IDENTIFICATION OF POTENTIAL UTILITY OF AND COLLATION OF EXISTING MARINE MAMMAL OBSERVER DATA

Final report to the Joint Industry Programme
Sound and Marine Life Programme

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Contents

1. Summary

Potential sources of available marine mammal observer (MMO) data were identified, and a questionnaire was distributed asking for information about the data held. The responses were used to compile a matrix of available/ potentially available MMO data, identify existing databases and identify what analyses of the data had already been performed or were planned for the future.

Data from various operations were recorded as being available or potentially becoming available at a later date, including military operations, seismic and site surveys and drilling operations, as well as a limited amount of data from other operations such as controlled source electromagnetic surveys (CSEM), pile driving and explosives operations. The largest sources of data were the records from military operations held by the UK Hydrographic Office, the Joint Nature Conservation Committee (JNCC) database of records from seismic and site surveys in UK and adjacent waters, and reports held by the Minerals Management Service (MMS) from seismic surveys in the Gulf of Mexico. It is estimated that there might be approximately 50,000 available or potentially available records of sightings (and many more accompanying records of effort and operations).

Details of five MMO databases were obtained, four containing MMO data collected during the course of oil and gas exploration activities and one containing data collected during the course of military operations. The JNCC MMO database and the UK Hydrographic Office (UKHO) Maritime Environment Data Store (MEDS) are the largest existing MMO databases, and the JNCC MMO database is also the most comprehensive, containing operational and survey information as well as effort and sightings data. However, none of the existing MMO databases represent a model to be used for a central MMO database. Instead a new MMO database design is proposed, incorporating some features of the JNCC MMO database (e.g. the relational structure, key data fields) but with an improved analytical capability.

To date, JNCC is the only regulator to have performed a detailed analysis of data from multiple surveys. Some other regulators, although they have not yet undertaken detailed analysis of the data, have nevertheless compiled summary reports either for individual surveys or on an annual basis. In addition, MMO data from some specific exploration programmes have been subject to analysis on behalf of some offshore exploration industry companies. Many MMO data remain as yet unanalysed, but there are plans for future analysis of some data, both by regulators and by industry.

As part of this project a one-day workshop was held to examine the current status of MMO data and the potential utility of these data. The workshop aimed to identify the key questions that various parties wish to have answered, and brought together delegates from regulatory bodies, industry, academia and MMOs in order to generate ideas and address this issue from as many perspectives as possible. Following the workshop a list of key questions that could potentially be answered using MMO data was compiled, and the types of data needed to answer these questions were considered. Some of the main areas considered as potential subjects for analysis were regulatory compliance, risk

assessment, effectiveness of mitigation measures, the impact of sound on marine mammals and the biology of marine mammals.

A comparison was made of the MMO data recording requirements in various countries. A total of 131 items are requested in the data recording requirements of all the countries that were considered. Only one quarter of these are requested in more than half the countries considered, with just seven items being universally requested in countries where there are specific recording requests. The diversity of recording formats and the variety of information contained within them does not facilitate collation of data into any central database and therefore limits the potential for pooling and using data from more than one source. It would be beneficial to have one standard recording format designed in conjunction with a central database for storage of multiple sets of data.

A set of standard recording forms was designed; collecting the information needed to enable the key questions of interest to be answered was a priority. The forms are designed primarily for seismic surveys, but the design also aims to make them adaptable for other operations during which MMOs may be recording observations. They are also designed to be capable of being used anywhere in the world. Those regulators who were supportive of the forms and indicated that they would accept their use included JNCC (UK), National Parks and Wildlife Service (Ireland), Department of Conservation (New Zealand) and MMS (Gulf of Mexico).

Incorporation of UK (and possibly other European) MMO data into the Joint Cetacean Protocol (JCP) would increase the value of MMO data whilst at the same time enhancing the JCP. The revised recording forms have been designed with consideration of the potential for inclusion of MMO data within the JCP or other similar protocols/ databases.

The design of a central MMO database to receive data from the revised recording forms was considered and a prototype constructed. The optimum solution is considered to be a web-based portal for organisations to upload their MMO data. The most significant advantage of this method is the ability of the web-portal to check the incoming data for consistency during the import process so that any errors can be corrected. The portal model provides a front-end which is easy to keep updated, provides a user-friendly and familiar interface, and will support many of the required functions such as user registration, document libraries, etc. Built into this portal will be data query and management functions. The results of the analyses of the data will be published on the web-based database for access by all authenticated users.

It is proposed that all unauthenticated users would have restricted initial access to the portal; in order for users to access more information, including the data, they must obtain an account login. It is proposed that their registration application is authorised by a system administrator who would decide whether to grant or withhold permission to access the data.

Regulators may have user accounts on the central web-based system; when they upload information to the central application they may elect to make it private or choose to make it public. Private data could not be accessed by other authenticated users, but

could be used by regulators as their own database. MMO data may contain sensitive information; the proposed system protects these sensitivities by preventing certain fields of information being part of data queries and hence forming part of their output.

A plan for a future phase of the project is discussed, including development and population of the database, and analysis of data to answer some of the identified key questions. It is estimated that a future phase would last for two years.

2. Introduction

There has been much concern in recent years about the potential impact of anthropogenic sound on marine mammals. As the ability to hear sounds is vital to marine mammals, anthropogenic sound has the potential to cause disturbance and, if the disturbance is significant enough, to interfere with life functions such as feeding, breeding and navigation, as well as the potential to cause physical harm. Several reports have called for more research into the effects of anthropogenic sound on marine mammals (e.g. National Research Council, 2000, 2003, 2005).

Marine seismic surveys, using airguns to generate sound for the purpose of exploration of geological features beneath the seabed, are one source of anthropogenic sound that has received much attention. Sound from seismic airguns has been recorded over large distances (e.g. Nieukirk *et al.*, 2004); the sound produced by the airguns is primarily at low frequencies that overlap with those used by mysticetes, which are therefore considered to be vulnerable to disturbance from seismic surveys. Studies have shown that higher frequency sound overlapping with the frequencies used by odontocetes are also emitted by airguns, giving rise to the potential for these species to be affected also (Goold and Fish, 1998). To address the conservation concerns that have arisen, in 1995 the UK government and the Joint Nature Conservation Committee (JNCC) issued guidelines for seismic operations (latest version: Joint Nature Conservation Committee, 2004, with a revised version currently under consultation). Some other countries have since issued their own sets of guidelines or regulations for seismic surveys: Australia (latest version: Department of the Environment and Water Resources, 2007); the US for surveys in the Gulf of Mexico (latest version: Minerals Management Service, 2007); Canada (latest version: Department of Fisheries and Oceans, 2007); Brazil (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, 2005a); New Zealand (Department of Conservation, 2006); and Ireland (latest version: Department of the Environment, Heritage and Local Government, 2007). There are also some draft guidelines available for operations other than seismic surveys, e.g. pile driving during wind farm construction and the use of explosives (Joint Nature Conservation Committee, 2008a,b); for some other activities (e.g. military trials, dredging operations, pipe laying) procedures may be put in place on a case-by-case basis for mitigating potential impacts of these operations on marine mammals.

