose less risk as well. Nothing is known about behaviours at lower sonar power levels, or in response to sounds other than mid-frequency sonar. In other situations (e.g. salmon farms), noise is used to deter marine mammals and it might be that suitable noises exist that could achieve this for beaked whales. There may be value in studying sounds that might elicit avoidance responses in beaked whales that do not pose the risks of sonars.

Monitoring

It is plain that much still needs to be learned about the interaction of marine mammals and sonar. Knowledge can be gained and potential mitigation measures identified through good observation and monitoring. Monitoring can include:

Noise monitoring Anthropogenic noise levels may usefully be recorded in order to be matched against any behavioural reactions by cetaceans. Such recordings also enable the sonar to be ranked against other local sources of noise.

Marine mammal observation The monitoring of local cetaceans would help confirm whether there is any obvious effect of the noise. Monitoring the distribution of individuals around the noise source can be by tagging, by using passive acoustic monitoring to detect vocalisation, or by using active acoustic monitoring.

The latter monitoring strategies may serve two purposes, either of demonstrating that there is an effect, or, if an effect is observed, of identifying the level at which it occurs. While it may be argued that the monitoring itself has an effect on the species, this effect may be outweighed by the process providing information which may be used in the longer term to conserve stocks of the species. It should be noted that no monitoring program can demonstrate that there is no effect, for the range of potential effects is large, and many effects would be too subtle for a generic monitoring program to detect. A more scientific approach would test for specific hypotheses about effects, with experiments designed with strong statistical power.