IWDG Policy Document

IWDG www.iwdg.ie
Irish Whale and Dolphin Group

POLICY ON THE EFFECTS OF NOISE POLLUTION ON CETACEANS

Potential impacts on cetaceans in Irish waters from oil and gas exploration, the development of marine renewable energy and active mid frequency sonar. Recommendations on mitigation, regulation and further research

Published by The Irish Whale and Dolphin Group, 2015.
Website: www.iwdg.ie Email: enquiries@iwdg.ie

ISBN 0-9540552-9-2
Printed by Walsh Colour Print,
Castleisland, Co. Kerry, Ireland.

Cover photograph: Marine seismic airgun array.
(© WildOcean.ie).
This page: Fin whale feeding in deep waters to the west of Ireland. Photo: Irish Air Corps.
Back cover: Sperm Whales in the Rockall Trough (Photo Air Corps Maritime Squadron).

Design & layout by Michael O'Clery

Citation: IWDG (2015). IWDG Policy on the Effects of Noise Pollution on Cetaceans: Potential impacts on cetaceans in Irish Waters from oil and gas exploration, the development of marine renewable energy and active mid frequency sonar. Recommendations on mitigation, regulation and further research. Irish Whale and Dolphin Group, Merchants Quay, Kilrush, Co Clare, Ireland.

Acknowledgement: The IWDG gratefully acknowledge the support of the Irish Environmental Network in providing funding towards the cost of producing this report.

Contents

Summary

Noise pollution can impact on cetaceans in a number of ways, causing physical injury, physiological effects, or disrupting behaviour and/or communication, this in turn can lead to direct or indirect impacts affecting individuals, groups or populations. Physical injury can take the form of permanent or temporary deafness and in extreme cases may result in death. Chronic effects have the potential to affect the communication of baleen whales across thousands of square kilometres of ocean, with unknown but potentially significant consequences.

Although almost all human activities conducted in the marine environment result in noise pollution, certain activities are of particular concern due to their intensity, frequency and/or duration of the noise generated. In Irish waters the noise pollution sources of greatest concern are from marine seismic surveys, blasting using explosives, marine pile driving and military active sonar. Additional noise sources with a strong potential to impact on marine mammals are multi-beam sonar, operating marine wind farms, tidal energy arrays and possibly electromagnetic surveys.

The IWDG welcomes the drive to a low carbon economy with electricity derived from renewable sources. It also acknowledges the need for Ireland to develop energy security and obtain maximum benefit from offshore resources. However the IWDG has a number of specific concerns relating to the impact on cetaceans from noise pollution arising from the exploration and/or construction phases of such developments and the need for adequate mitigation and monitoring. To date the IWDG has responded in a case-by-case basis to particular projects or issues related to the offshore oil and gas and marine renewables sector. In light of a forecast increase in activity in these sectors over the next decade, the IWDG has commissioned this policy document to cover these activities and their likely impacts on cetaceans in Irish waters

Achoimre

Is féidir go mbeadh tionchar ag truailliú ó thorann ar chéiticigh ar bhealaí éagsúla, agus gortú coirp, iarmhairtí fiseolaíocha, nó cur isteach ar a n-iompar agus/nó ar a gcumarsáid mar thoradh air; dá réir sin is féidir go mbeadh tionchar díreach nó indíreach aige a chuireann isteach ar ainmhithe aonair, ar ghrupaí nó ar phobail ainmhithe. Is féidir go léirítear an gortú coirp mar bhodhaire bhuan nó shealadach agus i gcásanna an-dona ar fad is féidir an bás a bheith i gceist. Tá an cumas ag iarmhairtí leanúnacha cur isteach ar an gcumarsáid idir mhíolta móra bailíneacha trasna na mílte ciliméadar cearnaithe den aigéan, agus torthaí anaithnide a d'fhéadfadh a bheith suntasach dá bharr.

Cé go mbíonn truailliú ó thorann i gceist leis an gcuid is mó de ghníomhaíochtaí an duine a chuirtear ar siúl sa timpeallacht mhuirí, tá gníomhaíochtaí ar leith ann ar cúis imní áirithe iad de bharr a ndéine, a minicíochta agus/nó an fad ama a mhaireann an torann a ghintear. In uiscí na hÉireann is iad foinsí an truaillithe ó thorann ar mó an chúis imní iad na suirbhéanna seismeacha, an pléascadh le pléascáin, an sá pílí san fharraige agus an sonóir míleata gníomhach. Chomh maith leo siúd is foinsí torainn sa bhreis, a bhfuil an cumas láidir iontu tionchar a bheith acu ar mhamaigh, iad an sonóir il-léis, feirmeacha gaoithe ag oibriú amach ón gcósta, trealamh fuinneamh taoide agus b'fhéidir fiú suirbhéanna leictreamaighnéadacha.

Tá fáilte curtha ag an IWDG leis an iarracht atá á déanamh eacnamaíocht ísealcharbóin le leictreachas ó fhoinsí in-athnuaite a chur chun cinn. Aithníonn sé, freisin, an gá atá in Éirinn le cinnteacht fuinnimh a fhorbairt agus leis an tairbhe is fearr a bhaint as acmhainní amach ón gcósta. Ach tá údair imní shainiúla ag an IWDG maidir leis an tionchar ar chéiticigh ó thruailliú ó thorann ag éirí as céimeanna taiscéalaíochta agus/nó tógála dá leithéidí d'fhorbairtí agus maidir leis an riachtanas atá ann maolú agus monatóireacht dhóthanach a dhéanamh. Go dtí seo, tá freagra tugtha ag an IWDG cás ar chás ar thionscadail áirithe nó ar cheisteanna a bhaineann leis na hearnálacha ola agus gáis agus acmhainní in-athnuaite muirí. I bhfianaise an mhéadaithe i ngníomhaíochtaí na n-earnálacha sin atá tuartha sna deich mbliana romhainn, tá an doiciméad beartais seo iarrtha ag an IWDG chun na gníomhaíochtaí sin agus an tionchar is dóichí a bheidh acu ar chéiticigh in uiscí na hÉireann a phlé.

1. Introduction

1.1 Exclusive economic zone

Ireland has an Exclusive Economic Zone (EEZ) of 410,000 km sq., an area ten times greater than its landmass [1]. Within this EEZ Ireland has the right to control access to oil and gas reserves and to regulate the construction of marine renewable energy developments (e.g. wind, wave and tidal power). The ability of nations to regulate other activities (e.g. the military activities of foreign states within their EEZ, beyond 12 nautical miles) is not so clear. The EEZ also contains a wealth of marine habitats which support a diversity of marine species, including whales, dolphins and porpoise (cetaceans).

1.2 Oil and gas development

Over the past decade, oil and gas exploration activity levels in the Irish EEZ have been relatively low. In 2006 the Department of Communications, Energy and Natural Resources (DCENR) initiated a review of the hydrocarbon-bearing potential of the Atlantic Ireland Basins and followed this up with a series of licensing rounds [2].

In the light of a concerted effort by the Irish State to attract oil and gas exploration companies to find and develop petrochemical reserves in Irish waters, an increase in oil and gas exploration levels is forecast over the coming decade [3].

1.3 Marine renewables development

In the last decade there has been significant growth in Ireland's renewable electricity generation output, driven largely by the EU Renewable Energy Directive (2009/28/EC) and the National Renewable Energy Action Plan. Ireland's target is for 40% of electricity demand to come from renewable sources by 2020. This equates to 6,000 MW from marine renewables, with 4,500 MW from offshore wind generation and 1,500 MW from wave energy [4].

Ireland's longer term goal of decarbonising its electricity system will require the expansion of its renewable generation portfolio to include present forms of renewable generation, such as offshore wind, and technologies still at the research, development and demonstration stage, such as wave and tidal power generating devices and floating offshore wind systems[4].

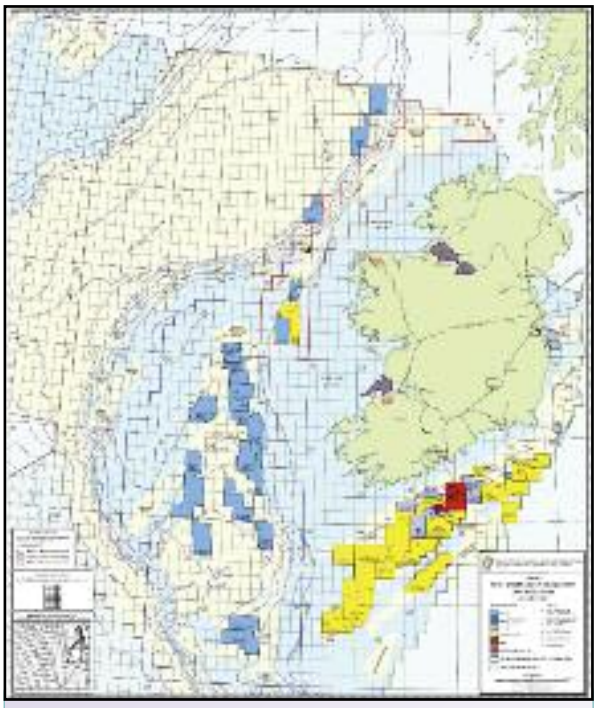

Figure 1.1. Ireland Petroleum Exploration and Development Concession Map 2014 (© DCENR)

1.4 Legal status of cetaceans

Irish cetaceans are protected under national legislation and under a number of international directives and agreements which Ireland is signatory to. All cetaceans are protected under the Wildlife Act (1976) and amendments (2000, 2005, 2010 and 2012). Under the act and its amendments it is an offence to hunt, injure or wilfully interfere with, disturb or destroy the resting or breeding place of a protected species (except under license or permit). The act applies out to the 12 nm limit of Irish territorial waters.