Mitigation of potential impacts on marine mammals usually involves a combination of various procedures, such as employing a soft start where the source power is gradually built up over a specified period from a low energy starting level, and utilizing an exclusion zone that should be clear of marine mammals (and in some cases also other animals such as sea turtles) before the source is activated. Some guidelines also require that an active source is deactivated as soon as a marine mammal (sometimes only applicable to certain species) enters the exclusion zone, while some also have a wider zone within which the occurrence of marine mammals requires the source to be powered down. To monitor the presence or absence of marine mammals within the exclusion zone requires visual (and sometimes also passive acoustic) monitoring. In many cases this monitoring is undertaken by dedicated marine mammal observers (MMOs) working on board the source vessel. In

the course of the monitoring MMOs record their observations, including behavioural observations of animals' reactions to operations, in some cases on recording forms provided by regulators. On a global scale, a large amount of data has been and continues to be collected by MMOs in the course of their duties.

Although the primary role of MMOs during seismic surveys is to alert the vessel operator to the presence of marine mammals and to ensure that appropriate mitigation measures are taken, the data collected by MMOs together with other operational data could in addition potentially provide insights into the distribution of marine mammals and their reaction to anthropogenic activities. There is a need for information on the behavioural responses of marine mammals to current mitigation measures (Kastalein and Wartzok, 2004); MMO data could contribute towards answering this need. In order to maximise the potential of the data collected by MMOs it would be beneficial if these data were collected using standardized methods and were contained within a central database. Current monitoring protocols for MMOs vary between projects, type of operation, the operator's requirements and the host country's regulatory requirements. The challenge now, and an aim of this project, is to provide recommendations that, if implemented, would lead to data collection using standardized methods and would facilitate consistent and useful data analysis.

The International Association of Oil and Gas Producers (OGP) Joint Industry Programme (JIP) identified collection and analysis of MMO data as an area of interest and provided funding for this project as part of their Sound and Marine Life Programme. The overarching objective of the JIP is to identify specific, operationally focused questions that relate to the effects of sound generated by the offshore exploration and production (E & P) industry on marine life, and to pursue a research programme that will test scientific hypotheses and produce the data needed to address these questions. The programme aims to: afford a more comprehensive understanding of the potential environmental risk(s) from oil and gas operations; inform and update public decision makers, and regulatory development processes that affect operations globally; determine the basis for mitigation measures that are protective of marine life, cost effective, and credible with outside stakeholders; and feed into planning for efficient and environmentally protective E & P project development. The programme supports research on all sources of sound produced by the offshore oil and gas industries, including seismic airguns, drilling, dredging, pile driving, construction equipment, removal of offshore structures using explosives, shipping, and others. The taxa of concern include marine mammals, fish (all life stages), turtles, birds and invertebrates.

3. Identification of available data

A search was made for MMO data collected from various operations. In many cases MMOs are placed on board vessels because of regulatory requirements, either contained within guidelines or regulations applicable to the activity concerned, or as part of a permit for a specific operation. In these cases it is likely that any data collected by the MMOs would be submitted to the regulators, either directly or via clients and/ or MMO providers. It was therefore decided that the most efficient way of accessing large volumes of data would be via the regulators. Countries to be contacted would include, but not be limited to, all those with published guidelines for mitigating the effects of seismic surveys. Regulators from ten countries were approached: the UK, Republic of Ireland, USA, Canada, Australia, New Zealand, Brazil, Denmark, Norway and Germany. In some cases, rather than being a regulatory requirement, MMOs may be employed as a case of best environmental practice. In these cases there will be no requirement to submit the results of any observations to a regulator; data are most likely to be submitted to the client as the end recipient. Client companies within the oil industry and military organisations were therefore also approached. In addition, MMO providers, some individual MMOs, and environmental contractors and research organisations known to have supplied MMOs were contacted. In total 115 individuals from 70 organisations were identified as potential sources of available MMO data.

A questionnaire (Appendix 1) was developed to gather information regarding the data, and was distributed to the 115 recipients (Table 1). It aimed to establish what types of information were contained within the data, regarding sightings, observation effort and operations. It also asked where the data were held, what format was used, and what quantity of data existed. Recipients were also asked whether any data were contained within an existing database and were asked to list any analyses performed on the data and to cite any reports or publications produced (these are included within the Bibliography).

The response to the search for data was low, with 29% of recipients responding. 42% of these respondents either completed the questionnaire or sent appropriate information, or sent MMO reports containing data. In addition, one regulator had already agreed access to data prior to the search commencing. The remaining respondents mostly sent further contacts (30% of respondents - these further contacts are included in the list of recipients in Table 1). Other respondents stated that the data they held were not owned by them (9% of respondents - ownership of the data was mostly by companies that had already been contacted), or that they did not hold any data (9%), that their data was not for release yet (3%) or that they would respond later (6%). Those regulators responding positively to the project included the UK Joint Nature Conservation Committee (JNCC), Brazil's Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), the US Minerals Management Service (MMS), the New Zealand Department of Conservation (DOC), Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) and the Irish National Parks and Wildlife Service (NPWS).

The responses where questionnaires were completed or data were forwarded were used to compile a matrix of available/ potentially available MMO data (Table 2). Data from various operations were recorded as being available or potentially becoming available at a later date, including military operations, seismic and site surveys and drilling operations, as well as a limited amount of data from other operations such as controlled source electromagnetic surveys (CSEM), pile driving and explosives operations. The largest sources of data were the records from military operations held by the UK Hydrographic Office, the JNCC database of records from seismic and site surveys in UK and adjacent waters, and reports held by MMS from seismic surveys in the Gulf of Mexico.

Other sizeable data sets included reports from seismic surveys in Brazil held by IBAMA, Scottish Fishermen's Federation records from seismic surveys mainly in UK waters, ExxonMobil records from seismic and site surveys in various locations and BP records for seismic surveys in various locations (the latter three sources include some duplicated records for UK waters that are also held within the JNCC database). The quality of the observations, as assessed mainly by the respondents, was mostly medium to high, with several respondents noting that quality was higher where trained, dedicated MMOs were used and that the use of standard recording forms contributed to the overall quality of the data.

It is estimated that there might be approximately 50,000 available or potentially available records of sightings (and many more accompanying records of effort and operations). Experience has shown that approximately 64% of sighting records are of sufficient quality to be used in analysis. It should be borne in mind that the amount of usable data will vary depending on the intended analysis, as some analyses may require selection of subsets of data.

While most sets of available/ potentially available data from seismic surveys included information on sightings, effort and operations, data from drilling operations lacked operational details and sometimes lacked effort data as well. Between data sets the precise extent of information recorded varied (Table 3). For effort data, date and time of the watch, and the location of the watch were almost universally recorded. Most sets of data also included the observer's name while some also included the platform used. Most effort data included some record of weather conditions during the watch, sea state and visibility being the most frequently recorded. Wind and/ or swell were also often recorded. The activity during the watch was recorded often for seismic surveys, but not for drilling operations.

Where operational data was recorded, which was mostly on seismic surveys, the times that the source was active and any mitigating actions taken were the most frequently recorded items. Times of the soft start were also often recorded, and some data sets included data on the visual clearing period prior to commencing use of the source.

Information on sightings was recorded in all data sets for all types of activities. Date and time of the sighting and the species seen were universally recorded, and almost always the location and the number of individual animals were also recorded. Behaviour was

also usually recorded. The distance of animals, usually from the source but sometimes from the vessel itself, was often recorded, as was the direction of travel of animals. The orientation of animals relative to the vessel and the activity of the source at the time of the sighting were sometimes omitted from data sets, although the majority of data sets did include this information. Only half of the data sets included multiple locations and times for each sighting.

