Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters

August 2007

Introduction

There are currently eighty-six recognised cetacean species in the world. Twenty-four species have been identified in Irish Waters from sighting or stranding records (see Appendix I). Of these six are large baleen whales (mysticeti) and eighteen smaller toothed- whale species (odontoceti). There are also two species of seal (Common Seal and Grey Seal) which breed in Ireland. All marine mammal species are afforded strict protection from interference and deliberate harm by the European Communities (Natural Habitats) Regulations 1997 and the Wildlife (Amendment) Act 1976 & 2000.

Hearing is the most important sense for cetaceans, and the ability to hear well is vital in all key aspects of their lives including finding food, navigating and social interactions (Richardson *et al.* 1995). Any reduction in hearing ability, whether by physical damage or masking by other sound, may seriously compromise the viability of individuals and, therefore, populations. Whilst at an extreme level noise can lead to cetacean mortality from barotrauma, sub-lethal effects may also have a significant impact (Crum & Mao, 1996**;** Frantiz, 1998). Sub-lethal effects could include threshold shift or complete hearing loss (Schlundt *et al*., 2000), which would seriously compromise the viability of individuals or entire populations. Displacement of cetaceans from important feeding, migration or reproductive sites could also lead to a change in population dynamics (Gordon *et al*. 1998).

There are many sound sources within the marine environment. Presumably some sources are so prevalent that marine mammals have become habituated. However, of particular concern are sources that are generated either intermittently or that may produce a damaging effect through either physiological or behavioural responses. As acoustic seafloor surveys rely on the generation and analysis of sound to map the profile of the seafloor, there is a clear necessity to develop a code of practice that will mitigate against potential impacts on marine mammals.

Sound in the Marine Environment

There are three components to sound generation in the sea. Sound can be characterised as having a pressure or intensity. Sound pressure is usually quoted in units of decibel micro Pascal. A decibel is a logarithmic scale of pressure i.e. 1, 10, 100 etc. equals 1, 2, 3. Since this unit of sound pressure is a relative measure it is necessary to quote a reference point (usually one micro Pascal (1 μPa) for sounds in water). Sound pressure and intensity are somewhat analogous. The unit of sound intensity is the Watt per metre square (W/m^2). The lower limit of human hearing is often given as an intensity of 10^{-12} W/m^2, corresponding to a pressure of 20.6μPa in air or 1160μPa in water. The difference is due to the acoustic differences between air and water.

The second component of sound is the frequency or pitch usually indicated in Hertz or Kilohertz; this is the number of cycles of sound generated per second. The band of reception for most mammals is defined as the range of frequencies to which the eardrum is capable of resonating and thus detecting. The frequency is different from the duty cycle which is the ratio between the length of the sound emission and the gap between emissions.

The third component is the range of frequencies generated within a sound source often referred to as tone (one frequency) or bandwidth (many frequencies within a range). For example a sound generating source can be over several frequencies within a detectable spectrum (broadband); this would be the case with a boat engine. This spreads the auditory load over a range of frequencies and leads to less point pressure on the auditory mechanism. The other situation is a mono-tonal sound source. The mono-tonal source places more discrete pressure on the auditory system. But if a sound source is sufficient to cause damage to the hearing a wide bandwidth has more serious implications.

In general terms sound sources that have high sound pressure and low frequency will travel greatest distances in the marine environment. Conversely, sources that have high frequency will tend to have greater attenuation over distance due to interference and scattering effects. For example, the absorption at 100kHz is 0.01dB/m, so that owing to absorption alone, a 200dB re 1μPa emission @1m is reduced to a 170dB re 1μPa level at a range of 3000m through the water column (Gisiner, 1998).

