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

Module E.

Marine Noise-generating Activities

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

E. Marine Noise-generating Activities

Geoff Prideaux
Wild Migration

E.1. Military Sonar

E.1.1. Low Frequency Active Sonar

The evolution of lower frequency active (LFA) sonar came from two needs. First, to increase detection ranges to overcome passive sonar systems and second, to compensate for the improvements of stealth designs in submarine hulls, part of which was an anechoic coating that absorbed incident waves. It was discovered this coating was less efficient when exposed to longer wave lengths.

LFA sonars work below the 1KHz range. For transmitting long distances efficiently, high powered modulated signals, typically 240 dB in water at 1m, peak value, (240 dB re 1µPa @ 1m peak) are produced lasting from tens of seconds to sometimes minutes. An example of this technology is the SURTASS-LFA of the US navy that operates within 100-500Hz range. (Lurton, 2010)

E.1.2. Mid Frequency Active Sonar

Mid frequency active (MFA) sonar is used for detecting submarines at moderate range, typically less than 10km.

MFA operates between 1-5 KHz range, with a sound intensity levels typically 235 dB in water at 1m, peak value, (235 dB re 1µPa @ 1m peak) with pulse duration of 1-2 seconds. (Hildebrand, 2009, Fildelfo *et al*, 2009)

E.1.3. Continuous Active Sonar

The concept of continuous active sonar (CAS) is generating interest in the anti-submarine warfare community, largely due to it's 100 per cent duty cycle offering the potential for rapid, continuous detection updates. CAS operates between 500Hz to 3KHz range with sound intensity levels typically 182 dB in water at 1m, peak value, (182 dB re 1µPa @ 1m peak) with a signal duration of 18 seconds (Murphy and Hines, 2015)

E.1.4. Mine Counter Measures Sonar

Underwater mines have proven, over time, to be very affective. There prevalence led to the development of the Mine Counter Measures (MCM) sonar. This system works at very high frequency, usually between 100-500KHz, to achieve high quality acoustic imaging of the sea floor and water column. Targets, semi-buried or suspended from the sea floor, are easily identified. (Lurton, 2010)

E.1.5. Acoustic Minesweeping Systems

Acoustic Minesweeping Systems are another mine counter-measure that produces a low frequency broadband transmission, mimicking the sound produced by certain vessels whereby detonating the mine. (Lurton, 2010)

E.2. Seismic Surveys

The commonly used surveying method for offshore petroleum exploration is 'seismic reflection'. This is simply sound energy discharged from a sound source (air gun array) at the sea surface that penetrates subsurface layers of the seabed and is reflected to the surface where it is detected by acoustic receivers (hydrophones).

These surveys are typically conducted using specially equipped vessels that tow one or more cables (streamers) with hydrophones at constant intervals. Air guns vary in size and in conjunction with the charge pressure, determine the sound intensity level and frequency.

Frequencies used for seismic surveys are between 10-200Hz and down to 4-5Hz for the larger air guns. However, there are unused high frequency components up to 150KHz, with a very high discharge at the onset of the pulse. Sound intensity levels of 170dB in water at 1m, peak to peak value, (170 dB re 1µPa @

1m p-p) at 10KHz down to 120dB in water at 1m, peak to peak value, (120 dB re 1µPa @ 1m p-p) at 100KHz respectively. (Goold and Coates, 2006)

The typical discharge of each pulse of an air gun array is around 260-262 dB in water at 1m, peak to peak value, (260-262 dB re 1µPa @ 1m p-p) (OSPAR, 2009) every 10-15 seconds, and surveys typically run more or less continuously over many weeks. (Urick, 1983, Clay and Medwin, 1997, Caldwell and Dragoset, 2000, Dragoset, 2000, Lurton, 2010, Prideaux and Prideaux, 2015)

E.3. Civil High Power Sonar

Seafloor mapping sonar systems are probably one of the most prolific forms of underwater noise generation. The main application is coastal navigation for the production of bathymetric charts. Other applications include geology, geophysics, underwater cables and oil industry exploration and exploitation. Three examples are Single Beam Sounders (SBES), Sidescan Sonas and Multibeam Echo Sounders (MBES).