All cetaceans are protected under the EU Habitats Directive and are included in Annex IV of the Directive as species 'in need of strict protection'. Under this Directive, the harbour porpoise *(Phocoena phocoena)* and bottlenose dolphin *(Tursiops truncatus)* are designated Annex II species which are of community interest and whose conservation requires the designation of special

areas of conservation. The EU Habitats Directive applies to the extent of each Member State's EEZ.

Ireland is a signatory to conservation agreements such as the Bonn Convention on Migratory Species (1983), the OSPAR Convention for the Protection of the Marine Environment of the northeast Atlantic (1992) and the Berne Convention on Conservation of European Wildlife and Natural Habitats (1979).

In 2007 the National Parks and Wildlife Service (NPWS) of the Department of Arts, Heritage and the Gaeltacht produced 'Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters'. This was subsequently reviewed and amended to produce 'Guidance to manage the risk to marine mammals from man-made sound sources in Irish waters' [5] which include mitigation measures specific to seismic survey, multi-beam, drilling, blasting and dredging. The guidelines recommend that listed coastal and marine activities be subject to a risk assessment for anthropogenic sound-related impacts on relevant protected marine mammal species to address any area-specific sensitivities, both in timing and spatial extent, and to inform the consenting process.

Figure 1.2. Long-finned pilot whale spy-hopping in Irish Shelf slope waters (© Dave Wall/IWDG)

Once the listed activity has been subject to a risk assessment, the regulator may decide to refuse consent, to grant consent with no requirement for mitigation, or to grant consent subject to specified mitigation measures.

1.5 Development of IWDG policy

The IWDG welcomes the drive to a low carbon economy with electricity derived from renewable sources. It also acknowledges the need for Ireland to develop energy security and obtain maximum benefit from offshore resources. However the IWDG has a number of specific concerns relating to the impact on cetaceans from noise pollution arising from the exploration and/or construction phases of such developments and the need for adequate mitigation and monitoring.

Figure 1.3. Marine wind farm (www.energyireland.ie)

In certain cases the IWDG may also have concerns regarding the impact of the physical presence, and routine operation and maintenance of installations in certain sensitive locations and/or the possibility of physical injury to cetaceans from such installations (e.g. in the case of certain types of tidal power devices).

Following two well documented mass strandings of beaked whales in 2008 and 2014, IWDG has become increasingly concerned at the possible impacts of mid-frequency active sonar on deep diving cetaceans in Irish waters.

To date the IWDG has responded in a case-by-case basis to particular projects or issues related to the offshore oil and gas and marine renewables sector. In light of a forecast increase in activity in these sectors over the next decade, the IWDG commissioned a policy document to cover these activities and their likely impacts on cetaceans in Irish waters.

2. Pre-development assessment: Prevention is better than cure

The development of oil and gas reserves and marine renewables involves a number of phases which may span a period of 50 years or more. Associated with each phase of development are possible impacts or issues relating to cetaceans. Some issues are common to the two development types, while others are specific to one or the other. Common to both is the requirement for a pre-development environmental risk assessment.

2.1 Risk assessment

The National Parks and Wildlife Service (NPWS) requires that risk assessment forms 'an important part of the decision-making framework for mitigating the effects of anthropogenic sound in the marine environment' [4]. It recommends that planned listed activities undergo a risk assessment for anthropogenic sound-related impacts on relevant marine mammal species to 'address any area-specific sensitivities, both in timing and spatial extent, and to inform the consenting process.' This requirement is in place for

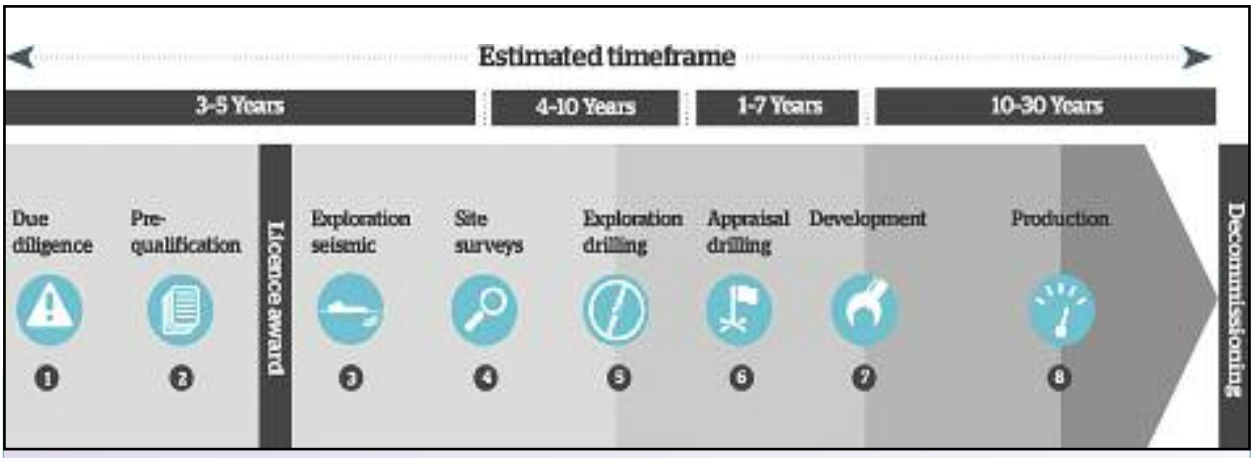

Figure 2.1. Oil and gas exploration and production life cycle (cairnenergy.com).

Figure 2.2. Wind Farm/Tidal Energy Farm development and production life cycle (agl.com.au)

offshore petroleum exploration and appraisal operations and is contained within the associated Rules and Procedures Manual of DCENR [6].

The NPWS guidelines further state that 'In order to be effective such an assessment must competently identify the risks according to the available evidence and consider (i) direct, (ii) indirect and (iii) cumulative effects of anthropogenic sound. It might also employ marine mammal and possibly marine acoustics expertise in order to comprehensively and scientifically evaluate the issue of risk to individual species. A conservative approach is fundamental and, in cases of uncertainty, it must be assumed that the effect of the introduced sound source(s) could be significant.'

It is the experience of the IWDG that the environmental risk assessments being conducted for oil and gas and marine renewable developments in Irish waters seldom amount to more than a brief review of published data, some of which may be quite dated (>10yrs old) and not necessarily reflect the current distribution or abundance of species in the area. Often there is little in the report that is specific to the survey site but refers to the wider region and may include data from habitats quite different to those in which the survey is being conducted.

In areas where little published data exist, there is seldom any effort on the part of the operator or Client Company to comply with the NPWS requirement to fill these gaps through use of 'marine mammal and possibly marine acoustics expertise'.

Figure 2.3. Bottlenose dolphins in Irish Shelf slope waters (© Dave Wall/IWDG)

Recommendation 1

Environmental impact assessments should be as site specific as possible and take cognisance of the habitat type in which the seismic survey is being conducted.

Even where significant spatial or temporal use of habitat by cetaceans has been well documented, there appears to be a reluctance on the part of the regulator to mitigate against the potential harmful effects of conducting a seismic survey e.g. by implementing a temporal ban on seismic survey activity. Such temporal bans are used in other jurisdictions to good effect and are of particular use in protecting areas of importance for foraging [7] and migrating [8] baleen whales.

Recommendation 2

Visual and acoustic cetacean survey methods should be employed to fill data gaps in licensed areas where seismic surveys are planned or can reasonably be foreseen.

2.2 Measures to protect baleen whale foraging areas off the south coast

Baleen whales are thought to be more susceptible to the impacts of seismic surveys and piling primarily due to the fact that the low frequency noise generated by such activities overlaps the frequencies at which baleen whales vocalise [9].

Two important foraging areas for baleen whales have been identified by the IWDG off the south coast of Ireland. The first area is outer Dingle Bay which is an important foraging area for humpback whales (from July to October) and minke whales (from April to October) [10].

Recommendation 3

Marine geophysical surveys should be prohibited in the Dingle Bay area from the beginning of July to the end of October to protect foraging humpback whales.

In light of the use of the outer Dingle Bay area by foraging minke whales from April to October, additional mitigation measures should be considered for seismic operations in this area.

Recommendation 4

Daytime only operations and a shut-down policy for baleen whales entering the 1000 m mitigation zone should be implemented for marine geophysical surveys operating in the Dingle Bay area, to protect foraging baleen whales.

The second area is the south coast from Cape Clear to Hook Head which is an important foraging area for fin whales (from July to January), minke whales (from April to November) and humpback whales (from October to February)[10].

Recommendation 5

Marine seismic surveys should be prohibited within 130 kilometres of the south coast from Cape Clear to Hook Head from the beginning of July to the end of February to protect foraging humpback and fin whales.

Figure 2.4. Minke whale foraging in the waters off West Cork. (© Dave Wall / IWDG)

In light of the use of the south coast by foraging minke whales from April to November, additional mitigation measures should be considered for seismic operations in this area.