Marine Acoustic Surveys

Marine seafloor surveys are conducted to simply calculate bottom contours or depth or biological parameters or in more advanced studies to identify geological processes and structures and locate geological structures of types often associated with petroleum deposits. Many surveys use various mapping techniques to assess the bottom contours or the nature of underlying rock formations. Methods used range from towed side-scan sonar to elucidate bottom contours, hull-mounted multibeam bathymetric echo-sounders to form an accurate map with detail of the nature of seafloor and seismic surveys that use an array of airguns to form an image of underlying rock and sediment beneath the sea floor (Table 1). In addition concerns over the effects of electromagnetic (EM) surveys on cetacean navigation necessitate the implementation of mitigation measures during EM surveys.

Sound type	*Frequency (kHz)*	*Duration (s)*	*Source level (dB re 1μPa)*
Depth sounders	12-200	>0.025	180+
Fish finders	20-30	>0.025	216-223
Bottom profilers	0.4- 30	0.1-160	200- 230
Side scan	50-500	0.01-0.1	220-230
Multibeam*	92-98	0.02	Up to 235
Airgun array	0.001 to 1	<1	216-260

Table 1. After Richardson *et al*. 1995, Marine Institute* and Internet sources

Fishing vessels use various sounding devices in normal operations. Normally a depth sounder will have a series of settings ranging from about 12kHz to 200kHz. The lowest setting is used in very deep water (up to 5000m) whilst the highest settings are used to give fine detail in normal operations. It is likely that most fishing vessels are operating at frequencies at approximately 100kHz. For focused echo sounders, such sound levels will be found in the narrow main lobe immediately below the transducer. Hence the most likely scenario for injury of an animal by acoustic equipment would be if the equipment were turned on full power while the animal was close to it. Fishing vessels also use sonar to find and identify shoals of fish. On most vessels the sound source is approximately between 216-223dB re 1μPa and is generated at frequencies between 20 and 30kHz. Richardson et al, (1995) reviewed literature, which indicated whales may react to lower frequency echo sounders, sometimes showing avoidance behaviour. Baleen whales seem to react to frequencies up to 28kHz but do not react to pingers, acoustic tags and echo sounders at 36KHz and above (O'Brien *et al*., 2005). The generally high frequency of echosounders and fish-finding sonar suggests that sound sources are rapidly attenuated in the water column.

Multibeam and side-scan echo-sounders are generally considered high acoustic density source and medium frequency generators. The level of sound pressure ranges from about 200 dB re 1μPa to 240 dB re 1μPa. The frequency ranges from about 50 to 500kHz. The nature of propagation varies with desired goals although it can generally be expected to conform to a conical pattern with a greater swath being covered in deeper water. To survey

deeper water it is necessary to use lower frequency due to the attenuating properties of seawater. However, the lower the frequency of source used the lower the resolution of images collected. Therefore, it is likely that for most operations the maximum detectable frequency will be used. There is a significant difference in the effects of both seismic and multibeam/side-scan surveys. Higher frequency emissions utilised in normal multibeam operations tend to be dissipated to safe levels over a relatively short distance despite having similar sound levels to seismic surveys.

Seismic surveys generally use a sound-generating device such as air guns, boomers, sparkers and chirpers. The type of equipment used will be dictated by the survey objectives and location. The guns are filled with air that through a sudden release of pressure generates a pressue wave that propagates through the water column. Although a single airgun is sometimes used, seismic surveys are usually conducted using an array of guns towed at a depth of 4-8m behind a ship. The deeper the subsurface feature to be surveyed generally the greater the acoustic source required. The source pressure ranges from approximately 216 dB re 1μPa (single airgun) to 260 dB re 1μPa (large array). The received frequency range for airguns will typically fall between 10-120Hz but some will fall within the higher 500-1000Hz band. The direction of propagation in most instances is downwards, however, horizontal propagation can be detected at great range because of the high intensity and low frequency of source. The low frequency source of airgun arrays tends to produce a larger acoustic footprint in the marine environment.