E.3.1. Single Beam Sounders

Single beam sounders point vertically below the vessel and transmit a short signal, typically 0.1ms. The frequencies vary on their application. For deep water, the frequency would be around 12KHz and increase to 200, 400 and even 700KHz for shallow water. The sound intensity level is usually around 240 dB in water at 1m, peak value (240 dB *re* 1µPa @ 1m peak). (Lurton, 2010)

E.3.2. Sidescan Sonar

Sidescan sonar system structures are similar to single-beam sonars. This sonar differs as it is installed on a platform or "towfish" and towed behind a vessel close to the seabed. Two antennae are placed perpendicularly to the body of the towfish, pointing fractionally to the sea floor. The transmission of the sidescan sonar insonifies the sea floor with a very narrow perpendicular band. The echo received along time, reflects the irregularities of the sea floor. A simple analogy is the scan mechanism of a photo copier. The operating frequency is usually in the range of many hundreds of KHz with the pulse duration 0.1ms or less. (Lurton, 2010)

E.3.3. Multibeam Echosounder

Multibeam echosounders are the major tool for seafloor mapping, for hydrography and offshore industry applications. The transmission and receiving arrays are mounted on the vessel to create a narrow beam, fan-like 150º spread, perpendicular to the keel.

Multibeam sounders can be put into three main catagories depending on their system structure and varied uses:

- Deep water systems, designed for regional mapping, 12Khz for deep ocean, 30Khz for continental slopes.
- Shallow water systems designed for mapping continental shelves, 70-200KHz and
- High-resolution systems for hydrography, shipwreck location and underwater structural inspection, 300-500Khz.

The attraction for multibeam systems is the scale of area that can be covered over time. For instance, a deep water configured multibeam sounder with a 20km fan/spread can cover 10,000km² per day. (Lurton, 2010)

E.3.4. Boomers, Sparkers and Chirps

Sparkers and boomers are high frequency devices which are generally used to determine shallow features in sediments. These devices may also be towed behind a survey vessel, with their signals penetrating several tens (boomer) or hundred (sparker) of metres of sediments. Typical sound intensity levels of sparkers are approximately 204-210 dB in water at 1m, rms value (204-210 dB re 1 µPa @ 1 m). Deep-tow boomer sound intensity levels are approximately 220 dB in water at 1m, rms value (220 dB re 1 µPa @ 1 m). The frequency range of both is 80Hz-10kHz and the pulse length is 0.2 ms. (Aiello *et al*, 2012, OSPAR, 2009)

Chirps produce sound in the upper frequency range around 20Hz-20 kHz. (Mosher and Simpkin, 1999) The sound intensity level for these devices is about 210-230 dB in water at 1m, peak value, (210-230 dB re 1 µPa @ 1 m) and the pulse length is 250ms. (Dybedal and Boe, 1994, Lee *et al*, 2008, OSPAR, 2009)

E.4. Coastal and Offshore Construction Works

E.4.1. Explosions

Explosions are used in construction and for the removal of unwanted seabed structures. Underwater explosions are one the strongest anthropogenic sound sources and can travel great distances. (Richardson *et al*, 1995) Sound

intensity levels vary with the type and amount of explosive used and the depth to which it is detonated. TNT, 1-100lbs, can produce a sound intensity level from 272-287 dB in water at 1m, zero to peak value, (272-287 dB re 1µPa zero to peak @ 1m) with a frequency range of 2-~1000Hz for a duration of <1-10ms. The core energy is between 6-21Hz. (Richardson *et al*, 1995, NRC, 2003)

E.4.2. Pile driving

Pile driving is associated with harbour work, bridge construction and wind farm foundations. Sound intensity levels vary depending on pile size and type of hammer. There are two types of hammers, an impact type (diesel or hydraulic) and vibratory type. Vibratory type hammers generate lower source levels, but the signal is continuous, where impact hammers are louder and plosive. The upper range is around 228 dB in water at 1m, peak value or 248-257 dB in water at 1m, peak to peak value, (228 dB re 1µPa peak @ 1 m/248-257 dB re 1µPa peak to peak @ 1m) with frequencies ranging within 20Hz-20KHz and a duration of 50ms. (Nedwell *et al*, 2003, Nedwell and Howell, 2004, Thomsen *et al*, 2006, OSPAR, 2009)

E.4.3. Dredging

Dredging is used to extract sand and gravel, to maintain shipping lanes and to route pipelines. The sound intensity level produced is approximately 168-186 dB in water at 1m, rms value, (168-186 dB re 1µPa @ 1m rms) with frequencies ranging from 20Hz->1KHz with the main concentration below 500Hz.