Recommendation 6

Daytime only operations and a shut-down policy for baleen whales entering the 1000 m mitigation zone should be implemented for marine seismic surveys operating within 65 kilometres miles of the south coast from Cape Clear to Hook Head, to protect foraging baleen whales.

2.3 Measures to protect baleen whale migration and foraging areas on the Irish Shelf slopes

In August 2014 the IWDG presented a strong case, supported by current data, for the temporal closure of the Porcupine Seabight and Irish Shelf Slopes to seismic survey activity each autumn and winter to protect migrating blue, fin and humpback whales using the Irish Shelf slopes as a migration corridor [11] and opportunistic foraging area [12] during their annual southward migration from foraging areas off Iceland and Norway [13].

The proposal was based on sightings data from IWDG surveys [14] and MMO reports from seismic surveys in the Porcupine Seabight in 2013 which showed large numbers of sightings of fin whales and blue whales along the Irish Shelf slopes during autumn and winter.

Disturbance to migrating whales, some of which are listed as endangered by the IUCN, may represent a breach of a number of national and international regulations and agreements to avoid disturbance to protected species, including fin whales and blue whales, in migratory or foraging areas (e.g. the Wildlife Act, the EU Habitats Directive, the Bern Convention and the OSPAR Convention).

Recommendation 7

Seismic surveys should be prohibited on the eastern slopes of the Porcupine Seabight and on the Irish Continental Shelf slopes in water depths from 200 m–3000 m from the start of August to the end of March each year to protect migrating and foraging fin, blue and humpback whales.

Figure 2.5. Blue whales on the Irish Shelf slopes. (© Irish Air Corps)

2.4 Measures to protect deep diving cetaceans on the Irish Shelf slopes

In 2013 the NPWS and DCENR established a Mitigation Zone along key parts of the continental shelf margin from which all seismic survey is excluded (figure 2.6). The mitigation zone was informed by two projects conducted by the IWDG.

These projects were the Atlas of the Offshore Distribution of Marine Mammals in Irish Waters [14] (part funded by the National Parks and Wildlife Service and the Marine Institute) and the Beaked Whale Passive Acoustic Monitoring Pilot, conducted in the Rockall Trough and funded by the Petroleum Affairs Division of DCENR.

Both these projects identified areas of the Irish Shelf slopes as being of importance to deep diving cetaceans such as beaked whales, sperm whales and pilot whales, and to a genetically distinct population of offshore bottlenose dolphins [15].

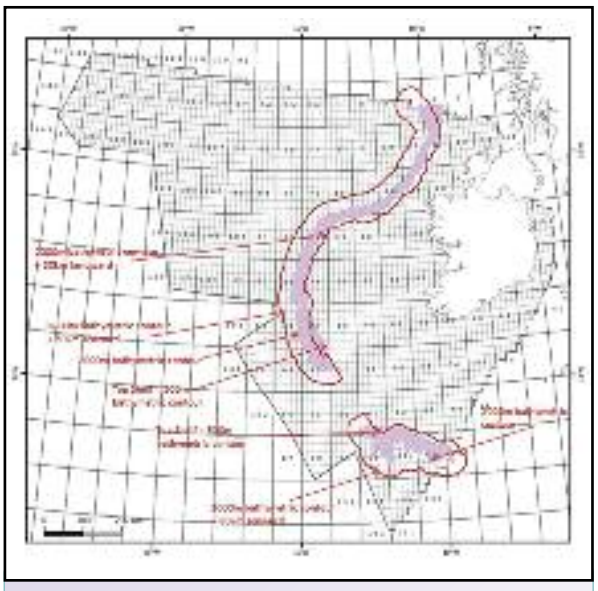

Figure 2.6. Established Mitigation Zone along key parts of the continental shelf margin from which all seismic survey is excluded. (© DCENR/NPWS)

Deep diving species can be difficult to detect and mitigate for as they spend a large part of their life foraging at depth. Beaked whales in particular may spend 95% of their lives below the sea surface, are difficult to detect visually at the surface, and are

difficult to detect using towed passive acoustic monitoring as they predominantly vocalise at depth [16, 17]. Beaked whales are particularly susceptible to noise disturbance as they have quite specific habitat requirements [14] and display a severe reaction (including stopping vocalising and foraging) to some types of noise pollution [18]. In the absence of a practical mitigation method that could be employed during seismic surveys, spatio-temporal avoidance is the sole mitigation measure available.

The Mitigation Zone along key parts of the continental shelf margin implemented for the protection of deep diving cetaceans correctly invokes the precautionary principle by acting to protect probable beaked whale habitat in the absence of robust data on the spatial and temporal use of such habitat by beaked whales. Further monitoring of these shelf slopes are required to determine their importance for beaked whales, after which this mitigation zone should be reviewed.

Recommendation 8

The IWDG strongly supports the Mitigation Zone along key parts of the continental shelf margin implemented by DCENR/NPWS for the protection of deep diving cetaceans. We recommend that this Mitigation Zone remains *in situ* until temporal or spatial gaps in beaked whale distribution are identified, using robust scientific methods, which might allow for seismic survey to safely be conducted.

Recommendation 9

The Mitigation Zone along key parts of the continental shelf margin implemented by DCENR/NPWS for the protection of deep diving cetaceans should be extended to the slopes of the Porcupine Seabight as this area has recorded regular beaked whale sightings.

2.5 Monitoring

In the case of all offshore development, but particularly in areas for which no monitoring data exist, the IWDG promotes the use of visual and acoustic monitoring before, during and after development. This requires some pre-planning on the part of exploration license holders but will produce data that is hugely valuable in assessing the short term and long term impacts of the development (if any) and assess how long it takes for cetacean activity to recover to baseline levels during or after the lifetime of the development.

Recommendation 10

Oil and gas prospects and marine renewable energy development sites should be monitored for cetacean activity using visual and passive acoustic techniques, for a minimum period of 12 months, and preferably 24 months, prior to the exploration phase of the development.

Recommendation 11

Oil and gas prospects and marine renewable energy development sites should be monitored for cetacean activity throughout the exploration and drilling/construction phases of the development.

Recommendation 12

Cetacean activity around oil and gas prospects and marine renewable energy development sites should be monitored during their operational lifetime and for a minimum of 12 months, and preferably 24 months, after decommissioning.

Figure 2.7. Fin whale foraging in waters off the south coast of Ireland. (© Dave Wall/IWDG)

3. Exploration and development What are the risks?

3.1 Seismic surveys

Seismic surveys (including sparkers, boomers, pingers and chirpers) are the primary survey method currently in use by the oil and gas industry for locating deposits beneath the sea floor. They are also used in site surveys prior to installation of rigs, wind farms and tidal energy installations. Typically a seismic survey vessel tows an airgun array which, through the coordinated release of air under pressure, generates low frequency sound waves that passes through the water column and into the sea bed (figure 3.1). These 'shots' generally occur every 10–12 seconds during a survey line.

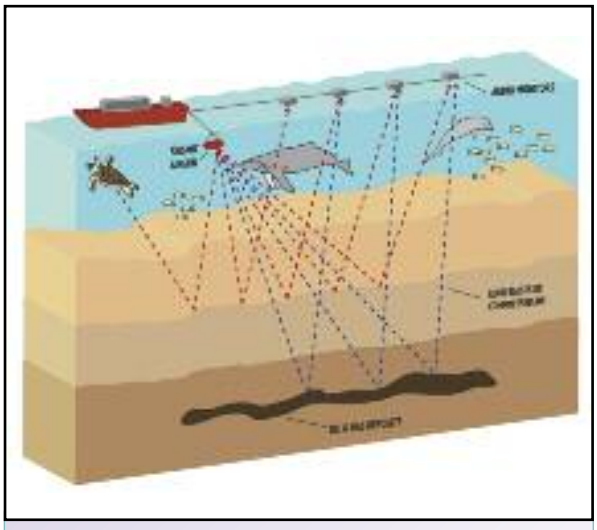

Figure 3.1 Diagram of marine seismic survey technique. (www.oceana.org)

Some of this sound energy is reflected back as it hits the various rock layers and is recorded by a hydrophone streamer or streamers towed behind the survey vessel or positioned on the ocean floor. Once this data is collected and processed an image of the rock layers below the seabed is obtained indicating areas where oil and gas deposits are likely to have collected [15].

The noise generated by marine seismic surveys can be extremely loud, with source levels reaching 260–262 dB re 1 µPa-m [20]. This is far louder than the noise generated by the largest ships and as loud as some major catastrophic events such as undersea earthquakes or volcanic eruptions (figure 3.2). Whereas major catastrophic events are extremely rare and generally short in duration, seismic surveys are widespread and may last for many weeks or months.

Recommendation 13

The regulator should promote shared access to seismic data and avoid duplication of survey effort to minimise the volume of noise pollution resulting from seismic surveys in Irish waters annually.

3.2 Pile driving

Pile Driving is the practice of pounding hollow steel pipes into the seabed. Piles are used to support underwater structures such as wind turbines, bridge supports and some types of oil and gas rigs.

Pile driving has the potential to produce sounds as loud as some seismic surveys with source levels exceeding 243–257 dB re 1 µPa-m [20, 21, 22] (see section 5 for recommendations on mitigation).

3.3 Blasting

Blasting of bedrock or boulders using explosives may sometimes be required for site clearance prior to construction of marine installations. Source levels vary with the type and amount of explosives used, and the water depth at which the explosion occurs. Source levels range from 272 to 287 dB re 1 µPa zero to peak at 1 m distance (1–100 lb. TNT) [23]. Of greater concern is that blasting also produces shockwaves capable of killing or severely injuring marine mammals in the vicinity of the blast [24].