Table 1 Recipients of questionnaire to identify available MMO data

Organisation	Contact person	Contact details
Regulators:		
Joint Nature Conservation Committee (UK)	Zoë Crutchfield Craig Bloomer	zoe.crutchfield@jncc.gov.uk Craig.Bloomer@jncc.gov.uk
Minerals Management Service (Gulf of Mexico)	Carol Roden Deborah Epperson	Carol.Roden@mms.gov Deborah.Epperson@mms.gov
Department of Conservation (New Zealand)	Helen McConnell Steve Smith	hmcconnell@doc.govt.nz marinemammals@doc.govt.nz
Department of Fisheries and Oceans (Canada)	Hugh Bain Camille Mageau Jack Lawson Kent Smebdol	bainh@dfo-mpo.gc.ca mageau@dfo-mpo.gc.ca LawsonJ@dfo-mpo.gc.ca smedbolk@mar.dfo-mpo.gc.ca
Canada-Newfoundland and Labrador Offshore Petroleum Board	Dave Burley	dburley@cnlopb.nl.ca
Canada-Nova Scotia Offshore Petroleum Board	Eric Theriault Elizabeth MacDonald ?	etheriault@cnsopb.ns.ca emacdonald@cnsopb.ns.ca spinks@cnsopb.ns.ca
Nova Scotia Department of Energy	Bruce Cameron	cameronB@gov.ns.ca
IBAMA (Brazil)	? Cristiano Guimaraes Jose-Tadeu Oliveira	elpn.sismica.rj@ibama.gov.br cristiano.guimaraes@ibama.gov.br jose-tadeu.oliveira@ibama.gov.br
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Department of the Environment and Water Resources (Australia)	Milena Rafic?	portsandmarine@environment.gov.au
Department of Industry, Tourism and Resources (Australia)	Steve Tarantala	steve.tarantala@industry.gov.au
Geoscience Australia	Tony Stephenson	tony.stephenson@ga.gov.au
Mineral Resources Tasmania	Chris Boron	cboron@mrt.tas.gov.au
National Parks and Wildlife Service (Ireland)	Dr. David Lyons	david_lyons@environ.ie
Miljøstyrelsen (Denmark)	Henning Karup	HPK@MST.DK
Skov- og Naturstyrelsen (Denmark)	?	MFM@sns.dk
Oljedirektoratet (Norwegian Petroleum Directorate)	Wenche Svela? Per Duus? Jan Stenløkk	wenche.svela@npd.no per.duus@npd.no Jan.Stenlokk@npd.no
Federal Agency for Nature Conservation, Germany	Wolfgang Dinter	wolfgang.dinter@bfn-vilm.de
German Federal Environment Agency	Heike Herata Hans Janssen David Scharte	heike.herata@uba.de hans.janssen@uba.de david.scharte@uba.de
Others:		
Irish Whale and Dolphin Group	Dave Wall	dave.wall@iwdg.ie
Australian Centre for Applied Marine Science	Nick Gales	nick.gales@add.gov.au
Geocet	Mary Jo Barkaszi	maryjo@geocet.com
Rogers Environmental & Safety Services, Inc.	Kathi Rogers	ress@houston.rr.com
Mseis	Mark Higginbottom	markhigginbottom@btinternet.com

Organisation	Contact person	Contact details
Marine Team Offshore Ltd	Alison Gill	alisongill@marineteam.com
GeoMotive Inc.	JuliAnne	mail@geomotive.net
Scottish Fishermen's Federation Services	Liam Byrnes	L.Byrnes@sff.co.uk
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Optica Marine	Colin Carter	colin@opticamarine.freeserve.co.uk
Sea Watch Subsea Environmental Agency	John Kettles	john-sea-watch@fsmail.net
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Seistech Limited	Candice Hawthornthwaite	candice@seistech.co.uk
National Federation of Fishermen's Organisations	Dave Bevan	dbevan@nffo.org.uk
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Centre for Marine Science and Technology, Curtin University	Rob McCauley	r.mccauley@cmst.curtin.edu.au
Chickerell Bioacoustics	Ed Harland	ejharland@chesilbeach.org
Marine Acoustics, Inc.	Kimberly Skrupky	kimberly.a.skrupky@marineacoustics.com
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UK Hydrographic Office	Kate Arnold	Kate.Arnold@UKHO.gov.uk
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Anadarko Petroleum Corporation	? ?	mclaughlin@anadarko.com mcbride@anadarco.com
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Table 2 Matrix of available/ potentially available MMO data

Type of operations	Location of operations	Holder of data	Format	Type of data available	Quantity	Quality	Contact
Military operations - UK Navy + some other countries' military data	Global	UK Hydrographic Office	Electronic - Oracle database (original paper records maintained)	Sightings data Effort data (some) Operations data (some)	1989 onwards - approx 2,000 sightings per year	Medium - observers generally not trained, observations from trained MMOs high quality; standard format used; data quality controlled and scored for accuracy of identification.	Kate Arnold Kate.Arnold@UKHO.gov.uk
Seismic and site surveys and VSP	UK (majority) Ireland Faroes Norway Denmark Netherlands Germany France	JNCC	Electronic - Paradox database (original paper and electronic records maintained - some Excel)	Sightings data Effort data Operations data	1995 onwards - approximately 60 surveys per year	Variable - some high quality data from trained, dedicated MMOs; standard recording forms used; data checked and assessed prior to entry into database.	Zoë Crutchfield zoe.crutchfield@jncc.gov.uk Craig Bloomer Craig.Bloomer@jncc.gov.uk
Seismic and site surveys	West Africa South Africa East Africa Gulf of Suez Pakistan Biscay Greenland	JNCC	Mostly paper	Sightings data Effort data (some) Operations data (some)	1998 onwards - approximately 3 surveys per year	Variable - some high quality data from trained, dedicated MMOs; standard recording forms sometimes used	Zoë Crutchfield zoe.crutchfield@jncc.gov.uk Craig Bloomer Craig.Bloomer@jncc.gov.uk
Seismic and site surveys and VSP	Gulf of Mexico	MMS	Electronic	Sightings data Effort data Operations data	2003 onwards - approximately 250 surveys per year	Medium to high	Deborah Epperson Deborah.Epperson@mms.gov
Seismic surveys	Brazil	IBAMA	Paper and electronic - not in database	Sightings data Effort data Operations data	7 years - approximately 6-13 surveys per year	High - especially since 2005; experienced, trained MMOs; standard recording forms.	Cristiano Vilardo Cristiano.guimaraes@ibama.gov.br
Seismic surveys	New Zealand	DOC	Paper and electronic - not in database	Sightings data Effort data Operations data	2005 - 1 survey 2007 - 2 surveys	Medium to high	Steve Smith smsmith@doc.govt.nz