The majority of this sound is constant and non-plosive. (Richardson *et al*, 1995, OSPAR, 2009)

E.5. Offshore Platforms

E.5.1. Drilling

Drilling can be done from natural or manmade islands, platforms, drilling vessels, semi submersibles or drill ships.

For natural or manmade islands, the underwater sound intensity level has been measured at 145 dB in water at 1m, rms value, (145 dB re 1µPa @1m rms) with frequencies below 100Hz. (Richardson *et al*, 1995)

The sound intensity level transmitted down the caissons with platform drilling has been measured at approximately 150 dB in water at 1m, rms value, (150 dB re 1µPa rms @ 1m) at 30-40Hz frequency. (Richardson *et al*, 1995)

Drill ships seem to emit the highest sound intensity level, 190 dB in water at 1m, rms value, (190 dB re 1µPa @ 1m rms) with the frequencies ranging between 10Hz-10KHz, due to the efficient transmission of sound through the ship's hull. Additionally, ships use their location thrusters to keep them on target, combining propeller, dynamic positioning transponder (placed on the hull and sea floor) pingers (see below), and drill noise. (Richardson *et al*, 1995, OSPAR, 2009, Kyhn *et al*, 2014)

E.5.2. Positioning Transponders

Positioning transponders are used to dynamically position drill ships and other offshore platforms. Each system uses a concatenation of master and slave transponders. These systems have been recorded to have sound intensity level of 100 dB in water at 2km, rms value (100 dB re 1µPa @ 2km rms) with the frequencies ranging between 20KHz to 35KHz. (Kyhn *et al*, 2014)

E.5.3. Related Production Activities

During production, noise sources include seafloor equipment such as separators, injectors and multi-phase pumps operating at very high pressures.

There have also been studies to measure the sound intensity levels during production maintenance operations. Sound intensity levels of 190dB rms from the drill ship (distance unknown) with a frequency range between 20Hz-10KHz were recorded. (Kyhn *et al*, 2014) To date there have been no other systematic studies to measure the source levels of production maintenance. It is likely the sound intensity level is high. This is an area that needs focused attention.

E.6. Playback and Sound Exposure Experiments

E.6.1. Ocean Tomography

Ocean science uses a variety of sound sources. These include explosives, air guns and underwater sound projectors. Ocean tomography measures the physical properties of the ocean using frequencies between 50-200Hz with a sound intensity level of 165-220 dB in water at 1m (165-220 dB re 1µPa @ 1m). The *Acoustic Thermometry of Ocean Climate* research programme emitted a sound source of 195 dB in water at 1m, peak value, (195 dB re 1µPa @ 1m peak) at a frequency of 75Hz.

Geophysical research activities, one of which is the study of sediments in shallow water, also use typical mid or low frequency sonar systems or echo-sounders. (OSPAR, 2009) These are discussed under Civil High Power Sonar.

E.7. Shipping and Vessel Traffic

Marine vessels, small to large, contribute significantly to anthropogenic noise in the oceans. The trend is usually, the larger the vessel, the lower the frequencies produced resulting in the noise emitted travelling greater distances. The sound characteristics produced by individual vessels are determined by the vessels class/type, size, power plant, propulsion type/design and hull shape with relation to speed. Also, the vessel's age in terms of mechanical condition and the cleanliness of the hull: Less drag means less noise.

E.7.1. Small Vessels

Small vessels (leisure and commercial) for this paper are vessels up to 50m in length. These include planing hull designs such as jet skis, speed boats, light commercial run-abouts as well as displacement hull designs like motor yachts, fishing vessels and small trawlers.