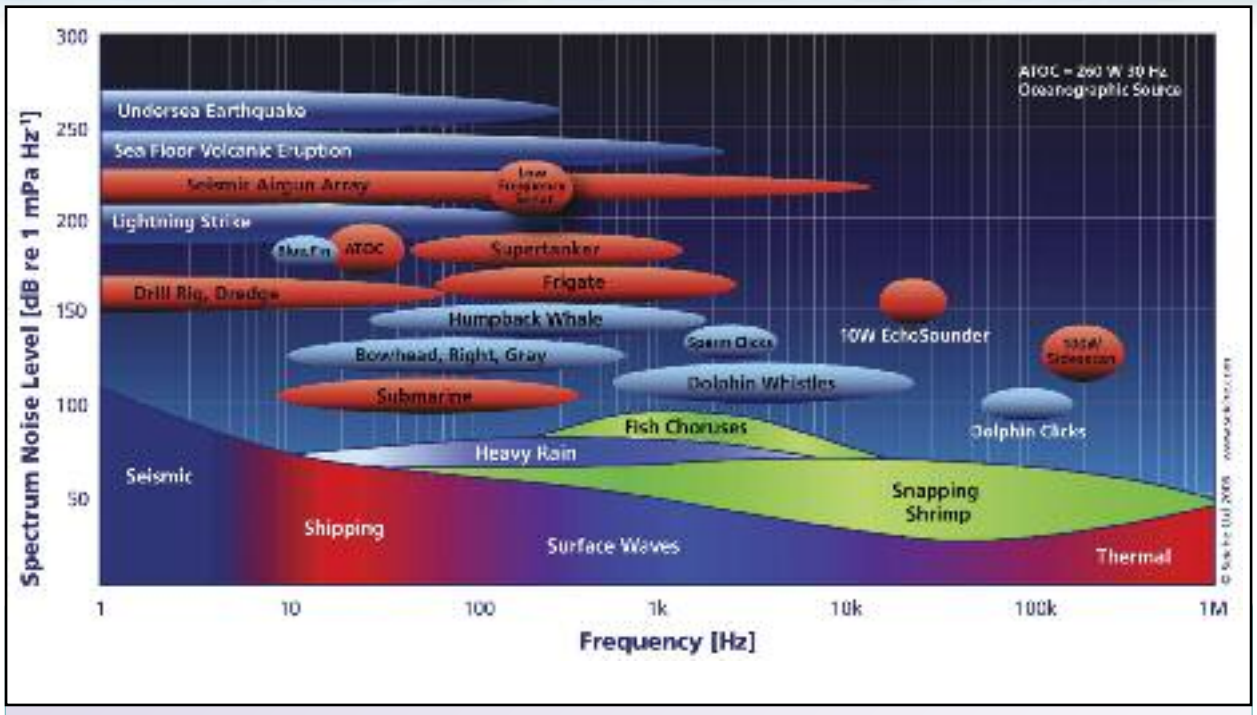

Figure 3.2. Ambient and localised noise sources in the ocean (www.seiche.com).

Recommendation 14

The mitigation zone for marine mammals during underwater blasting should be calculated by an expert on the impacts of underwater blasting, using modelling and acoustic profile measurement. The calculated mitigation zone should take into account the likelihood of death, injury, and hearing damage, but for practical management and safety purposes, should be a minimum of 500 m.

3.4 Multi-beam/Sidescan Sonar

Multi-beam and side scan sonar surveys generate noise at higher frequencies than seismic, piling or blasting. However, depending on the systems being used and the water depth being surveyed, the frequencies used can overlap with those commonly used by dolphins and toothed whales (odontocetes) for communication and navigation. Both systems can operate at very high source levels in excess of 200 dB re 1 μPa Hz-1 [25]. Multi-beam operating in deep water at 12 kHz has been implicated in at least one mass stranding event [26].

The IWDG welcomes the fact that the NPWS guidelines mitigate for multi-beam surveys in enclosed bays and within 1500 m of the entrance to such bays. It is not clear whether these guidelines are being adhered to in all cases, especially in the case of non-industry surveys.

In some cases the mitigation zone for surveys within Special Areas of Conservation (SACs) have been adjusted by NPWS based on data from an acoustic profile of the survey. The IWDG is concerned that the resultant mitigation zones (as little as 20 m in some cases) were unworkable on a practical basis by the MMO and could have resulted in cetaceans being exposed to a very loud multi-beam source with the potential for TTS or PTS injury.

Recommendation 15

The IWDG welcomes the use of acoustic profiling of acoustic survey sources for determination of appropriate mitigation zones, however such profiling should be conducted to the full depth of the water column by an expert in marine acoustics.

Recommendation 16

Where mitigation zones are adjusted based on acoustic profile data, the resultant mitigation zone should be a minimum of 200 m for practical management purposes.

Recommendation 12

Consideration should be given to introducing mitigation measures for low frequency multi-beam surveys in deep water as these surveys output at high source levels and at frequencies which overlap those used by deep diving cetaceans.

Figure 3.3 Minke whale in Irish Shelf waters. (© Dave Wall / IWDG)

3.5 Electromagnetic surveys

The use of very strong electromagnetic (EM) sources is a developing technology in oil and gas surveys, while cables transporting electricity from marine renewables developments have been shown to emit EM signals [27].

Research needs to be carried out into the possible barrier and other disturbance effects of EM signals [28]. This should include possible direct effects on cetaceans as well as indirect effects on prey species. EM signals have been shown to deter some echo locating species, such as bats [29].

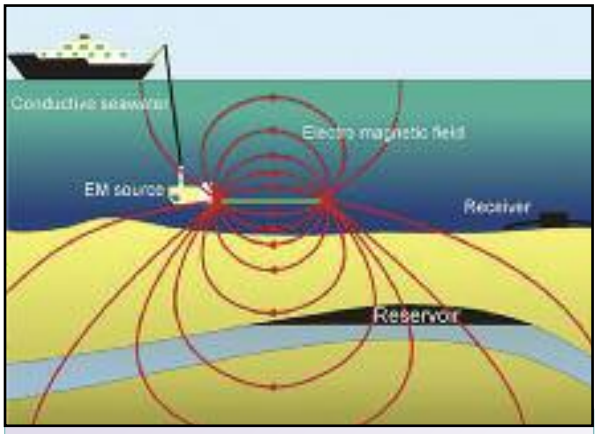

Figure 3.4 Diagram of marine electromagnetic survey technique. (www.noc.ac.uk)

Recommendation 18

Research into the effects of electromagnetic sources on cetaceans, and their prey species, should be conducted prior to the widespread use of this method in Irish waters.

3.6 Drilling rig presence/noise

Drilling rigs generate low to mid frequency noise, typically at source levels below 170 dB (rms) re1µPa@1 m but source levels from drilling ships may approach 200 dB (rms) re 1 µPa@1 m [30, 20]. While disturbance to marine mammals from rigs is generally thought to be low, bowhead whales have been noted to avoid rigs, leading to long-term displacement from preferred habitat. Similar avoidance may occur in other cetaceans [30].

3.7 Wind farm presence/noise

Operating wind turbines produce low frequency tonal noise typically with a source level below 120 dB (rms) re 1 µPa@1 m, with the noisiest turbine reported with a source level of 180 dB re 1 µ Pa (RMS) [31]. Although the source levels suggest that the operating noise from wind farms should not have a major impact on cetaceans, research on porpoises at the Nysted Offshore Wind Farm in the Baltic Sea indicated that long-term displacement had occurred with levels only returning to 29% of the baseline activity after ten years in operation [32].

Recommendation 19

The minimum monitoring requirements for an environmental impact assessment of proposed sites for locating wind farms or tidal energy sites should include 24 months of pre-development visual and acoustic cetacean monitoring to ensure robust baseline data.

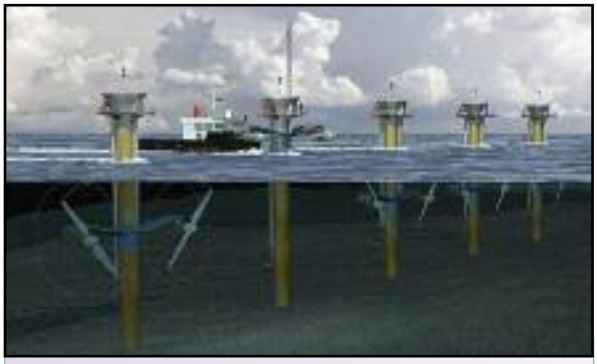

Figure 3.5 SeaGen tidal power generator in Strangford Lough. (www.seageneration.co.uk)

3.8 Tidal farm presence/noise

As yet no large scale tidal energy farms have been developed. Modelling studies indicate a source level of 165–175 dB re 1µPa-m [20] and also suggest that a high collision risk would exist between cetaceans and tidal energy farms. The actual collision risk would depend on the nature of the devices, the reaction of cetaceans when confronted by such devices and the ambient noise at the site (as high ambient noise reduces the distance at which animals detect objects and increases risk of collision [33].

Recommendation 20

Monitoring requirements for an environmental impact assessment of proposed sites for locating wind farms or tidal energy sites should include use of static acoustic monitoring arrays (including control sites) for a minimum of 24 months pre-construction to achieve a strong baseline data set and understand how cetaceans use the proposed development area on a spatial and temporal scale.