Type of operations	Location of operations	Holder of data	Format	Type of data available	Quantity	Quality	Contact
Seismic surveys	Canada	Canada-Nova Scotia Offshore Petroleum Board	Paper	Sightings data Effort data Operations data	Continuous - 1 report held	High - experienced MMOs with marine mammal identification training, dedicated observations.	Elizabeth MacDonald emacdonald@cnsopb.ns.ca
Seismic surveys	UK*	BP	Electronic - pdf	Sightings data Effort data Operations data	2006 - 2 surveys submitted (these and other surveys held within JNCC database)	High - trained dedicated MMOs; standard recording forms used.	Bill Streever streevbj@bp.com Ann-Marie McLaughlin ann-marie.mclaughlin@uk.bp.com
Seismic surveys	Gulf of Mexico+	BP	Electronic - pdf	Sightings data Effort data Operations data	2006 and 2007 - 2 surveys	High - trained, dedicated MMOs; standard recording forms.	Terry Rooney Terry.Rooney@bp.com
Seismic surveys	Angola	BP	Electronic - Excel	Sightings data Effort data Operations data (possibly)	2003 and 2005 - 2 surveys in total	High - trained and experienced MMOs used; standard format used; overseen by a single experienced MMO.	Daniel Touzel touzeldf@bp.com
Seismic surveys	Sakhalin	Elvary Neftegaz, Zapad-Shmidt Neftegaz, Vostok-Shmidt Neftegaz, BP	Electronic - Excel	Sightings data Effort data	2006 - 1 report covering 2 seismic surveys and 1 site survey	High - trained MMOs; standard recording forms.	Zourab Gagnidze gagnz0@bp.com Environmental.Sakhalin@bp.com
Seismic surveys	UK* Libya Tunisia	Scottish Fishermen's Federation	Electronic - not in database	Sightings data Effort data Operations data	6-7 years - approximately 30 surveys per year	High for UK - MMOs trained; standard recording forms used. Unknown elsewhere.	Liam Byrnes L.Byrnes@sff.co.uk
Seismic surveys	Canada	Chevron & LGL	Paper and electronic - Excel	Sightings data Effort data Operations data	2004 and 2005 - 1 survey per year	High - trained biologists used.	Andre d'Entremont AdEntremont@chevron.com
Seismic surveys	Gulf of Thailand (Thailand, Cambodia, Vietnam)	Chevron	Electronic - Excel	Sightings data Effort data Operations data	2004-2006 - 1 report per year	Medium - OOW maintains log of sightings from information received from marine crew and chase vessels (local fishermen).	Glen Redekop regl@chevron.com

Type of operations	Location of operations	Holder of data	Format	Type of data available	Quantity	Quality	Contact
Seismic surveys	Angola Australia Canada Libya Russia UK* USA	ExxonMobil	Paper and electronic - a few in Access but no central database	Sightings data Effort data Operations data	1995 onwards - 12-15 surveys since 1995, most within last 3 years	Higher quality data where trained MMOs used and a standard format. Lower quality for surveys with casual observation by bridge watch.	Kurt Tweedy kurt.b.tweedy@exxonmobil.com
Site surveys	Canada Nigeria UK* USA	ExxonMobil	Paper and electronic - not in database	Sightings data Effort data Operations data	2000 onwards - 15-20 site surveys since 2000, most within last 3 years	Variable - higher quality for surveys with trained and dedicated MMOs and lower quality for surveys with casual observations by bridge crew.	Kurt Tweedy kurt.b.tweedy@exxonmobil.com
CSEM surveys	Brazil	IBAMA	Paper and electronic - not in database	Sightings data Effort data Operations data	3 years - 5-6 surveys in total	High - experienced, trained MMOs; standard recording forms.	Cristiano Vilardo Cristiano.guimaraes@ibama.gov.br
CSEM surveys	Canada (Eastern)	ExxonMobil	Paper	Sightings data Effort data Operations data	2006 onwards - 2 CSEM surveys	High - trained, dedicated MMOs.	Kurt Tweedy kurt.b.tweedy@exxonmobil.com
Geophysical/ geotechnical + environmental baseline surveys	Angola	BP	Electronic - Excel	Sightings data (basic) Effort data	2005 and 2006 - more than 3 surveys	Unknown	Daniel Touzel touzeldf@bp.com
VSP	Tangguh	BP	Electronic - Excel	Sightings data (basic) Effort data (basic) Operations data	2007 - 1 survey		Lidia Ahmad lidiaa@bp.com
Pile driving	UK	Scottish Fishermen's Federation	Electronic - not in database	Sightings data Effort data Operations data	1 survey	Unknown	Liam Byrnes L.Byrnes@sff.co.uk
Drilling	Canada	Canada-Nova Scotia Offshore Petroleum Board	Paper	Sightings data (basic) Effort data (basic)	Continuous - 1 report held	Medium - experience of observers unknown; numerical data only provided	Elizabeth MacDonald emacdonald@cnsopb.ns.ca

Type of operations	Location of operations	Holder of data	Format	Type of data available	Quantity	Quality	Contact
Drilling	Australia Russia	ExxonMobil	Paper and electronic - Access database (Russian data).	Sightings data Effort data	Late 1980s onwards (Australia); Late 1990s onwards (Russia) - several hundred observation reports annually from Russia	Higher quality data for Russia with trained MMOs.	Kurt Tweedy kurt.b.tweedy@exxonmobil.com
Drilling	Sakhalin	Elvary Neftegaz, Zapad-Shmidt Neftegaz, Vostok-Shmidt Neftegaz, BP	Electronic - Excel	Sightings data Effort data	2006 - 1 report covering 2 drilling wells	High - trained MMOs; standard recording forms.	Zourab Gagnidze gagnz0@bp.com Environmental.Sakhalin@bp.com
Drilling	UK	JNCC	Paper	Sightings data	1998 onwards - approximately 2 surveys per year	Medium - untrained undedicated personnel recording casual sightings	Zoë Crutchfield zoe.crutchfield@jncc.gov.uk Craig Bloomer Craig.Bloomer@jncc.gov.uk
Explosives	UK	JNCC	Electronic - not in database	Sightings data Effort data Operations data	2002 onwards - approximately 2 surveys per year	Variable - some high quality data from trained, dedicated MMOs; adapted recording forms used	Zoë Crutchfield zoe.crutchfield@jncc.gov.uk Craig Bloomer Craig.Bloomer@jncc.gov.uk

* indicates some duplication with JNCC dataset
+ indicates some duplication with MMS dataset

Table 3 Type of information included in available/ potentially available MMO data (Y = data included; S = data sometimes included)

	Data set (for source see list below)																									
	Military 1	**Seismic 1**	**Seismic 2**	**Seismic 3**	**Seismic 4**	**Seismic 5**	**Seismic 6**	**Seismic 7**	**Seismic 8**	**Seismic 9**	**Seismic 10**	**Seismic 11**	**Seismic 12**	**Seismic 13**	**Seismic 14**	**Site surveys 1**	**CSEM 1**	**CSEM 2**	**Geophysical & geotechnical 1**	**VSP 1**	**Pile driving 1**	**Drilling 1**	**Drilling 2**	**Drilling 3**	**Drilling 4**	**Explosives 1**
Effort data:																										
Date & times of watch	S	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Location of watch	Y	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y		Y
Observer's name	S	Y	S	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y
Platform	Y	Y	S	Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y			Y		Y	Y		Y
Weather during watch:																										
wind	S	Y	S	Y		Y		Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y		Y			Y
sea state	S	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y
swell		Y	S	Y	Y	Y		Y	Y	Y		Y			Y	Y	Y	Y	Y	Y	Y		Y			Y
visibility	S	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y
other											glare		depth		Y	Y		Y					Y	glare		
Source activity during watch	S	Y	S		Y	Y	Y	Y	Y	?		Y	Y	Y	Y	Y	Y	Y		Y	Y					Y
Operational data:																										
Times sources active	S	Y	S	Y	Y	Y	Y	Y	Y	?		Y	Y	Y	Y	Y	Y	Y		Y	Y					Y
Times of soft start	S	Y	S	Y	Y		Y	Y	Y	?		Y	Y	Y	Y	Y	Y	Y		Y	Y					S
Visual clearing period	S	Y	S	Y	Y			Y	Y	?		Y	Y		Y	Y	Y	Y		Y	Y					S
Mitigating action	S	Y	S	Y	Y	Y	Y	Y	Y	?		Y	Y	Y	Y	Y	Y	Y		Y	Y		Y			S
Sighting data:																										
Date & time of sighting	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Location	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Multiple locations and time per sighting					Y		Y			Y		Y	Y	Y	Y	Y	Y	Y	Y		Y		Y			
Species	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Number	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y	Y	Y
Behaviour	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	?	S	Y		Y	Y	Y	Y
Distance from source (^{v} = from vessel)	S	Y	Y	Y	Y	Y	Y	Y	Y	?	Y^{v}	Y	Y^{v}		Y	Y	Y	Y		Y	Y		Y	Y^{v}		Y
Direction of travel	Y	Y	Y	Y	Y	Y		Y	Y	?	Y	Y	Y	Y	Y	Y	Y	Y			Y		Y	Y	Y	Y
Relative orientation		Y	Y	Y	Y	Y	Y	Y	Y	?	Y	Y	Y		Y	Y	Y	Y			Y	Y	Y	Y		Y
Source active/ inactive	S	Y	Y	Y	Y	Y	Y	Y	Y	?	Y	Y	Y		Y	Y	Y	Y		Y	Y			Y		Y