Effects of Acoustic Sources on Marine Mammals

The hearing ranges of marine mammals differ from one species to another. Each species has different characteristics and ranges of perception of sound frequencies. The sensitivity of marine mammals depends on their specific audiogram as shown in Table 2.

	Range kHz,	*Peak Sensitivity kHz*
Harbour Porpoises	3 - 130	125-130
Bottlenose Dolphins	5-110	5 kHz
Common Seals	4-45	32 kHz
Grey Seals	8 - 40	not available

Table 2. Range and peak sensitivity for selected marine mammals (Richardson et al., 1995).

Seals may be affected by noise particularly during periods when they are pupping or moulting. Most seismic surveys are undertaken in the offshore and hence this document will primarily be designed to afford protection to cetaceans. However, surveys undertaken adjacent to seal habitats may also be subject to restriction and mitigation.

Studies have demonstrated that source levels greater than 210 dB re 1μPa can produce barotrauma and potentially cause death in marine mammals (see Table 3). However, it is considered that source levels below 190dB re 1μPa are unlikely to produce lethal effects. A significant reduction in hearing capability of cetaceans was demonstrated by source levels in the range from 190dB re 1μPa upwards for a short period of time. This threshold shift can be permanent or temporary although because of the nature of cetacean research it is difficult to establish a long-term pattern from short-term exposure. It does however demonstrate that sounds can have an impact.

Repeated exposure of cetaceans to source levels above 170 dB re.1 μ Pa can cause a reduction of hearing capability in cetaceans. However, sound pressure may also have other physiological effects on cetaceans (Table 3).

	Source level	*Effect*	*Reference*
Gas filled spaces	217dB	produces rupture	Turnpenny et al 1994
Bowel	>237dB	no prolonged effect	Gisiner, 1998
Lungs	>237 dB	haemorrhage & barotraumas	Fletcher et al, 1976
Cardiac	N/A	theoretically possible arrhythmia	Gisiner, 1998
Reproduction	223-236dB	reduced embryonic viability	Gisiner, 1998
Decompression	190dB @ >250Hz	Cavitation & Barotrauma	Crum & Mao, 1993 & 1996

Table 3. Demonstrated effects of sound pressure on cetaceans

Development of the Code

This code was prepared by the National Parks & Wildlife Service of the Department of the Environment, Heritage & Local Government. Consultations were undertaken with the Irish Whale and Dolphin Group (particularly Mr Dave Wall & Dr Simon Berrow), Coastal Marine Resource Centre (University College Cork) (particularly Dr Oliver O' Cádhla), Geological Survey of Ireland, Marine Institute, Petroleum Affairs Division (Department of Energy, Marine and Natural Resources) and the Irish Offshore Operators Association. The text was based on the Joint Nature Conservation Committee's document "Guidelines for Minimising Acoustic Disturbance to Marine Mammals from Seismic Surveys" (2004).

This code will be subject to periodic reviews to streamline any difficulties experienced and/or incorporate any developments in best practice.

Code of Practice

General Planning

1. This code is applicable to all seismic surveys, to multibeam and side-scan sonar surveys in bays, inlets or estuaries and within 1500m of the entrance of enclosed bays/inlets/estuaries or if so advised by National Parks & Wildlife Service.
2. When planning seismic surveys a minimum distance of 100km should be maintained between adjacent seismic surveys in open water.
3. The minimum source level required to achieve results should be used and frequencies chosen to minimise impacts on marine mammals.
4. Continuous noise is likely to be more damaging to marine mammals than pulsed sounds and should be avoided where possible.
5. The use of sub-threshold acoustic deterrents, e.g. whale guns, is not permitted.
6. Available methods should be used to reduce and/or baffle unnecessary high frequency noise produced by airguns or other acoustic energy sources during the survey.
7. Qualified and experienced Marine Mammal Observers[1] (MMOs) must be present on board all vessels conducting seismic (including boomers) or electromagnetic surveys at all times during the survey. If a survey involves time-sharing, then MMOs should be placed on all source vessels.
8. The MMO must use a distance measuring stick, reticle telescope or binoculars to ascertain distances to marine mammals.
9. MMOs must be engaged solely in monitoring the operator's implementation of these guidelines and conducting visual/acoustic observation of mammals during the survey.
10. The MMO must submit a report, as outlined in Appendix II, within 30 days of completion of the survey to the relevant Licensing Authority and copy the report to the National Parks & Wildlife Service[2].
11. The vessel operator must provide a report (including a daily log) on the operation of the seismic equipment that will indicate the soft starts and their duration to the MMO. This information will be made available to National Parks & Wildlife Service.
12. Operators are encouraged to make this data publicly available.
13. It is the responsibility of the vessel operator to ensure full compliance with this code.