Studies of the impact of the SeaGen tidal device in Strangford Lough on harbour porpoise indicated that while harbour porpoise still transited past the device, porpoise activity inside the Lough was slightly lower when the turbine was in operation. There was also a degree of local avoidance of the turbine, resulting in reduced risk of collision [34].

Recommendation 21

Cetacean monitoring at wind farms or tidal energy sites should continue during the construction and operational phases until such time as cetacean activity levels return to baseline levels or failing that, for a minimum of five years post-construction.

3.9 Mid-frequency active sonar

Military mid-frequency active sonar (MFAS) emits pulses of sound from an underwater transmitter to help determine the size, distance, and speed of objects. The US Navy indicates MFAS is the only reliable way to track submarines, especially more recently designed submarines that operate more quietly, making them more difficult to detect.

Source levels reach 223–235 dB re 1µPa-m [20] and MFAS has been linked to a series of strandings of deep diving cetaceans, especially beaked whales [35, 36, 37, 38]. In some cases MFAS induced mass strandings may have caused the extirpation of the local beaked whale population [38].

In Ireland two mass strandings of beaked whales have been reported in the last 10 years. In 2008 56 deep diving cetaceans (27 beaked whales and 29 pilot whales) stranded over a seven month period on the Irish and Scottish coasts, but with an indicated mortality date of mid-January 2008 [39]. In December 2014 and January 2015 a mass stranding of 12 Cuvier's beaked whales was recorded, again on the Irish and Scottish coasts [10]. In both these cases the number of strandings is likely to reflect only a small fraction of the total number of animals killed as most of the corpses will have sunk, washed up in inaccessible areas or been scavenged at sea [40].

No cause was identified for the 2008 mass stranding but the state of decomposition indicated a single mass-mortality event in mid-January. The 2014 mass mortality has been tentatively linked to a major UK Navy operation to search for a Russian submarine which took place in early December 2014, however investigations are still ongoing.

The potential for MFAS to cause mass mortality events which may lead to the extirpation of local beaked whale populations requires that MFAS activity should be temporally and spatially excluded from areas of beaked whale activity.

While the Irish Naval Service has no MFAS capability, foreign military vessels transiting or conducting exercises in the Irish EEZ, do have MFAS.

Recommendation 22

The Irish Government and Defence forces should liaise with, and bring utmost pressure on naval forces from other nations to ensure no MFAS operations are conducted within the Irish Cetacean Sanctuary (which encompasses the entire Irish EEZ).

Figure 3.6. Humpback whale breaching in waters off Co. Wexford. (© Pádraig Whooley/IWDG)

4. What are the potential impacts of noise pollution on cetaceans?

Noise pollution can impact on cetaceans in a number of ways, causing physical injury, physiological effects, or disrupting behaviour and/or communication, this in turn can lead to direct or indirect impacts affecting individuals, groups or even populations [9, 41].

4.1 Physical impacts

The potential physical impacts to cetaceans from noise pollution created by geophysical surveys, piling, blasting and MFAS include:

Body tissue damage from very close range exposure to very loud noise, though this is thought to be unlikely due to the nature of air gun and piling noise pulses. Exposure to the shockwave of an underwater explosives blast is capable of killing cetaceans and there are many documented cases where his has occurred [24].

Induced bends in deep diving species (e.g. beaked whales) arising from bubble growth in body tissues caused by exposure to low frequency sound [42] or from rapid surfacing in reaction to loud sound sources (e.g. MFAS).

Gross ear damage can be caused by very close range exposure to airgun shots or piling noise. As with body tissue damage this is a theoretical risk but has not been identified in any airgun exposure cases to date.

Temporary hearing threshold shift (TTS) is a hearing sensitivity reduction resulting from exposure to noise of sufficiently high intensity that is transitory in nature, with recovery after minutes or hours.

Permanent hearing threshold shift (PTS) is a hearing sensitivity reduction resulting from exposure to noise of sufficiently high intensity which is permanent in nature, with no hearing recovery. Sounds that can cause TTS usually cause PTS if the subjects are exposed to them repeatedly and for a sufficient length of time. Very intense sounds, however, can cause irreversible cellular damage and instantaneous PTS.

4.2 Perceptual impacts

Cetaceans live in a largely acoustic world. Sound plays a vital role in foraging, communication, navigation, orientation, defence (e.g. predator detection), and social cohesion. Noise pollution may be perceived by animals at far greater distances than those at which a behavioural reaction is evident.

Seismic noise pollution can drown out the frequencies at which many cetaceans vocalise and/or force animals to alter their vocalisation rates or volume, with resultant impacts on efficacy and energy consumption [9, 41].

4.3 Behavioural impacts

Behavioural impacts can affect movement, vocalisation, socialisation and feeding. Acute changes may occur for a period of time as the vessel approaches the animal or vice versa. Many baleen whale species have been noted to show avoidance behaviour as far away as 10 km from a seismic source vessel, whereas sperm whales have been noted to cease vocalising at distances greater than 300 km from a seismic survey (figure 4.2).

Figure 4.1 Sperm whale fluking in Rockall Trough. (©Dave Wall/IWDG)

Species	Location	Observation	Source	Received level	Range	Behaviour	Water depth	Prop Model	Reference
Common dolphin	Irish Sea	Operating seismic	2D Seismic 2,120 cu. In.		>1 km	Reduced vocalisation rate within vocal range and/or exclusion within 1 km.	90-100 m		Goold [1996]
Bottlenose dolphin	Captivity		1 sec 20 kHz pulse	- 178 (75 0-to) dB-186 (3 kHz dB		Behavioural avoidance response at 178 dB			Ridgway et al. (1996)
Humpback whale	S.E. Alaska	Experimental playback	Seismic gun 1.64L (220 dB)	- 150-160	<3.2 km	Short-term startle response. No clear avoidance at levels up to 172 dB re. 1m Pa effective pulse pressure level.			Malme et al. (1985)
Humpback whale	North West Cape, W. Australia	Operating seismic	Seismic array 44 (250 dB re. 1 μPa²-m p-p))	- 170 dB P-P - 162 dB P-P - 157 dB P-P	3-4 km 5 km 8 km	Stand-off (General avoidance) Avoidance manoeuvres Avoidance manoeuvres	100-120 m	25 sqR	McCauley et al. (1998)
Humpback whale	Exmouth Gulf, W. Australia	Experimental playback	Seismic gun 0.33L (227 dB re. 1 μPa²-m p-p))	- 166 dB P-P - 150 dB P-P	1 km 2 km	General avoidance Course alteration begin	10-20 m		McCauley et al. (1998)
Blue whale	North Pacific Ocean	Operating seismic	Seismic source 1,500 cu. In. (215 dB re. 1 μPa 1 m p-p).	- 143 dB P-P	10 km	Closest approach 10 km? Cessation of vocalisations for c 1 hr. Resumption of vocalisations and movement away from source	2,400 m		Macdonald et al. (1995)
Sperm whales	Southern Ocean	Opportunistic	Seismic Be151 (260 dB re. 1 μPa - m)	- 112 dB	>300 km	Cessation of vocalisation in response to some instances of air gun activity	>500 m 50-100 m		Bowles et al. (1994)

Figure 4.2 Observations of cetacean behavioural changes recorded in response to seismic surveys (Gordon *et al.*, 2003 [9]).

Behaviours may also be modified rather than cease but may become less effective through modification. Animals may suffer displacement from preferred habitat or a migratory route for short or long periods (some seismic surveys can last for six months or more and piling for wind farm arrays can also last for extended periods). Noise pollution may cause disruption to social cohesion, group interaction and/or mother-calf associations.

4.4 Chronic impacts

Extended exposure to even quite low levels of sound can cause stress and lead to health problems in humans. Noise pollution has been shown to cause stress in some cetaceans [43] and is likely to reduce the fitness of individual marine mammals and, where it affects a wide area, may decrease the viability of some marine mammal populations [44] (see section 5.3).

Stress caused by chronic noise pollution may leave cetaceans more vulnerable to disease and parasites due to an impaired immune system [45]. It may also lower the threshold at which other environmental stressors (e.g. chemical pollution) have an impact.

For deep diving cetaceans, which already live at the edge of their physiological limits, the impacts of chronic noise pollution may tip the balance against survival [46].

Chronic noise pollution may lead to habituation to the noise and the possibility that animals would remain close to damaging noise sources, resulting in TTS or PTS. Stress responses may also occur without any detectable behavioural reaction. It is therefore important to note that the absence of a behavioural reaction does not necessarily prove the absence of an impact.

4.5 Indirect effects

Noise pollution can cause indirect effects which may impact on cetaceans. It may cause displacement of cetacean prey species. Impairment of hearing and vocalisation detection may leave cetaceans more vulnerable to predation, entrapment in fishing gear, stranding and other hazards.

Acoustic geophysical and multi-beam surveys in areas of complex coastline or shallow bathymetry may cause cetaceans to become embayed and subsequently strand. The reaction by deep diving cetaceans to loud noise sources may cause the animals to surface rapidly, leading to decompression sickness [42].

Figure 4.3. Sowerby's beaked whale breaching during seismic survey in Porcupine Basin. (RPS 2014) [47].