Military 1: Military data (global), held by UK Hydrographic Office
Seismic 1: Seismic + site surveys + VSP (UK + some adjacent waters), held by JNCC
Seismic 2: Seismic + site surveys (West Africa, South Africa, East Africa, Gulf of Suez, Pakistan, Biscay, Greenland), held by JNCC
Seismic 3: Seismic + site surveys + VSP (Gulf of Mexico), held by MMS
Seismic 4: Seismic surveys (Brazil), held by IBAMA
Seismic 5: Seismic surveys (New Zealand), held by Department of Conservation
Seismic 6: Seismic surveys (Canada), held by Canada-Nova Scotia Offshore Petroleum Board
Seismic 7: Seismic surveys (UK*), held by BP
Seismic 8: Seismic surveys (Gulf of Mexico^{+}), held by BP
Seismic 9: Seismic surveys (Angola), held by BP
Seismic 10: Seismic surveys (Sakhalin), held by Elvary Neftegaz, Zapad-Shmidt Neftegaz, Vostok-Shmidt Neftegaz, BP
Seismic 11: Seismic surveys (UK*, Libya, Tunisia), held by Scottish Fishermen's Federation
Seismic 12: Seismic surveys (Canada), held by Chevron
Seismic 13: Seismic surveys (Gulf of Thailand), held by Chevron
Seismic 14: Seismic surveys (Angola, Australia, Canada, Libya, Russia, UK*, USA), held by ExxonMobil
Site surveys 1: Site surveys (Canada, Nigeria, UK*, USA), held by ExxonMobil
CSEM 1: Controlled source electromagnetic surveys (Brazil), held by IBAMA
CSEM 2: Controlled source electromagnetic surveys (Canada), held by ExxonMobil
Geophysical & geotechnical surveys 1: Geophysical/ geotechnical + environmental baseline surveys (Angola), held by BP
VSP 1: Vertical seismic profiling (Tangguh), held by BP
Pile driving 1: Pile driving (UK), held by Scottish Fishermen's Federation
Drilling 1: Drilling (Canada), held by Canada-Nova Scotia Offshore Petroleum Board
Drilling 2: Drilling (Australia, Russia), held by ExxonMobil
Drilling 3: Drilling (Sakhalin), held by Elvary Neftegaz, Zapad-Shmidt Neftegaz, Vostok-Shmidt Neftegaz, BP
Drilling 4: Drilling (UK), held by JNCC
Explosives 1: Explosives (UK), held by JNCC
* indicates some duplication with JNCC dataset (Seismic 1)
$^{+}$ indicates some duplication with MMS dataset (Seismic 3)

4. Investigation of existing databases

Recipients of the questionnaire to identify available MMO data (see section 3) were asked whether any data they held were contained within a database. Where respondents indicated that data were held within a database, those respondents were contacted to ascertain the nature of that database. Details of five MMO databases were obtained, four containing MMO data collected during the course of oil and gas exploration activities and one containing data collected during the course of military operations.

Table 4 summarises the information gathered about existing MMO databases, including the fields contained within these databases. Only two of the existing MMO databases contain information in more than one table structured as a relational database, the JNCC MMO database and the UK Hydrographic Office (UKHO) Maritime Environment Data Store (MEDS). The other databases are single table spreadsheets.

All of the existing MMO databases hold sightings information; in each case all sightings information is contained within one table, which in some cases also holds effort data. The JNCC MMO database contains the greatest range of information on each sighting. Species and number of animals are the only sighting fields contained within all the databases. Movement relative to the vessel and behaviour are included in three of the databases. The distance of the animals is also included in three of the databases, although in some cases it is distance from the source while in others it is distance from the vessel, and in only two cases is it specified that it is the closest distance of approach that is entered. Other fields, such as the animal's heading or speed, occur in fewer than three databases.

Effort data is included in all MMO databases but one, although in two cases effort data are combined with sightings data in one table. The range of information included within the effort data fields varies considerably from a simple record of date, time and location to more detailed records of watches including weather conditions during the watch (sea state and visibility being the weather conditions most frequently included).

Not all data recorded have been entered into the existing MMO databases. One database contains no effort data even though these have been recorded, and there is also at least one database where operations data, although recorded, is not included. Only the JNCC MMO database contains any operational data, but even then only those data necessary for enabling assessment of compliance with the relevant guidelines are entered, rather than all the operational data collected being entered.

Only the JNCC MMO database contains a separate table with survey information (e.g. start and end dates, operator and contractor, type of survey, airgun volume, type and number of MMOs and use of PAM). One other database contains some airgun parameters within a combined effort and sightings table, but all other databases contain no information on the survey.

The JNCC MMO database and UKHO MEDS are the largest existing MMO databases, and the JNCC MMO database is also the most comprehensive, containing operational and survey information as well as effort and sightings data.

Although it is the most comprehensive of the existing databases, there is still room for improvement within the JNCC MMO database - the effort data collected and entered into this database contain a location for the watch in the form of blocks transited, rather than precise positions in latitude and longitude, and this limits the types of analyses that can be done. Although compliance with the guidelines can be assessed using the limited operations data within this database, inclusion of fuller operational data as is recorded would also enable greater analysis of the data.

None of the existing MMO databases represent a model to be used for a central MMO database. Instead a new MMO database design is proposed, incorporating some features of the JNCC MMO database (e.g. the relational structure, key data fields) but with an improved analytical capability.