---

[1] A qualified and experienced MMO is a person who has undergone marine mammal observation training (JNCC MMO training course or equivalent) and has spent a minimum of six weeks of marine mammal survey experience at sea over a three-year period.

[2] Offshore Unit,
National Parks & Wildlife Service,
Department of the Environment, Heritage & Local Government,
Ely Court,
7 Ely Place,
Dublin 2, Republic of Ireland.
offshore@environ.ie

Multibeam and side-scan sonar surveys

Pre start scan for marine mammals

1. Survey work must start at the inner most part of the bay, inlet or estuary to be surveyed and work outwards. This is to ensure that cetaceans are not driven into en enclosed area which could cause them to panic.
2. MMOs should survey the area for the presence of cetaceans **30 minutes** before the starting operations.
3. A minimum distance of **1000 metres** is required between the centre of the array/sound source and the nearest cetacean before starting.
4. If marine mammals are seen within **1000 metres** of the centre of the sound source the start of the sound source(s) should be delayed until they have moved away, allowing adequate time after the last sighting for the animals to leave the area (**30 minutes**). If the cetaceans do not leave the area it is recommended that the survey vessel alter course to ensure that the animals are outside the **1000 metres** exclusion zone when soft start commences.

Soft start procedures for multibeam and side-scan sonar

5. The sound level must be allowed to gradually build over a period of 20 minutes; where this is not possible, the equipment should be turned on and off over a 20 minute period to act as a warning signal and allow cetaceans to move away from the sound source.
6. Multibeam or side-scan sonar start-up must occur during daylight hours when MMO's can carry out the required start-up procedure.
7. The start-up procedure should be implemented at all times including during testing of the sound source.
8. If, for any reason, the sound source is stopped and not restarted for at least 5 minutes a full start-up procedure should be carried out.
9. Once the sound source has achieved its maximum output the survey need not be halted if cetaceans approach the vessel.
10. If turn-around time between sample lines or stations is greater than the time required to conduct a start-up procedure (30 minutes), then the sound source should be stopped and a full start-up procedure should be used prior to commencing the new line.

Seismic surveys

Pre soft start scan for marine mammals (waters up to 200m depth)

1. MMOs should survey the area for the presence of cetaceans **30 minutes** before the onset of the soft start.
2. A minimum distance of **1000 metres** is required between the centre of the array/sound source and the nearest cetacean before soft start can commence.
3. If marine mammals are seen within **1000 metres** of the centre of the sound source the start of the sound source(s) should be delayed until they have moved away, allowing adequate time after the last sighting for the animals to move leave the area (**30 minutes**). If the cetaceans do not leave the area it is recommended that the survey vessel alters course to ensure that the animals are outside the **1000 metre** exclusion zone when soft start commences.
4. Soft start should commence after a **1000 metre** area around the vessel has been confirmed clear of cetaceans for **30 minutes**.