5. What can be done to mitigate the impacts of noise pollution?

Where an unacceptable level of risk exists, best practice is to reduce that risk to an acceptable level using mitigation measures. Where no mitigation is possible the risk must be avoided through removing the risk incurring action or through temporal or spatial avoidance of the species being impacted.

5.1 Risk of death or injury from noise pollution

The statutory method of mitigating lethal or sub-lethal injury from acoustic surveys and blasting in the Republic of Ireland is the requirement to adhere to the NPWS 'Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters' [5].

Figure 5.1. Common Dolphins on the Irish Shelf. (© Dave Wall).

These guidelines are based on monitoring a prescribed mitigation zone around the acoustic source and soft starting or ramping up the power and intensity of the sound source (where this is possible).

The mitigation zone is monitored for cetaceans and clearance for soft start is given once the zone has been confirmed clear of animals for 30 minutes (waters <200 m) or 60 minutes (waters >200 m). Animals outside of the zone are assumed to be at sufficient distance that they are safe from injury.

Animals entering the mitigation zone after the source has reached full power are assumed to do so at their own choosing and thus presumed not to be suffering from the effects of exposure to the sound source.

The IWDG welcomed the implementation of marine mammal mitigation guidelines in 2007 and their continued revision (most recently in 2014). They are some of the most robust guidelines in Europe for the protection of marine mammals, especially in terms of the size of the mitigation zone, the length of the pre-soft start search and the method of soft start.

However the IWDG has a number of concerns regarding the implementation and effectiveness of these guidelines.

5.11 Night time operations

The guidelines stipulate that the sound source may not be started during the hours of darkness, in poor visibility or in poor sea conditions. During line turn the vessel has the option of shooting a mitigation gun (source level <170 dB re 1 µPa @1 m) or shutting down and conducting a full soft start for the next line (daylight hours only).

The guidelines do not stipulate how the vessel should ramp up from the mitigation gun to the first normal gun in the array (source level c220 dB re 1 µPa @1 m). Therefore vessels using this option are potentially jumping from a source level slightly louder than the engine noise of the seismic vessel to a source level which could cause TTS or PTS in a cetacean near to the source. All this would occur without checking the mitigation zone was clear of animals and could potentially lead to hearing injuries to animals within the mitigation zone.

Recommendation 23

The NPWS guidelines should stipulate a ramp up procedure (with defined intermediate source level requirements) from the mitigation gun source level <170 dB re 1 µPa @1 m, to the smallest operational gun in the seismic array.

It is debateable whether mandating the firing of a mitigation gun at <170 dB re 1 µPa @1 m during the entire line turn is necessary as a soft start commencing at this level is unlikely to cause PTS or TTS in cetaceans. Mandating use of a mitigation gun is mandating additional noise pollution in the environment, which is undesirable.

Figure 5.2. Seismic airgun array on deck of ship. (Photo: www.rolls-royce.com).

A combination of use of PAM for mitigation for dolphins and sperm whales, in tandem with a soft start beginning at the lower threshold of 170 dB re 1 µPa @1 m, with an appropriate ramp up procedure from the mitigation gun to the smallest gun in the array, would be an acceptable (though not ideal) compromise for night time start up, all be it that PAM cannot detect baleen whales from seismic ships (due to vessel noise).

This compromise would

1. minimise noise input to the environment
2. avoid the need for continuous shooting during night time line changes
3. allow for mitigation for those species detectable by PAM
4. minimise risk of injury to species not detectable by PAM

Recommendation 24

The NPWS should consider - where no more than 2 baleen whales or beaked whales have been sighted in the previous 24 hours - allowing vessels to shut down during night time line turns and restart using PAM for mitigation and a lower baseline soft start commencing at <170 dB re 1 µPa @1 m, gradually ramping up to the smallest gun in the array, and from there continuing a normal full soft start of the array.

The regulator (DCENR, supported by NPWS) has licensed seismic acquisition during line turns on several surveys in Irish waters. The value of such line turn 'data' is highly questionable as the normal specifications for collection of quality seismic data cannot be achieved during line turns and therefore the data is poor.

It is our experience that operators believe such 'data' are acquired principally to avoid the requirement to shut down during line turns, where a mitigation gun is not being used. Indeed gun maintenance often occurs during such turn lines further degrading the value of any 'data' collected.

Figure 5.3. Harbour Porpoise, Blasket Islands, Co. Kerry. (© Randal Counihan/IWDG/NPWS).

By licensing shooting during line turns the regulator is allowing for continuous shooting, 24 hours a day for weeks or months on end. This results in a massive increase in severe noise pollution to the marine environment, for very dubious gain and is in direct contravention of the stated requirement of the NPWS guidelines that "every effort should be made by marine users and operators to minimise the duration and power/energy output of their sound-producing activity".

Recommendation 25

The regulator should immediately halt the licensing of shooting during line turns and require that operators adhere to the NPWS requirement during line turns for use of a mitigation gun (night time only) or for shut down until start of the next data acquisition line.

Recommendation 26

The use of a mitigation gun or alternative soft start procedure (see recommendations 23 and 24) during line turns should only be permitted where effective MMO/PAM mitigation is not feasible (e.g. during darkness, poor weather or fog) and where no more than 2 baleen whales or beaked whales have been sighted in the previous 24 hours. At all other times adherence to the normal requirements for source shut down and soft start procedures, during line changes and breaks in firing, should be mandatory.

5.1.2 PAM mitigation for harbour porpoise and sperm whales

The NPWS guidelines rely solely on visual methods for the detections of cetaceans within the mitigation zone. Whereas this works well in good visibility and reasonable sea conditions for most whales and oceanic dolphins, there are significant problems in visually detecting harbour porpoise in anything but the calmest sea states [48] and in detecting deep diving species which may spend more than 95% of their time below the surface [16, 17].

Figure 5.4. PAM system in operation on board seismic vessel. (© WildOcean).

The use of PAM would be of immense value in aiding the detection of harbour porpoise during seismic surveys, although the detection range for harbour porpoise is a maximum of 300–500 m [49, 50] from the PAM array. In joint visual and acoustic surveys, where a PAM array capable of detecting porpoise and operated by an experienced PAM operator is employed, acoustic sightings of porpoise outnumber visual detections by a ratio of up to 8:1 [51, 52], in all but the very calmest sea state.

Recommendation 27

Towed PAM should be used as a mitigation measure in addition to the use of MMOs in areas where harbour porpoise are likely to occur.

Sperm whales spend the majority of their lives (over 70%) below the surface and undetectable by MMOs [53]. Even with the extended period of pre-soft start search effort stipulated in the NPWS Guidelines it is highly likely that sperm whales will go undetected or may surface in the mitigation zone during soft start.

The IWDG welcomes the inclusion in 2014 of the requirement to use PAM as a support tool for detection of deep diving cetaceans in the license conditions for seismic surveys in deep waters (>200 m). However for PAM to be used effectively as a support tool the guidelines must be amended to allow for localised PAM detections of deep diving cetaceans to be used as a stand-alone measure to implement mitigation measures during daylight operations without the need for concurrent or subsequent MMO detection.

Recommendation 28

Localised PAM detections of deep diving cetaceans should be accepted as adequate for implementing NPWS mitigation measures in deep waters (>200 m) without the requirement for concurrent or subsequent detection by the MMOs, as MMOs may not detect cetaceans which are foraging at depth and still present within the mitigation zone.

With the increasing use of PAM in tandem with MMOs for mitigation it is important that PAM systems are fit for purpose and are operated by qualified and experienced operators. Current commercially available PAM systems vary greatly in terms of hydrophone sensitivity and hardware quality. The choice of PAM system can therefore significantly alter monitoring capabilities for odontocete species.

Recommendation 29

Regulators (DCENR/NPWS/JNCC) should require that PAM systems be fit for purpose and must be independently certified as to their operational frequency range and detection range for given signal (click) types.

5.1.3 Mitigation for beaked whales

There is currently no real time mitigation method available to reliably detect beaked whales during seismic surveys or other sound generating activities [54].

Since no real time mitigation is possible, and the considerable risks to beaked whales from seismic survey noise and other sound sources cannot be reduced to an acceptable level, the risk should be removed through implementing temporal or spatial avoidance.

The NPWS Mitigation Zone along key parts of the continental shelf margin from which all seismic survey is excluded currently protects beaked whales from exposure to seismic survey noise and should continue to be implemented until spatial or temporal gaps in beaked whale activity are identified using bottom mounted Static Acoustic Monitoring (SAM).

Recommendation 30

A system of static acoustic monitoring should be implemented along the Irish Shelf Slopes to identify the temporal and spatial extent of beaked whale activity in shelf slope habitats.

Figure 5.5. IWDG Deep C-POD static acoustic monitoring unit being deployed at 500m in 3000m of water from the RV *Celtic Explorer.* (© Dave Wall / IWDG).

5.2 Mitigating piling noise

Due to the static nature of the sound source in piling and the technology involved, a number of noise mitigation options are available for piling operations.

Bubble curtains have been shown to be effective in significantly reducing piling noise, with reductions of up to 20 db reported. Bubble curtains have limitations in that they have reduced effectiveness in areas of strong current [59].

