Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities

Module B.3.

Beaked Whales

The full CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities and the stand-alone modules are online at:

cms.int/guidelines/cms-family-guidelines-EIAs-marine-noise

B. Expert Advice on Specific Species Groups

The sea is the interconnected system of all the Earth's oceanic waters, including the five named 'oceans' - the Atlantic, Pacific, Indian, Southern and Arctic Oceans - a connected body of salty water that covers over 70 percent of the Earth's surface.

This vast environment is home to a broader spectrum of higher animal taxa than exists on land. Many marine species have yet to be discovered and the number known to science is expanding annually. The sea also provides people with substantial supplies of food, mainly fish, shellfish and seaweed. It is a shared resource for us all.

Levels of anthropogenic marine noise have doubled in some areas of the world, every decade, for the past 60 years. (McDonald, Hildebrand *et al* 2006, Weilgart 2007) When considered in addition to the number other anthropogenic threats in the marine environment, noise can be a life-threatening trend for many marine species.

Marine wildlife rely on sound for its vital life functions, including communication, prey and predator detection, orientation and for sensing surroundings. (Hawkins and Popper 2014, Simmonds, Dolman *et al* 2014) While the ocean is certainly a sound-filled environment and many natural (or biological) sounds are very loud, wildlife is not adapted to anthropogenic noise.

The species groups covered in the following sub-modules are:

- Inshore Odontocetes
- Offshore Odontocetes
- Beaked Whales
- Mysticetes
- Pinnipeds
- Polar Bears
- Sirenians
- Marine and Sea Otters
- Marine Turtles
- Fin-fish
- Elasmobranchs
- Marine Invertebrates

General principles

Building on the information from module section B.1, sound waves move through a medium by transferring kinetic energy from one molecule to the next. Animals that are exposed to elevated or prolonged anthropogenic noise may experience passive resonance (particle motion) resulting in direct injury ranging from bruising to organ rupture and death (barotrauma). This damage can also include permanent or temporary auditory threshold shifts, compromising the animal's communication and ability to detect threats. Finally, noise can mask important natural sounds, such as the call of a mate, the sound made by prey or a predator.

Table 1: Potential results of sound exposure (from Hawkins and Popper 2016)

Impact	Effects on animal
Mortality	Death from damage sustained during sound exposure
Injury to tissues; disruption of physiology	Damage to body tissue, e.g internal haemorrhaging, disruption of gas-filled organs like the swim bladder, consequent damage to surrounding tissues
Damage to the auditory system	Rupture of accessory hearing organs, damage to hair cells, permanent threshold shift, temporary threshold shift
Masking	Masking of biologically important sounds including sounds from conspecifics
Behavioural changes	Interruption of normal activities including feeding, schooling, spawning, migration, and displacement from favoured areas
These effects will vary depending on the sound level and distance	

These mechanisms, as well as factors such as stress, distraction, confusion and panic, can affect reproduction, death and growth rates, in turn affecting the long-term welfare of the population. (Southall, Schusterman *et al*, 2000, Southall, Bowles *et al*, 2007, Clark,

Ellison *et al*, 2009, Popper *et al*, 2014, Hawkins and Popper 2016)

These impacts are experienced by a wide range of species including fish, crustaceans and cephalopods, pinnipeds (seals, sea lions and walrus), sirenians (dugong and manatee), sea turtles, the polar bear, marine otters and cetaceans (whales, dolphins and porpoises)–the most studied group of marine species when considering the impact of marine noise.

The current knowledge base is summarized in the following module.

This important volume of information should guide the assessment of Environmental Impact Assessment proposals.

References

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B.3. Beaked Whales

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Consider when assessing

- Military sonar
- Seismic surveys
- Civil high power sonar
- Coastal and offshore construction works
- Offshore platforms
- Playback and sound exposure experiments
- Vessel traffic greater than 100 metric tons
- Vessel traffic less than 100 metric tons
- Pingers and other noise-generating activities

Related CMS agreements

- Agreement on the Conservation of Cetaceans of the Black Seas Mediterranean Seas and Contiguous Atlantic Area (ACCOBAMS)
- Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)
- MOU for the Conservation of Cetaceans and their Habitats in the Pacific Islands Region (Pacific Islands Cetaceans)