Table 4 Information included in existing MMO databases

	JNCC MMO database	UKHO Maritime Environment Data Store	BP Angola MMO database	Chevron Canada MMO database	Elvary Neftegaz/ Zapad-Shmidt Neftegaz/ Vostok-Shmidt Neftegaz/ BP MMO database
Type of operations	Seismic and site surveys and VSP	Military	Seismic and geophysical/ geotechnical surveys	Seismic surveys	Seismic surveys and drilling
Location	UK and adjacent waters	Global	Angola	Canada	Sakhalin
Database programme	Paradox	Oracle	Excel	Excel	Excel
Sightings data fields	Date Time Watch status Vessel Observer Position Depth Species Certainty of id. No. animals No. adults No. juveniles Photograph taken Relative movement Heading Behaviour Source activity Closest distance to source	Month Vessel Species Quality of id. Size class No. animals Heading Speed Comments	Survey Date Time Vessel Observer Position Species No. animals	Species No. animals Relative movement Behaviour Initial distance Closest distance	Species No. animals Relative movement Behaviour Distance Speed Sighting cue

	JNCC MMO database	**UKHO Maritime Environment Data Store**	**BP Angola MMO database**	**Chevron Canada MMO database**	**Elvary Neftegaz/ Zapad-Shmidt Neftegaz/ Vostok-Shmidt Neftegaz/ BP MMO database**
Effort data fields	Vessel Date Observer Start time Stop time Location Depth zone Watch duration Duration of active source Wind direction Wind force Sea state Swell Visibility	Date Position Location		Licence no. Vessel Date Seismic line no. Watch status Observer Time Position Depth Seismic activity No. guns Array volume Array depth Sea state Visibility Water temperature	Survey type Vessel Date Observer Time Position Sea state Visibility Light/ dark Glare
Operations data fields *Table 1:* (gun usage)	Survey no. Year Total no. gun starts No. day gun starts No. night gun starts Type of soft start				
Table 2: (pre-shooting searches)	Survey no. Date Length of search (short searches only)				
Table 3: (soft starts)	Survey no. Date Length of soft start				
Table 4: (delays)	Survey no. Date Sighting reference Observer Delay Time animals last seen Time guns started Length of delay Length of soft start Full power reached?				
Survey data fields	Year Survey no. Start date End date Location Vessel(s) Type of survey Airgun volume Operator Contractor Type of observer No. MMOs PAM used PAM vessel				

	JNCC MMO database	UKHO Maritime Environment Data Store	BP Angola MMO database	Chevron Canada MMO database	Elvary Neftegaz/ Zapad-Shmidt Neftegaz/ Vostok-Shmidt Neftegaz/ BP MMO database
Quantity of data	Years 1994-2002 (later years due to be added) 97,755 hrs effort 4,614 sightings 15,293 soft starts	Years since 1989 ~2,000 sightings per year	Years 2003-2006 1,067 sightings	Years 2004-2005 3,854 hrs effort 10,250 records of effort and sightings	Year 2006 > 5,000 hrs effort 639 sightings
Comments	All tables linked by unique survey reference no., all sightings identified with unique reference no.	Two tables linked by observation no. and job no.		Effort and sightings joined in one table	Effort and sightings joined in one table

5. Existing and planned analyses of MMO data

Where data are entered into databases there is potential for analysis of those data. Recipients of the questionnaire to identify available MMO data (see section 3) were asked what analyses had been performed on their data and what analyses were planned.

To date, JNCC is the only regulator to have performed a detailed analysis of data from multiple surveys. Some other regulators, although they have not yet undertaken detailed analysis of the data, have nevertheless compiled summary reports either for individual surveys or on an annual basis. In addition, MMO data from some specific exploration programmes have been subject to analysis on behalf of some offshore exploration industry companies. Many MMO data remain as yet unanalysed, but there are plans for future analysis of some data, both by regulators and by industry.

MMO data returned to JNCC from seismic surveys (including site surveys and VSP) have been analysed up to and including data from 2002 (Stone, 1997, 1998, 2000, 2001, 2003a,b, 2008; Stone and Tasker, 2006). The analysis that has been undertaken focuses on two aspects: compliance of surveys in UK waters with the JNCC guidelines, and examination of the effects of airgun activity on the occurrence and behaviour of marine mammals.

Amongst the other regulators compiling summary reports, IBAMA has produced regulatory compliance reports for individual seismic surveys in Brazilian waters and MMS produce annual summary reports documenting sightings of protected species in the Gulf of Mexico. Some regulators may hold reports containing analysis of data from individual programmes, but their data have not been pooled for analysis e.g. Canada's CNSOPB holds some reports containing analysis of data from specific drilling or seismic programmes (Jacques Whitford Environment Ltd., 2002; LGL Limited, 2004). Guidelines in New Zealand and Ireland, and thus the requirement to submit reports, are relatively new and therefore it would not be expected that DOC or NPWS respectively would have acquired sufficient data as yet to merit analysis.

In addition to regulators performing analysis of data submitted to them, the offshore exploration industry also has an interest in analysing MMO data. Some client companies hold MMO reports containing analysis of data from specific exploration programmes; these analyses may consider spatial and temporal presence of marine mammals and/ or sea turtles and may examine the behaviour of marine mammals in relation to the activity of seismic sources (e.g. Gilders *et al.*, 2007; Moulton *et al.*, 2005, 2006; Weir, 2006a,b,c, 2007, 2008). Off Sakhalin Island there have been a number of jointly funded studies of marine mammals focussing on the population, behaviour and habitat utilization of the western gray whale *Eschrichtius robustus* and the impact of anthropogenic sound on this species. These studies have utilized observers not only on seismic survey vessels but also on research vessels and aircraft, and have resulted in many reports and papers (e.g. Gailey *et al.*, 2007; Meier *et al.*, 2002, 2007; Yazvenko *et al.*, 2007a,b).

Amongst those regulators planning future analyses, JNCC plans to utilise data from UK waters that have not yet been analysed (year 2003 onwards). Through their Environmental Studies Program MMS plan in the near future to use MMO data from the Gulf of Mexico to evaluate existing mitigations and their effectiveness; reports from the years 2002-2006 will be analysed to examine seismic activity levels, species occurrence and behaviour, and observer effort. In Brazil there is a graduation thesis in the process of being prepared using MMO data submitted to IBAMA. Development by IBAMA of digital environmental databases (to include MMO data) is ongoing, but is currently in an early phase. IBAMA has an objective of performing more analyses of MMO data but has not done so to date. New Zealand's DOC may possibly perform some analyses of the MMO data held by them in the future but at present have no specific plans to do so. The NPWS in Ireland has identified a need to collect and collate and undertake some analysis of data received, which has led to a project to develop an Irish Cetacean Database that would be tolerant of data from various sources including that collected by MMOs during seismic surveys - this database is currently in development and should be in existence before the end of 2008. In Australia the Department of the Environment, Water, Heritage and the Arts (DEWHA, formerly the Department of the Environment and Water Resources) have longer term plans to develop a database to collect, store and analyse MMO data.

Some client companies also have future plans for further analysis of data. For example, ExxonMobil plan to continue periodically analysing data from around Sakhalin Island as part of the jointly funded studies there. Chevron Canada Ltd. plan to pool their existing data with data from other eastern Canada seismic programmes for compilation into a manuscript for the primary literature to compare sightings and behaviour of marine mammals during the soft start, with operating airgun arrays and with the airguns inactive.

The UK Navy was the only military organisation to respond positively to requests for information. The UKHO, that holds MMO data collected by the UK Navy, has not performed any analyses of the data so far and has no plans for any future analysis at this time.

6. Identification of key questions

As part of this project a one-day workshop was held to examine the current status of MMO data and the potential utility of these data. The workshop was held in Oxford, UK, on 27th September 2007. A key objective of this workshop was to examine what could be achieved with the large amount of data from around the world that are collected each year by MMOs. The workshop aimed to identify the key questions that various parties wish to have answered, and to assess whether these could be answered with the existing recording practices and existing databases or whether these would require new developments to be made. The workshop brought together delegates from regulatory bodies, industry, academia and MMOs in order to generate ideas and address this issue from as many perspectives as possible.