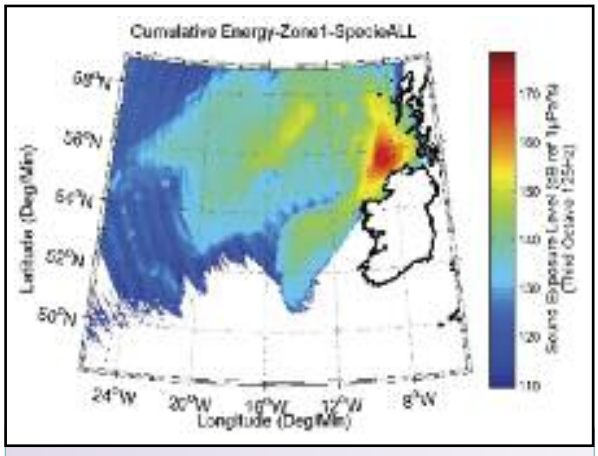

Figure 5.6. Cumulative energy of a single airgun footprint for a survey which took place in spring 2000 (total 25,920 pulses). (Sutton and Jessopp, 2014) [59].

Vibropiling uses unbalanced vibrators for pile driving of smaller piles into suitable substrate. Vibropiling has the dual benefit of achieving a noise reduction of 15–20db while also limiting the frequency of noise output to the low Hz which many cetaceans are less sensitive to [56].

Isolation casings used to surround the pile during piling to create a discontinuity in the transmission path of the traveling sound waves has achieved noise reductions of up to 17 db [55].

Recommendation 31

The use of one or more noise reduction measures should be required during open water piling operations in Irish coastal and offshore waters.

5.3 Mitigating perceptual, behavioural, chronic and indirect impacts of noise pollution

The NPWS guidelines are primarily designed to mitigate impacts which could cause physical injury or death to marine mammals. The guidelines do not mitigate the other impacts of noise pollution highlighted in Section 4.

The Irish Offshore Strategic Environmental Assessments recognised the issue of cumulative impacts from seismic surveys and recommended that a minimum separation of 100 km be maintained between concurrent seismic surveys in Irish waters.

While this was a welcome measure, the extent of esonification by seismic surveys has only recently come to light. A single seismic survey is capable of esonifying thousands of square kilometres of ocean, especially if the survey is conducted in deep water or along the shelf edge [57, 58]. This esonification can cause baleen whales such as fin, blue and humpback whales to cease vocalising over thousands of square kilometres of ocean [58]. The chronic effects of seismic surveys (and similar noise sources) can potentially impact endangered whale species in Irish waters at a population level.

There is no mitigation method available to reduce the esonification area of a seismic survey other than to ensure the minimum source level required to achieve the data is used and unnecessary shooting is avoided (as whales have been shown to recommence vocalising during breaks in seismic output [57, 58]).

Recommendation 32

Seismic surveys and other high source level, low frequency sound outputs (e.g. piling) should be restricted to the months of lowest baleen whale density for the survey region.

Since no mitigation of the esonification footprint is possible, the risk should be removed primarily by temporal avoidance, as spatial avoidance may be difficult due to the large areas esonified.

Recommendation 33

In light of the very large areas esonified by seismic (and similar) noise and the effect this has been shown to have on baleen whale communication, shooting during marine geophysical surveys should be kept to the absolute minimum required, and shooting during line turns and extended test shooting should be prohibited.

Note:
The IWDG also has concerns regarding the impact of seismic surveys on marine turtles. Marine turtles can be slow to react to survey vessels, especially when at the surface (perhaps after being forced to the surface by airgun noise).

A number of near collisions have been recorded in Irish waters and a risk of impact with the survey vessel and towed seismic gear exists, as does a risk that a turtle ahead of the vessel will dive into the direct path of the airgun. The IWDG therefore recommends that:

1. A shut down requirement be put in place where any marine turtle approaches to within 300 m of the vessel or the seismic source.

2. All tail buoys and other gear with the potential to trap marine turtles be fitted with turtle guards.

References

[1] http://www.seaaroundus.org/eez/372.aspx

[2] DCENR. 2011. *Fourth Strategic Environmental Assessment for Oil and Gas Activity in Ireland's Offshore Waters: IOSEA4 Irish and Celtic Seas.* Department of Communications, Energy and Natural Resources, 29-31 Adelaide Road, Dublin 2, Ireland.

[3]. PwC. 2014. *PwC Oil and Gas Survey Report 2014.* PwC, One Spencer Dock, North Wall Quay, Dublin 1.

[4] DCENR. 2014. *Offshore Renewable Energy Development Plan: A Framework for the Sustainable Development of Ireland's Offshore Renewable Energy Resource.* Department of Communications, Energy and Natural Resources, 29-31 Adelaide Road, Dublin 2, Ireland.

[5] NPWS. 2014. *Guidance to manage the risk to marine mammals from man-made sound sources in Irish waters.* National Parks and Wildlife Service, 7 Ely Place, Dublin 2.

[6] DCENR. 2014. Rules and procedures manual for offshore petroleum exploration and appraisal operations conducted under an exploration licence or other authorisation. Petroleum Affairs Division, Department of Communications, Energy & Natural Resources, Dublin.

[7] Harwood, L., Joynt, A., Kennedy, D., Pitt, R., and Moore, S. 2009. Spatial restrictions and temporal planning as measures to mitigate potential effects of seismic noise on cetaceans: A working example from the Canadian Beaufort Sea, 2007 – 2008. DFO Canadian Science Advisory Secretariat Research Document 2009/040. iv + 14 p.

[8] http://www.petroleumagencysa.com/images/pdfs/Seismics.pdf

[9] Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M. P., Swift, R., & Thompson, D. 2003. A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal*, 37(4), 16-34.

[10]. IWDG. 2015. *IWDG online sightings & strandings databases.* http://www.iwdg.ie.

[11] Charif R.A. and Clark C.W. 2009. Acoustic monitoring of large whales in deep waters north and west of the British Isles: 1996–2005. *Cornell Laboratory of Ornithology, Technical Report* 08-07.

[12] Wall D., O'Kelly I., Whooley P. and Tyndall P. 2009. New records of blue whales *(Balaenoptera musculus)* with evidence of possible feeding behaviour from the continental shelf slopes to the west of Ireland. *Marine Biodiversity Records,* Vol. 2; e128; 2009.

[13 http://www.iwdg.ie/index.php?option=com_k2&view=item &id=2522:iwdg-propose-temporal-closure-of-the-porcupin-seabight-to-seismic-activity

[14] Wall D., Murray C., O'Brien J., Kavanagh L., Wilson C., Ryan C., Glanville B., Williams D., Enlander I., O'Connor I., McGrath D., Whooley P. and Berrow S. 2013. *Atlas of the distribution and relative abundance of marine mammals in Irish offshore waters 2005–2011.* Irish Whale and Dolphin Group, Merchants Quay, Kilrush, Co Clare. ISBN 0-9540552-7-6.

[15] Mirimin, L., Miller, R., Dillane, E., Berrow, S. D., Ingram, S., Cross, T. F. and Rogan, E. (2011), Fine-scale population genetic structuring of bottlenose dolphins in Irish coastal waters. *Animal Conservation,* 14: 342–353.

[16] Barlow, Jay, Megan C. Ferguson, William F. Perrin, Lisa Ballance, Tim Gerrodette, Gerald Joyce, Colin D. Macleod, Keith Mullin, Debra L. Palka, and Gordon Waring. "Abundance and densities of beaked and bottlenose whales (family Ziphiidae)." *Journal of Cetacean Research and Management* 7, no. 3 (2005): 263.

[17] Barlow, J. (1999). Trackline detection probability for long-diving whales. *Marine Mammal Survey and Assessment Methods.* Balkema, Rotterdam, The Netherlands, 209-221.

[18] www.nature.com/news/2008/080801/full/news.2008.997.html

[19] http://www.ogp.org.uk/pubs/448.pdf

[20] OSPAR. (2009). Assessment of the environmental impact of underwater noise. *London: OSPAR Commission Biodiversity Series. Publication* no. 436/2009. 43 pp.

[21] Norro, A., J. Haelters, B. Rumes, and S. Degraer 2010. "Underwater noise produced by the piling activities during the construction of the Belwind offshore wind farm (Bligh Bank, Belgian marine waters)." Offshore wind farms in the Belgian part of the North Sea. Early environmental impact assessment and spatio-temporal variability. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models. *Marine ecosystem management unit (2010)*: 37-51.

[22] Bailey, Helen, Bridget Senior, Dave Simmons, Jan Rusin, Gordon Picken, and Paul M. Thompson. 2010. "Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals." *Marine Pollution Bulletin* 60, no. 6 (2010): 888-897.

[23] OSPAR Commission. "Overview of the impacts of anthropogenic underwater sound in the marine environment." *Report 441* (2009): 2009.

[24] Ketten, Darlene R. 1995. "Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions." *Sensory systems of aquatic mammals* (1995): 391-407.

[25] Hildebrand, John A. 2009. "Anthropogenic and natural sources of ambient noise in the ocean." *Marine Ecology Progress Series* 395, no. 5 (2009).

[26] Southall, Brandon L., Teri Rowles, F. Gulland, R. W. Baird, and P. D. Jepson. 2013. "Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon headed whales *(Peponocephala electra)* in Antsohihy, Madagascar." *Report to the U.S. Marine Mammal Commission*, 75pp.

[27] Centre for Marine & Coastal Studies. "A baseline assessment of electromagnetic fields generated by offshore windfarm cables." *Report to Collaborative Offshore Wind Research into the Environment (COWRIE) group, Crown Estates, 2003.*

[28] Dolman, Sarah J., Mick Green, and Mark P. Simmonds. 2007. "Marine renewable energy and cetaceans." *Report for the Scientific Committee.* Whale and Dolphin Conservation Society, Chippenham, United Kingdom, SN15 1LJ UK (2007).