Related modules

- Refer also to modules B.10, B.12 and C when assessing impact to beaked whales

B.3.1. Species Vulnerabilities

Beaked whales (Ziphiids) became widely known to the public due to mass mortalities of whales stranded with gas/fat emboli when exposed to submarine-detection naval sonar or underwater explosions (Jepson *et al*, 2003, Fernández *et al*, 2005). Most researchers agree that a 'fight or flight' stress response is responsible for the deaths of whales following noise disturbances (Cox *et al*, 2006). Interruption of foraging and avoidance at high speed have been found in different species of beaked whales subject to playbacks of naval sonar at 1/3rd octave RMS received levels as low as 89–127 dB re 1 μPa (Tyack *et al*, 2011, DeRuiter *et al*, 2013, Miller *et al*, 2015). Beaked whales may also be sensitive to other sources of anthropogenic noise, as suggested by the effectiveness of acoustic pingers in reducing the bycatch of beaked whales in deep-water fisheries, much higher than for other species (Carretta *et al* 2011), and by their apparent response to low levels of ship noise (Aguilar de Soto *et al* 2006). There has been a number of mass-strandings of beaked whales coincident in time and space with seismic activities (Malakof 2001, Castellote and Llorens 2016), but the lack of adequate post-mortem examinations has prevented assessing possible cause-effects relationships in these cases. This means that any intense underwater anthropogenic noise can be considered as of concern for beaked whales: blasting, intense naval and scientific sonar, seismics, pingers, etc.

It is still unknown why beaked whales are more sensitive to noise than many other marine mammal species. The reasons may lie in their specialized way of life. Ziphiids stretch their physiological capabilities to perform dives comparable to sperm whales, but with a much smaller body size (Tyack *et al* 2006). Their poor social defences from predators such as highly vocal killer whales may explain why beaked whales limit their vocal output (Aguilar de Soto *et al* 2012) and respond behaviourally to sound at relatively low received levels. The combination of a low threshold of response and a potentially delicate physiological balance may explain why behavioural responses can cause mortalities (Cox *et al* 2006).

Population data for beaked whales are scarce offshore, but long-term monitoring shows that local populations in nearshore deep-waters are small (<100-150 individuals), have high site-fidelity and apparently low connectivity and calving rate (Claridge, 2013, Reyes *et al* 2015). These characteristics generally reduce animal resilience to population-level impacts. Differences in population structure, with a reduced number of young, have been found between beaked whales inhabiting a naval training range and a semi-pristine neighbouring area in the Bahamas (Claridge, 2013). In summary, while discrete noise activities are of concern due to potential acute exposures/responses, there is a risk for population-level effects of noise on beaked whales inhabiting areas where impacts are repetitive.

B.3.2. Habitat Considerations

Some of the 22 species of the Ziphiidae family can be found in the deep waters of all oceans. However, beaked whales have a low probability of visual and acoustic detection (Barlow *et al* 2006, Barlow *et al* 2013) and knowledge about their distribution and abundance is poor, preventing identification of hot-spots offshore. Until more data exist, the assumption is that any area with deep waters is potential beaked whale habitat year-round.

Most mass-strandings related to naval sonar or underwater explosives have been recorded when the activities occurred in nearshore areas of steep bathymetry, suggesting that whales might die due to the stranding process. However, there is at least one mass-stranding case indicating that animals can die offshore before stranding: the naval exercise "Majestic Eagle". This exercise occurred > 100 km offshore from the Canary Islands and dead whales were carried to the shore by the current and winds. The whales showed the same pathological findings identified previously as symptomatic of whales stranded alive in coincidence to naval exposure (Fernández *et al* 2012).

Thus, the vulnerability of beaked whales and their wide distribution make EIA relevant whenever human activities emitting intense sound occur near the slope or in abyssal waters offshore.

B.3.3. Impact of Exposure Levels

Beaked whales show strong avoidance reactions to a variety of anthropogenic sounds with the most sensitive fraction of the population responding at received levels of naval sonar below 100 dB re 1 μPa, and most of the animals tested responding at received levels of 140 dB re 1 μPa. This corresponds to ranges of several km from the ship operating the sonar (Miller *et al* 2015, Tyack *et al*, 2011).

There are no data for thresholds of response for other noise sources. The range at which beaked whales may be expected to be at risk of disturbance from a given anthropogenic noise can be estimated from the characteristics of the sound source, acoustic propagation modelling and the dose: response data provided by behavioural response studies. For example, Tolstoy *et al* (2009) present broadband calibrated acoustic data on a seismic survey performed in shallow waters and received at deep (1600 m) and shallow water (50 m) sites. The line fit to have 95% of the received levels falling below a given received level (RL) was RL = 175.64 – 29.21 $\log_{10}$(range in km) for the deep water site and RL = 183.62 – 19 $\log_{10}$(range in km) at the shallow site. Solving the equation for shallow water and a RL of 140 dB at which beaked whales may be expected to be disturbed, the potential disturbance range would be range = $10^{43.62/19}$ = 197 km. The range predicted to disturb more sensitive individuals within the population would be greater.