The workshop comprised a number of presentations regarding MMO data, followed by small group discussions on various topics. The outcomes of the workshop were summarised on a web site http://clientzone.extranet.rsk.co.uk/clients/mmodata, with password access distributed to all who attended the workshop and those who were unable to attend but had expressed an interest in being informed of the outcomes.

Presentation session

Six presentations were given, looking at the current status of MMO data, viewing it from the perspectives of the various interest groups (industry, regulators, researchers and MMOs, with each perspective presented by a representative from the various groups) and introducing databases and their uses. The presentations were put on the workshop web site after the event.

- The industry perspective - what can industry gain from MMO data (Rodger Melton - ExxonMobil)
- MMO data - current status, what is available (Carolyn Barton)
- The regulatory perspective - why the MMO programme exists, what is its purpose (Zoë Crutchfield - JNCC)
- The research perspective - what are the gaps in current marine mammal research, what could be achieved with MMO data (Charles Paxton - Centre for Research into Ecological and Environmental Modelling)
- The MMO perspective - what role do MMOs play (Alison Gill - Marine Team)
- An introduction to databases and their uses (Mike Mason - RSK)

Discussion groups

There were six topics for discussion, listed below together with a summary of the main points that were raised for each discussion topic. These were also made available on the workshop web site after the event.

What are the priorities for regulators?

- To ensure that industry can keep going - assess the balance between mitigation and the needs of industry
- To have a balanced approach to the use of marine resources
- To maintain a healthy environment
- Mitigation is the priority - it is important to protect marine mammals and other marine life, and to ensure that there is no significant impact on marine mammals (including irreversible impacts)
- There is a need to be aware of the effects of operations
- To gain feedback for future regulations - it is important to have feedback that can be used
- Risk assessments - to be able to assess the risk to marine mammals from operations within a given area at a given time
- Proper protocols should be designed and established for mitigation and for the collection of data - appropriate mitigation measures that reflect the environmental risk should be used, and decisions should be based on scientific data or the precautionary principle
- To examine the precautionary principle versus risk assessment
- To understand the efficacy of new mitigation tools, e.g. acoustics
- There should be a review of PAM trials
- To ensure that the required data is collected by using the consent/ permit process
- To ensure compliance with current legislation, ensure conditions of licences are met, and ensure applicable guidelines are followed
- To determine levels of compliance for individual operations
- The data should be robust - it should be capable of being used in an audit trail
- Regulators may be concerned with the local area within their jurisdiction
- There should be a broader outlook - other industries, cumulative effects and the effects of combinations of operations should be considered
- Regulators may wish to certify trainers
- There should be a continuous review - this may require more resources for data analysis
- To consult with all interested parties
- To liaise with international regulators and also with countries with no regulations
- To avoid duplication of effort
- To make data available
- Priorities for regulators have lots in common with those for industry

What are the key questions for industry?

- What are the levels of risk of exposure in varying conditions? Information should be available prior to a survey to determine the minimum impact.
- A priori real time knowledge of marine mammal densities

- Are mitigation measures justified and effective (and cost effective)? There is a need for confirmation that current mitigation measures are working based on scientific data.
- Mitigation should be based on sound science - there should be a scientific basis for regulatory development, based on data (evidence based)
- Measures should be practical
- There should be mitigation of the actual risk - a distinction should be made between mitigation and attenuation, and there should be a comparison of actual risk versus perceived risk
- Justification of soft starts - are soft starts working?
- Specific methodological questions need answering - e.g. regarding the soft start or slow start, shutdown buffer and soft end
- There should be a study of the effectiveness of the slow start and any soft end
- Is it necessary to shut down to protect animals from harm?
- Can unnecessary mitigation measures be removed?
- Regulatory compliance is important - industry needs to satisfy regulators and meet licence conditions, and where regulations don't exist industry should develop their own reasonable methods
- A minimum standard should be established for industry
- Industry wants to show responsibility - that it is employing best practice and not causing harm
- Industry wants confidence - that they are acting responsibly, that they get value for money, and that there is effective mitigation
- There should be a balance with other industries
- Should there be independence in hiring MMOs - what level of competency is required to satisfy mitigation requirements and data collection?
- MMOs must understand legislation
- MMOs should be educated about the industry/ offshore operations and regulatory bodies
- MMOs could be involved in planning and managing risk
- Quality assurance of data is important
- Improvements could be made to the data form to increase its value - data forms should be designed to answer the key questions that industry are interested in

What are the research needs that could be addressed with MMO data?

- Research needs should be defined - these will be stakeholder dependent
- There is a need to assess the quality and accuracy of the data
- To assess the extent of variation, consistency (repeatability) of survey results, and limits of inference (be aware of the dangers of extrapolating)
- Could sampling methodology be improved to decrease uncertainty?
- Care should be exercised not to overanalyse the data
- To establish evidence-based (scientifically justified) mitigation methods
- The soft start - is it effective as a mitigation measure?
- To answer questions relating to impacts of sound on marine mammals
- There should be an analysis of data prior to the initial start up to avoid bias due to recent noise
- To examine species-specific responses (gross)

- To determine the distance at which animals divert from the airguns
- To consider long term and broad scale impacts - beyond real time seismic survey impacts
- Current models from existing research could be verified/ calibrated with new data
- Data should be collected in new areas offshore to fill in gaps
- To answer basic questions about densities
- Distribution and abundance studies - seismic survey vessels are a biased platform (problems of noise driving animals away), methodology would need to be considered e.g. MMO data not suitable for distance sampling but could be used for presence/ absence or relative abundance (need accurate positional data), or look at changes in relative abundance in an area
- To examine environmental preferences by species
- MMO data could possibly be used for habitat modelling or testing models
- Identification of pods
- Independent observers could be used for determining the probability of detecting marine mammals - two independent MMOs would be needed to collect data to stand up to rigorous analysis
- To correlate visual MMO data and PAM data

What additional data could be collected by MMOs?

- Prioritise the existing data fields - reduction in total number of fields and standardise these between different areas/ operations
- Consider what the data collected will be used for
- More details on changes in effort and conditions/ more regular recording of effort and environmental data (records every hour?)
- Effort during the soft start - distinguish the length of time during the watch that the guns were firing at reduced volume from the time they were firing at full power (to enable calculation of sighting rates during the soft start versus full power)
- Record changes in environmental variables e.g. sunglare
- Expand on the types of sighting conditions recorded e.g. sunglare
- Day/ night
- Speed of vessel
- GPS waypoints/ course of vessel/ whether vessel is travelling straight or turning
- Times that airguns are switched on or off relative to observer effort
- Height of eye and other general effort/ methodological information
- Record the equipment used e.g. binoculars
- Seismic line and shot-point number
- Shot interval
- Source status - volume, depth
- Information on other activities in the area/ other nearby vessels/ cumulative sources
- Habitat type
- MMOs should be named not anonymous
- Latitude and longitude at beginning and end of event
- Distance and bearing/ angles at first sighting
- Track of vessel relative to animal
- Track of animal
- Changes in behaviour

- Biological state of animals e.g. calving
- Relate sightings to activity of vessel - to clarify at what stage action is taken
- How MMOs estimate distance
- Photographs/ video footage/ use of PAM
- PAM forms - develop a standardised form, link visual and PAM forms
- Record other animals - seabirds, turtles, sharks

The soft start - what do we need to know and how do we achieve this?