Pre soft start scan for marine mammals (waters deeper than 200m depth)

5. MMOs should survey the area for the presence of cetaceans **60 minutes** before the onset of the soft start.
6. A minimum distance of **1000 metres** is required between the centre of the array/sound source and the nearest cetacean before soft start can commence.
7. If marine mammals are seen within **1000 metres** of the centre of the sound source the start of the sound source(s) should be delayed until they have moved away, allowing adequate time after the last sighting for the animals to leave the area (**60 minutes**). If the cetaceans do not leave the area it is recommended that the survey vessel alters course to ensure that the animals are outside the **1000 metre** exclusion zone when soft start commences.[3]
8. In situations where seals are congregating immediately around a drilling or production platform, it is recommended that commencement of the seismic sources begin at least **1000 metres** from the platform.
9. Soft start should commence after a **1000 metre** area around the vessel has been confirmed clear of cetaceans for **60 minutes**.

Soft start procedure

10. Soft starts should achieve maximum (or desired) output after **20 to 40 minutes**.
11. Power should be built up slowly from a low energy start-up (e.g. starting with the smallest airgun in the array and gradually adding in others) over at least **20 minutes** to give adequate time for marine mammals to leave the vicinity.
12. This build up of power should occur in uniform stages to provide a constant increase in output from the sound source.

[3] The longer survey time and wider exclusion zone in waters deeper than 200 m recognise that the footprint of an acoustic source covers a much wider area in deep waters and so animals at a greater distance from the vessel will be affected. It is also necessary to allow cetaceans feeding at greater depth time to re-surface and leave the area affected.

13. There should be a soft start every time the sound source(s) is used including before test firing of the sound source, **even if no marine mammals have been seen**.
14. Soft starts must occur during daylight hours when MMO's can carry out the required pre soft start scan.
15. To minimise additional noise in the marine environment, a soft start (from commencement of soft start to commencement of the line) should take no longer than 40 minutes.
16. If, for any reason, firing of the sound source has stopped and not restarted for at least 5 minutes a full soft start for the appropriate depth should be carried out.
17. After a break in firing of any duration a visual check should be made for marine mammals within the 'exclusion zone'. If a marine mammal is present then re-commencement of shooting should be delayed as per the instructions above.
18. When time-sharing, where two or more vessels operate in adjacent areas and take turns to shoot to avoid causing seismic interference to each other, all vessels shooting should follow the full soft start procedure for each line started.
19. Once the sound source has achieved its maximum output (post soft start) it is not necessary to stop the survey should cetaceans approach the vessel.
20. If a soft start is not possible this should be identified at the time of application to the relevant Licensing Authorities and measures identified as to how the operator proposes to deal with this issue.

Line change

1. If a break in output greater than 5 minutes occurs at any time whilst sampling then a full soft start (including pre soft start scan) for the appropriate water depth should be used prior to recommencing use of the sound source.
2. With the sound source running, if turn-around time between sample lines or stations is greater than the time required to conduct a soft start (including pre soft start scan) for the appropriate water depth, then the sound source should be stopped and a soft start for the appropriate water depth should be used prior to commencing the new line.
3. For line changes which take less time than that required to undertake a soft start, the sound source (e.g. full array of airguns) should continue firing during the line turn (e.g. for a site survey line turn of 5 minutes continue firing at full power).
4. For high resolution site surveys line changes it is preferable to reduce airgun output at the end of each line to an output of 150dB. The increase from 150 dB to full power, prior to the start of the next line, should be undertaken in a stepped manner similar to a full soft start.

Undershoot operations[4]

1. The MMO should always be onboard the source vessel.
2. Operators who foresee a problem placing an MMO onboard a vessel undertaking an undershoot operation must notify the relevant Licensing Authority during the application process.

[4] During an undershoot operation a second vessel is employed to tow a seismic source or airguns although the main vessel will still tow the streamer array. This is to allow shooting under platforms or around any other obstructions at sea.

Appendix I: List of cetacean species recorded in Irish Waters.