The spectrum of the air gun sounds reported by Tolstoy *et al* (2009) is highest below 80 Hz, well below the naval sonars whose effects have been studied for dose-response curves, and in a frequency range where beaked whales are expected to have less sensitive hearing. It is difficult to weight the level of air guns by the hearing of beaked whale given the data available, but it is possible to make a rough estimate of the energy from air guns in the third octave band (which roughly match the frequency bands over which the mammalian ear integrates energy) of the naval sonars whose effects have been measured. The broadband SEL measured at 1 km for shallow water was 175 dB re 1 $\mu Pa^2 s$. Third octave levels were also reported for a shot recorded in shallow water at 1 km range. The third octave level for this shot at the 3 kHz sonar frequency was about 130 dB re1 $\mu Pa^2 s$, suggesting that this frequency band was about 45 dB lower than the broadband source level (SL). This suggests using a sound pressure level of 183.62 - 45 dB to estimate received level in this frequency band at 1 km range. In addition, seawater absorbs sound at about 0.18 dB/km at the 3 kHz sonar frequencies, and this absorption must be accounted for in the transmission loss. Therefore Transmission Loss (TL)= 19 $\log_{10}$(range) + 0.18*range. The range at which sensitive beaked whales, which respond at 100 dB re 1 μPa may respond, given that TL = SL – RL, i.e. 19 $\log_{10}$(range) + 0.18*range = 183.62-45-100 = 38.62, is estimated at 43 km.

These rough calculations show that beaked whales could be expected to be disturbed by exposure to airguns at ranges of 43-197+ km, assuming conditions as found by Tolstoy *et al* (2009). The actual values will depend upon the actual signature of the air gun array to be used, and the propagation conditions in the area. This guidance coupled with current data on beaked whale responses to anthropogenic noise suggests that each proposer should assess how sound is expected to propagate from the survey site to any beaked whale habitat with hundreds of km. If any of this habitat is expected to be exposed to levels of sound above those shown to disturb beaked whales (i.e. 100 dB re 1 μPa for the most sensitive individuals tested), then a further assessment should be made of the number of animals likely to be disturbed.

B.3.4. Assessment Criteria

EIA should consider different types of impacts, ranging from exposure of whales to intense received levels causing hearing damage to behavioural reactions with potential physiological consequences in some cases, to displacement and ecological effects (e.g. reduction in feeding rates or displacement

from preferred habitat due to avoidance behaviour resulting in lower fitness).

A framework for mitigation targeted to reduce risk of the different impacts above needs to be included in the EIA, including actions during the planning-phase, real-time mitigation protocols and post-activity reporting to inform future planning and mitigation (e.g. Aguilar de Soto *et al* 2015). An effective mitigation method is spatio-temporal avoidance of high density areas (Dolman *et al* 2011). This is informed by surveys and habitat modelling and can be aided by simulation engines. However, the scarcity of data supporting density maps for beaked whales increases uncertainty about the number of whales to be expected in a given area and the identification of high density areas. Thus, planning-phase mitigation is essential but it does not eliminate the possibility of encountering and affecting/harming beaked whales. Another aspect of planning-phase mitigation is the choice of acoustic devices to be used during the activity, as well as the source levels required to achieve the objectives of the activity. *In situ* measurements of sound transmission loss shortly before the activity may allow adjustment of source level to below the maximum, so that the maximum is not used by default. A protocol towards reducing total acoustic energy and peak source levels transmitted to the environment should be defined before the activity, for any activity, within workable limits.

Depending on the activity, EIA may require updated information of the density of beaked whales and other vulnerable species, before the activity, in order to allow current data to be compared with existing density maps and to improve their accuracy. Also, if a choice of locations is evaluated, it would be possible to decide locating the activity in the place with lower concentration of vulnerable species.

A powerful and cost-effective way to monitor the effects would be to moor passive acoustic recorders in the beaked whale habitats exposed to sound levels above 100 dB re 1 μPa and to monitor both the actual levels of anthropogenic sound and also to monitor for the rates at which beaked whale echolocation clicks are detected. In the case of seismic, modern seismic surveys often include the deployment of cabled geophones at the seabed. These could be easily equipped with high frequency hydrophones to record beaked whales and other marine fauna.

Given the low probability of visual detection of beaked whales even in good sea conditions, real-time mitigation methods proposed in the EIA require increasing probability of detection by using passive acoustic monitoring systems with detectors programmed for automated classification of beaked whale vocalizations. Automatic detections can then be checked by trained personnel to take decisions about initiation of mitigation protocols.

B.3.5. Species not listed on the CMS Appendices that should also be considered during assessments

All beaked whales not currently listed by CMS seem to be particularly vulnerable to anthropogenic marine noise.

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