The greater portion of sound produced by these vessels is mainly above 1KHz mostly from propeller cavitation. Factors that generate frequencies below 1KHz are engine and gearbox noise as well as propeller resonance. The sound intensity level produced is approximately 160-180 dB in water at 1m, rms value, (160-180 dB re 1µPa @ 1m rms) with frequencies ranging 20Hz ->10KHz. This, however, is dependent on the vessel's speed in relation to hull efficiency and economic speed to power settings. (Richardson *et al*, 1995, OSPAR, 2009)

E.7.2. Medium Vessels

Medium vessels for this paper are vessels between 50-100m, such as tugboats, crew-boats, larger fishing/trawler and research vessels. These vessels tend to have slower revving engines and power trains. The frequencies produced tend to mimic large vessels with the majority of sound energy below 1KHz. The sound intensity level produced is approximately 165-180 dB in water at 1m, rms value (165-180 dB re 1µPa @ 1m rms). (Richardson *et al*, 1995, OSPAR, 2009)

E.7.3. Large Vessels

Large vessels for this paper are vessel lengths greater than 100m, such as container/cargo ships, super-tankers and cruise liners.

Large vessels, depending on type, size and operational mode, produce their strongest sound intensity level of approximately 180-190 dB in water at 1m, rms value, (180-190 dB re 1µPa @ 1m rms) at a few hundred Hz. (Richardson *et al*, 1995, Arvenson and Vendittis, 2000) In addition, a significant amount of high frequency sound, 150 dB in water @ 1m, rms value, (150 dB re 1µPa @ 1m rms) or broadband frequencies, 0.354-44.8 kHz of 136 dB in water at 700m distance, rms value, (136 dB re: 1µPa @ >700m rms) can be generated through propeller cavitation. This near-field source of high-frequency sound is of concern particularly within shipping corridors, shallow coastal waters, waterways/canals and/or ports. (Arveson and Vendettis, 2000, Aguilar Soto *et al*, 2006, OSPAR, 2009)

E.8. Pingers

E.8.1. Acoustic Navigation and Positioning Beacons

Acoustic navigation and positioning beacons mark the position of an object and measure its height above the seabed. Most underwater beacons emit a short continuous wave tone, commonly 8-16 kHz octave band, with a stable ping rate. Typical sound intensity levels are around 160-190 dB in water at 1m, peak value (160-190 dB *re* 1µPa @ 1m peak). They are designed to be omnidirectional so as to be heard from any direction. Simple systems are programmed to transmit a fixed ping rate whilst more sophisticated systems transmit after receiving an interrogating signal. (Lurton, 2010)

E.8.2. Acoustic Deterrent Devices

Acoustic Deterrent Devices (ADDs) are a low powered device, 130-135 dB in water at 1m, peak value, (130-135 dB *re* 1µPa @ 1m peak) designed to deter fish from entering places of harm such as water inlets to power stations. The frequencies range from 9-15KHz for a duration 100-300ms every 3-4 seconds. (Carretta *et al*, 2008, Lepper *et al*, 2004, Lurton, 2010, OSPAR Commission, 2009)

E.8.3. Acoustic harassment devices

Acoustic Harassment Devices (AHDs) are a higher powered device, 190 dB in water

at 1m, peak value, (190 dB *re* 1µPa @ 1m peak) originally designed to keep marine mammals away from fish farms by causing them pain. Frequencies range from 5-20KHz for repelling pinipeds and 30-160KHz for delphinids. (Carretta *et al*, 2008, Lepper *et al*, 2004, Lurton, 2010, OSPAR, 2009)

E.9. Other Noise-generating Activities

E.9.1. Acoustic Data Transmission

Acoustic modems are used as an interface for subsurface data transmission. Frequencies range around 18-40KHz with a sound intensity level around 185-196dB in water at 1m (185-196 dB re 1µPa @ 1m). (OSPAR, 2009)

E.9.2. Offshore Tidal and Wave Energy Turbines

Offshore tidal and wave energy turbines are new, so acoustic information is limited. However, they appear to emit a frequency range of 10Hz-50KHz and a sound intensity level between 165-175dB in water at 1m, rms value, (165-175 dB re 1µPa @ 1m rms) depending on size. (OSPAR, 2009)

E.9.3. Wind turbines

The operational sound intensity levels for wind generators depend on construction type, size, environmental conditions, type of foundation, wind speed and the accumulative effect from neighbouring turbines. A 1.5MW turbine in 5-10m of water with a wind speed of 12m/s has been recorded producing 90-112 dB in water at 110m, rms value, (90-112 dB re 1µPa @ 110m rms) with frequencies ranging 50Hz-20KHz. (Thomsen *et al*, 2006, OSPAR, 2009)