		Waters < 200m	*Waters > 200m*
Atlantic White-Sided Dolphin	*Lagenorhynchus actus*	br	
Beluga	*Delphinapterus leucas*	va/arc	va /arc
Blue Whale	*Balaenoptera musculus*	sp	sp
Bottlenose Dolphin	*Tursiops truncatus*	br/co	
Common Dolphin	*Delphis delphis*	br/co	
Cuvier's Beaked Whale	*Ziphius cavirostris*	sp	ra
False Killer Whale	*Pseudorca crassidens*		ra
Fin Whale	*Balaenoptera physalus*	se/co	
Gervais' Beaked Whale	*Mesoplodon europaeus*	sp	va/st
Harbour Porpoise	*Phocoena phocoena*	br/co	
Humpback Whale	*Megaptera novaeangliae*	se	se
Killer Whale	*Orcinus orca*		sp /br
Minke Whale	*Balaenoptera acutorostrata*	br/co	
Northern Bottlenose Whale	*Hyperoodon ampullatus*	sp	sp
Northern Right Whale	*Eubalaena glacialis*		va/arc
Pilot Whale (long-finned)	*Globicephala melas*	br	
Pygmy Sperm Whale	*Kogia breviceps*		sp
Risso's Dolphin	*Grampus griseus*	br/co	
Sei Whale	*Balaenoptera borealis*	sp	sp
Sowerby's Beaked Whale	*Mesoplodon bidens*	sp	
Sperm Whale	*Physeter macrocephalus*		co/br
Striped Dolphin	*Stenella coeruleoalba*	sp	sp
True's Beaked Whale	*Mesplodon mirus*	sp	
White-Beaked Dolphin	*Lagenorhynchus albirostris*		co

arc, arctic species; br, breeds in Irish waters; co, common; se, seasonal; sp, sporadic; st, known only from strandings; va, vagrant

Appendix II: Marine Mammal Observer Report Format and Forms

Cetacean sighting report:

1. Date and location of the survey
2. Name and address of MMOs on the vessels
3. MMO Qualification
4. Name of any other vessels involved in the survey
5. Grid references for the area surveyed
6. Details of watches made for marine mammals and the acoustic survey activity during watches (using enclosed forms)
7. Marine mammal sightings (using enclosed forms).
8. Reports from any observers on board.
9. A record of all occasions when the airguns or other sound sources were used
10. The vessel's operations report

Operations report:

1. Vessel name/s participating in the survey.
2. The survey reference number supplied by the PAD or other statutory body.
3. Date and location of the survey.
4. Grid references for the area surveyed.
5. Acoustic equipment used.
6. For seismic surveys: number and volume of each airgun used and a calculated total volume of the array.
7. For seismic surveys: nature of airgun array/acoustic source discharge frequency (in Hz or KHz), intensity (in dB re. 1µPa) and firing interval (seconds), or details of other acoustic or electromagnetic sources used.
8. Details of any problems encountered during marine mammal detection procedures, or during the survey.
9. A daily log of how and when the equipment was used including 'soft starts'.

MARINE MAMMAL RECORDING FORM - RECORD OF SIGHTING

Options in italics should be circled or underlined as appropriate

Date	**Time** (UTC)		**Sighting no.**

How did this sighting occur? (please tick box)

While you were keeping a continuous watch for marine mammals _
Spotted incidentally by you or someone else _
Other (please specify) _

Ship	**Observer**

Ship's position (latitude and longitude)	**Water depth** (metres)

Species	**Certainty of identification (underline)** Definite / probable / possible

Total number	**Number of adults** **Number of juveniles**

Description (include features such as overall size; shape of head; colour and pattern; size, shape and position of dorsal fin; height, direction and shape of blow)	**Photograph or video taken** *Yes / No*
	**Direction of travel of animals in relation to ship** (draw arrow)

Behaviour	**Direction of travel of animals** (compass points)

Activity of ship	**Airguns firing** (when animals first seen) *Yes / No / Soft-start*	**Closest distance of animals from airguns** (metres) (Record even if not firing)