[29] Nicholls, Barry, and Paul A. Racey. 2009. "The aversive effect of electromagnetic radiation on foraging bats—a possible means of discouraging bats from approaching wind turbines." *PLoS One 4, no. 7* (2009): e6246.

[30] Review and Assessment of Underwater Sound Produced from Oil and Gas Sound Activities and Potential Reporting Requirements under the Marine Strategy Framework Directive. 2011. *Genesis Oil and Gas Consultants report for the Department of Energy and Climate Change.*

[31] Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. & Tyack, P. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Marine Ecology Progress Series,* 309, 279–295.

[32] Teilmann, Jonas, and Jacob Carstensen. 2012. "Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic—evidence of slow recovery." *Environmental Research Letters* 7, no. 4 (2012): 045101.

[33] Wilson, B. Batty, R. S., Daunt, F. & Carter, C. (2006) Collision risks between marine renewable energy devices and mammals, fish and diving birds. *Report to the Scottish Executive.* Scottish Association for Marine Science, Oban, Scotland, PA37 1QA

[34] Keenan, G., C. Sparling, H. Williams, and F. Fortune. 2011. "SeaGen Environmental Monitoring Programme Final Report." *Royal Haskoning: Edinburgh, UK, January.*

[35] Frantzis, A. (2004). The first mass stranding that was associated with the use of active sonar (Kyparissiakos Gulf, Greece, 1996). *ECS Newsletter,* 42, 14-20.

[36] Freitas, L. (2004). The stranding of three Cuvier's beaked whales *Ziphius cavirostris* in Madeira Archipelago–May 2000. *ECS Newsletter*, 42, 28-32.

[37] Martín, V., Servidio, A., & García, S. (2004). Mass strandings of beaked whales in the Canary Islands. *ECS Newsletter*, 42, 33-6.

[38] Balcomb III, K. C., & Claridge, D. E. (2001). A mass stranding of cetaceans caused by naval sonar in the Bahamas. *Bahamas Journal of Science*, 8(2), 2-12.

[39] Haulbowline, C. (2008). *A preliminary note on the unprecedented strandings of 45 deep-diving odontocetes along the UK and Irish coast between January and April 2008.*

[40] Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Dorémus, G., Huon, M., & Ridoux, V. (2012). The significance of stranding data as indicators of cetacean populations at sea: Modelling the drift of cetacean carcasses. *Ecological Indicators*, 18, 278-290.

[41] IACMST. 2006. Underwater sound and marine life. Southampton: Inter-agency Committee on Marine Science and Technology working group report No.6. 19 pp.

[42] Cox, Tara M., T. J. Ragen, A. J. Read, E. Vos, R. W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, and L. Crum. Understanding the impacts of anthropogenic sound on beaked whales. *Space and naval warfare systems centre San Diego CA, 2006*.

[43] Rolland, Rosalind M., Susan E. Parks, Kathleen E. Hunt, Manuel Castellote, Peter J. Corkeron, Douglas P. Nowacek, Samuel K. Wasser, and Scott D. Kraus. 2012. "Evidence that ship noise increases stress in right whales." *Proceedings of the Royal Society B: Biological Sciences 279, no. 1737* (2012): 2363-2368.

[44] Wright, Andrew J., Natacha Aguilar Soto, Ann Linda Baldwin, Melissa Bateson, Colin M. Beale, Charlotte Clark, Terrence Deak *et al.* 2007. "Do marine mammals experience stress related to anthropogenic noise?" *International Journal of Comparative Psychology* 20, no. 2.

[45] Romano, T. A., M. J. Keogh, C. Kelly, P. Feng, L. Berk, C. E. Schlundt, D. A. Carder, and J. J. Finneran. 2004. "Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure." *Canadian Journal of Fisheries and Aquatic Sciences* 61, no. 7 (2004): 1124-1134

[46] Wright, Andrew J., Terrence Deak, and E. C. M. Parsons. 2011. "Size matters: management of stress responses and chronic stress in beaked whales and other marine mammals may require larger exclusion zones." *Marine pollution bulletin* 63, no. 1 (2011): 5-9.

[47] RPS. 2014. *Marine Mammal Observer report during Ruadhan 3D seismic survey, Porcupine Basin, Licence blocks 35/13, 35/14, 35/15p, 35/18 & 35/19, offshore Ireland for Capricorn Ireland Ltd.* Downloaded from www.dcenr.ie

[48] Evans, P.G.H., Hammond, P.S., 2004. Monitoring Cetaceans in European Waters. *Mammal Review* 34 (1), 131-156.

[49] Sveegaard, S., Teilmann, J., Berggren, P., Mouritsen, K. N., Gillespie, D., and Tougaard, J. 2011. Acoustic surveys confirm the high-density areas of harbour porpoises found by satellite tracking. *ICES Journal of Marine Science*, 68: 929–936

[50] Goodson, A.D., Sturtivant, C.R., 1996. Sonar characteristics of the harbour porpoise *(Phocoena phocoena):* Source levels and spectrum. *Ices Journal of Marine Science* 53:465-472.

[51] Gillespie, D., and Tougaard, J. 2011. Acoustic surveys confirm the high-density areas of harbour porpoises found by satellite tracking. *ICES Journal of Marine Science*, 68: 929–936

[52] Gillespie, D., Berggren, P., Brown, S., Kuklik, I., Lacey, C., Lewis, T., Matthews, J., McLanaghan, R., Moscrop, A., Tregenza, N., 2005. Relative abundance of harbour porpoises *(Phocoena phocoena)* from acoustic and visual surveys of the Baltic Sea and adjacent waters during 2001 and 2002. *Journal of Cetacean Research and Management* 7, 51–57.

[53] Watwood, Stephanie L., Patrick JO Miller, Mark Johnson, Peter T. Madsen, and Peter L. Tyack. 2006. "Deep-diving foraging behaviour of sperm whales *(Physeter macrocephalus)." Journal of Animal Ecology* 75, no. 3 (2006): 814-825.

[54] Barlow, Jay, and Robert Gisiner. 2006. "Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales." *Journal of Cetacean Research and Management* 7, no. 3 (2006): 239-249.

[55] Koschinski S. & Lüdemann K, 2013. *Development of noise mitigation measures in offshore windfarm construction.* Commissioned by the Federal Agency for Nature Conservation.

[56] Elmer K-H, Measurement and Reduction of Offshore Wind Turbine Construction Noise. *DEWI Magazine* Nr. 30, February 2007.

[57] Clark, Christopher W., and George C. Gagnon. 2006. "Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales." *IWC/SC/58 E 9 (2006).*

[58] Sutton, G. Jessopp, M. 2014. "Mapping the spatio-temporal distribution of underwater noise in Irish Waters". *Associated datasets and digital information objects connected to this resource are available at: Secure Archive for Environmental Research Data (SAFER) managed by Environmental Protection Agency Ireland http://erc.epa.ie/safer/resource?id=c5afaeb4-2ced-11e3-8c2d-005056ae0019 (Accessed: 2014-11-07).*

[59] Lucke, Klaus, Paul A. Lepper, Marie-Anne Blanchet, and Ursula Siebert. "The use of an air bubble curtain to reduce the received sound levels for harbor porpoises *(Phocoena phocoena)." The Journal of the Acoustical Society of America* 130, no. 5 (2011): 3406-3412.

Author biography

Dave Wall has been a member of the IWDG since the mid 90's and is currently Ship Surveys Officer with the Irish Whale and Dolphin Group. He has conducted cetacean surveys and monitoring for the past 20 years and has spent much of the last 10 years conducting ship-based cetacean surveys in Irish offshore waters. He has also worked as an ecological consultant in the oil and gas sector, monitoring marine mammal visual and acoustic mitigation during marine seismic surveys worldwide.

Nóta Beathaisnéise an Údair

Tá Dave Wall ina bhall den IWDG ó lár na 1990 idí agus faoi láthair is é an tOifigeach Suirbhéanna Loingis le Lucht Faire na Míolta Móra agus na nDeilfeanna. Tá suirbhéanna agus monatóireacht ar chéiticigh curtha i gcrích aige le fiche bliain anuas agus tá cuid mhaith de na deich mbliana atá imithe caite aige i mbun suirbhéireachta ar chéiticigh, bunaithe ar longa sna farraigí amach ó chósta na hÉireann. D'oibrigh sé freisin mar chomhairleoir éiceolaíochta san earnáil ola agus gáis, agus monatóireacht á déanamh aige ar mhaolú an tionchair ar mhamaigh mhara trí amharc agus éisteacht le linn suirbhéanna seismeacha mara ar fud an domhain.

The **Irish Whale and Dolphin Group** (IWDG) was established in December 1990 as an all-Ireland group dedicated to the conservation and better understanding of cetaceans (whales, dolphins and porpoises) in Irish waters through study, education and interpretation. This document recognises the growing importance of cetacean welfare science to the understanding of cetaceans in Irish waters and the protection and conservation of healthy, sustainable cetacean populations into the future.

The IWDG relies on members and partnerships to achieve its goals. Please visit www.iwdg.ie and join the IWDG to support our work.

IWDG
www.iwdg.ie
Irish Whale and Dolphin Group