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Table 9: Noise-generating activity, sound intensity level, bandwidth, major amplitude, duration and directionality

Sound	Sound Intensity Level (dB re1 ìPa)	Bandwidth	Major Amplitude	Duration	Directionality
Military					
Military Low Frequency Active Sonar	240 Peak @ 1m	<1KHz- 1Khz	[unknown]	600-1,000ms	Horizontally focused
Military Mid Frequency Active Sonar	235 Peak @ 1m	1-5KHz	[unknown]	1-2s	Horizontally focused (3 degrees down)
Continuous Active Sonar	182 Peak @ 1m	500Hz – 3KHz	[unknown]	18 seconds	Horizontally focused
Military Mine Counter Measures Sonar	[unknown]	100KHz-500KHz	[unknown]	[unknown]	[unknown]
Seismic Surveys					
Seismic Surveys	260-262 Peak to Peak @ 1m	10Hz-150KHz	10-120Hz also 120dB up to 100Kz	30-60ms	Vertically focused
Civil High Power Sonar					
Single Beam Sounders	240 Peak @ 1m	12KHz-700KHz depending on the application	[unknown]	0.1ms	Vertically focused
Sidescan Sonar	240 Peak @ 1m	12KHz-700KHz depending on the application	[unknown]	0.1ms	Vertically focused fan spread
Multibeam Echosounders	240 Peak @ 1m	12KHz-30KHz, 70KHz-200KHz, 300KHz-500KHz depending on the application	[unknown]	0.1ms	Vertically focused fan spread
Sparkers and Boomers	204-220rms @ 1m	80Hz-10KHz	[unknown]	0.2ms	[unknown]
Chirps	210-230 Peak @ 1m	20Hz-20KHz	[unknown]	250ms	[unknown]
Coastal and Offshore Construction Works					
Explosions, TNT 1-100lbs	272-287 Peak @ 1m	2Hz-~1,000Hz	6-21Hz	<1-10ms	Omnidirectional
Pile Driving	248-257 Peak to Peak @ 1m	20Hz-20KHz	100Hz-500Hz	50ms	Omnidirectional
Dredging	168-186 rms @ 1m	20Hz-1KHz	500Hz	Continuous	Omnidirectional
Offshore Platforms					
Platform Drilling	150 rms @1m	30Hz-40Hz	[unknown]	Continuous	Omnidirectional
Drill Ships (including maintenance)	190 rms @ 1m	10Hz-10KHz	[unknown]	Continuous	Omnidirectional
Positioning transponders	100 rms @ 2km	20KHz - 35KHz	[unknown]	Continuous	Omnidirectional

Sound	Sound Intensity Level (dB re1 ìPa)	Bandwidth	Major Amplitude	Duration	Directionality
Playback and Sound Exposure Experiments					
Ocean Tomography	165-220 Peak @ 1m	50Hz-200Hz	[unknown]	[unknown]	Omnidirectional
Shipping and Vessel Traffic					
Small Vessels	160-180 rms @ 1m	20Hz-10KHz	[unknown]	Continuous	Omnidirectional
Medium Vessels	165-180 rms @1m	Below 1KHz	[unknown]	Continuous	Omnidirectional
Large Vessels	Low Frequency 180-190 rms @ 1m High Frequency 136 rms @ 700m	Low Frequency A few hundred Hz High Frequency 0.354Khz-44.8Khz	[unknown]	Continuous	Omnidirectional
Pingers					
Acoustic Navigation Beacons	160-190 Peak @ 1m	8KHz-16KHz	[unknown]	[unknown]	Omnidirectional
Acoustic Deterrent Devices	130-135 Peak @ 1m	9KHz-15KHz	[unknown]	100-300ms	Omnidirectional
Acoustic Harassment Devices	190 Peak @ 1m	5Khz-20KHz, 30KHz-160KHz depending on the application	[unknown]	[unknown]	Omnidirectional
Other Noise-generating Activities					
Acoustic Data Transmission	185-196 @ 1m	18KHz-40KHz	[unknown]	[unknown]	Omnidirectional
Offshore Tidal and Wave Energy Turbines	165-175 rms @ 1m	10Hz-50KHz	[unknown]	Continuous	Omnidirectional
Wind Turbines	90-112 rms @ 110m	50Hz-20KHz	[unknown]	Continuous	Omnidirectional