Please continue overleaf or on a separate sheet if necessary

Complete this form every time the airguns are used, including overnight, whether for shooting a line or for testing or for any other purpose.
(Times should be in UTC)

Date	Airgun activity			Pre-shooting search					Action necessary		
	Time when soft start began	Time when airguns reached full power	Time when airguns stopped	Who carried out a search for marine mammals? (Job title)	Time when pre-shooting search for marine mammals began	Time when search for marine mammals ended	Was there any reason why marine mammals may not have been seen? (e.g. visibility, fog, swell, etc.)	Were hydro-phones used?	Were marine mammals present in the 30 minutes before the airguns began firing?	If yes, give time when marine mammals were last seen	If marine mammals were present, what action was taken? (e.g. delay shooting)

Ship: **Ship type (seismic/guard, etc):** **Survey type (site, 2D, 3D, 4C, etc):**

Please record the following information every day (as many lines per day as you wish), even if no marine mammals are seen.

Date	Observer	Time you started looking for marine mammals (UTC)	Time you stopped looking for marine mammals (UTC)	Duration of watch for marine mammals (mins)	Length of time airguns were shooting while you were looking for marine mammals (mins)	Blocks transited while looking for marine mammals (or start and end position if blocks not known)	Wind force and direction (use Beaufort scale)	Sea state Beaufort Wind Scale	Swell Choose from: 0 = no Swell 1= <1 m 2 = 1-2 m 3 = 2+ m	Visibility Choose from: 1 = < 1 km 2 = 1-5 km 3 = > 5 km

Appendix III: References

1. Crum, LA & Mao, Y. (1993). Calculations of the thresholds for growth and growth rate of bubbles in mammalian tissues from exposure to low frequency sound. Report No. C-193, US Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT, Dec 31, 1993.
2. Crum, L.A. & Mao, Y. (1996). Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. Journal of the Acoustical Society of America, 99: 2898-2907.
3. Fletcher, E.R., Yelverton, J.T. & Richmond, D.R. (1976). The thoraco-abdominal systerm's response to underwater blast. Final Technical Report for ONR contract N00014-75-C-1079.
4. Frantiz, A. (1998). Does acoustic testing strand whales? Nature 392, 29.
5. Gisiner, R.C. (1998). Proceedings on workshop on the effects of anthropogenic noise in the marine environment. 10-12 February 1998. Marine Mammal Science Program, Office of Naval Research, VA, USA.
6. Gordon, J.C.D., Gillespie, D., Potter, J., Frantiz, A., Simmonds, M.P. & Swift, R. (1998). The effects of seismic surveys on marine mammal. In Tasker M.L., and Weir, C. (editors) Proceedings of the seismic and marine mammals workshop. London. June 1998.
7. JNCC, 2004. Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys. Joint Nature Conservation Committee, Peterborough, UK (www.jncc.gov.uk).
8. O'Brien, J., Berrow, S. & Wall, D. (2005). The impact of multibeam on cetaceans: A review of best practise. Irish Whale & Dolphin Group, Merchant's Quay, Kilrush, Co. Clare (www.iwdg.ie).
9. Richardson, W.J., Greene, C.R., Malme, C.I. & Thompson, D.H. (1995). *Marine mammals and noise*. Academic Press, San Diego.
10. SCAR (2001). Report on marine acoustic technology and the Antarctic environment. XXVII ATCM. IP 078.
11. Schlundt, C.E., Finneran, J.J., Carder, D.A. & Ridgway, S.H. (2000). Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. Journal of the Acoustical Society of America, 107: 3496-3508.
12. Turnpenny A.W.H., Thatcher K.P. & Nedwell, J.R. (1994). The effects on fish and other marine animals of high-level underwater sound. Fawley Aquatic Research Laboratory Ltd. Report FRR 127/94. Oct 1994.