- Does the soft start work?
- How effective is the soft start?
- Does the soft start prevent TTS and PTS, i.e. is it an effective mitigation measure?
- Species-specific effectiveness - how effective is the soft start for different species, what are the reactions of different species?
- Is the soft start necessary?
- What should the duration (minimum and maximum) of the soft start be?
- How does the sound build up over time?
- What influence does shot point interval have on the effectiveness of the soft start?
- What alternatives are there to the soft start?
- The slow start - is this effective?
- What is the behaviour of animals during the soft start?
- Use UK MMO data (no requirement to shut-down) to assess the minimum distance that animals approach during the soft start
- Is there habituation as a result of the soft start?
- Does the soft start attract mammals?
- Does the soft start have a detrimental effect?
- To determine if it works - can we get this from MMO data or are controlled experiments in a variety of conditions needed?
- Use of long-term data - to increase the sample size and thus the ability to perform statistical tests
- Design studies e.g. a behavioural response study
- Deliberate exposure of animals to a soft start, with a change in exclusion zones - but providing this is non-injurious
- Change buffer distances stepwise in the experimental design
- Need to address the problem of a moving sound source

What are the sensitivities of available data?

- Permission for release of data/ ownership issues
- Would ownership be retained?
- Intellectual property - clients/ MMOs/ other interested parties
- Who publishes the data, who is an author?
- Confidentiality of data (especially military) - time aspect, classified
- Release of the data may be time consuming - personnel issues
- Some regulators may be sensitive
- Operational considerations
- Sensitive areas - clients concerned that MMO data will highlight sensitive areas where they are operating
- Locations of speculative surveys may be revealed

- Mitigation measures used/ position/ name of vessel would be revealed
- Instances of non-compliance would be revealed
- Concerns about the correct interpretation of data
- There needs to be reassurance of competent analysis taking into account data limitations/ bias/ regional differences
- Concern over data collection bias - methodology needs to be understood by those accessing data
- Objective use of data - it should be subject to peer review
- A confidence scale should be applied to data quality
- Who has access and who manages access - would access be controlled, could anonymous codes be used?
- Can regulators enforce access as a condition of the permit?
- Where would data be stored?
- How would data be maintained?
- Data exchange/ common exchange format

The scope of these discussions extended beyond identifying questions that could be answered by performing analysis of MMO data. However, many potential subjects for analysis were identified, and following on from the workshop a list of key questions that could potentially be answered using MMO data was compiled (Table 5). Priority questions were identified based on the discussions at the workshop and other communications/ correspondence. An assessment was made of the types of data that would be needed in order to answer each of the key questions.

Some of the main areas considered as potential subjects for analysis were regulatory compliance, risk assessment, effectiveness of mitigation measures, the impact of sound on marine mammals and the biology of marine mammals.

MMO data can be used to assess regulatory compliance, that licence conditions are met and applicable guidelines followed. As the requirements of regulations/ guidelines differ between areas, there is a need to be able to distinguish between the different areas of jurisdiction; there is also a need for regulators to be able to identify individual surveys, with details of operators and contractors. For areas where there are no regulations in existence, data could be used to show that the offshore industry is developing its own reasonable methods of mitigation.

It would be beneficial when planning future operations if MMO data could be used to assess the risk of those operations in a given area at a given time; this would require relevant MMO data to be made available. This risk assessment could be used when planning appropriate mitigation. Alongside this is a need to assess the effectiveness of the various mitigation measures available. Of particular interest is assessing the effectiveness of the soft start - the points raised in the workshop discussion groups and the list of identified key questions reflect the level of interest in this topic.

Underlying the various regulations/ guidelines and their requirements for mitigating measures to be taken is the potential for acoustic operations to cause disturbance or physical harm to marine mammals and other marine animals. Another key area where MMO data could be used is to assess the impacts of operations on marine mammals, with long term and cumulative impacts being considered as well as immediate responses.

It is also thought that MMO data could be used to complement other studies on the biology of marine mammals by providing further information on distribution and abundance. There would need to be recognition that MMO data collected from platforms such as seismic survey vessels may be biased in that the acoustic operations undertaken from these platforms may influence the distribution and abundance of marine mammals. However, MMO data could provide some useful additional information particularly in areas where there are existing gaps in knowledge.

Table 5 Key questions that could be answered using MMO data (**P** = priority question)

Category	Key questions	Minimum data needed
Regulatory compliance* (or application of best environmental practice in areas with no regulations) ** for individual surveys or overall within geographic areas*	Are appropriately qualified MMOs being employed? **P**	Survey reference, area of jurisdiction, number and credentials of MMOs
	Is PAM being utilised where appropriate? **P**	Survey reference, area of jurisdiction, usage of PAM
	Are watches of appropriate duration? **P**	Survey reference, area of jurisdiction, date, times of start and end of watches, times of start and end of firing
	Are soft starts of appropriate duration? **P**	Survey reference, area of jurisdiction, type of survey, date, time of commencement of soft start, time of full power, time of start of line
	Are airguns deactivated/ reduced in output/ continually fired between lines (as required depending on guidelines)? **P**	Survey reference, area of jurisdiction, type of survey, date, time of start of line, time of end of line, time of reduced output, time source stopped, time soft start began, time full power reached
	Are delays/ power-downs/ shut-downs enacted as required? **P**	Survey reference, area of jurisdiction, date, time of sighting/ acoustic detection, species, age class (some jurisdictions only), closest distance of approach, operational activity, mitigating action, time soft start began, time of reduced output, time full power reached, time source stopped
Risk assessment for operations	What is the likelihood of encountering marine mammals within a given area at a given time (spatial and temporal abundance)? **P**	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species
	What is the ability to detect marine mammals (and therefore take mitigating action) in varying conditions? **P**	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species
	How close do marine mammals approach active operations? **P**	Date, species, operational activity, closest distance of approach*, time of closest approach, time soft start began, time full power reached, time source stopped, area of jurisdiction ** need to use only data from jurisdictions that do not require shut-downs*
Effectiveness of mitigation measures	Are soft starts working? **P**	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species/ species group, operational activity, movement of animal relative to vessel, first, closest and last observed distances during soft start

Category	Key questions	Minimum data needed
	How effective is the soft start for different species? **P**	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, operational activity, movement of animal relative to vessel, first, closest and last observed distances during soft start
	Does the soft start prevent TTS and PTS? **P**	Species, operational activity, closest distance of approach during soft start, source characteristics, distance of onset of TTS and PTS* * *from literature or studies*
	What should the minimum and maximum duration of the soft start be? **P**	Date, time soft start began, time full power reached, time of sighting, species, operational activity, movement of animal relative to vessel, first, closest and last observed distances during soft start
	What is the behaviour of marine mammals during the soft start?	Species, operational activity, behaviour
	What is the minimum distance that animals approach during the soft start? **P**	Species, operational activity, closest distance of approach during soft start, jurisdiction* * *may need to use only data from jurisdictions that do not require shut-downs*
	Is there habituation as a result of the soft start?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, operational activity, behaviour, movement of animal relative to vessel, first, closest and last observed distances during soft start
	Does the soft start attract animals?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, operational activity, behaviour, movement of animal relative to vessel, first, closest and last observed distances during soft start
	What is the influence of shot point interval on the effectiveness of the soft start?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, operational activity, movement of animal relative to vessel, first, closest and last observed distances during soft start, shot point interval
	Does the slow start work?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, operational activity, movement of animal relative to vessel, first, closest and last observed distances during soft start, method of soft start
	Is it necessary to shut-down to protect animals from harm? **P**	Date, species, operational activity, time of shut-down, jurisdiction, closest distance of approach*[1], time of closest approach, movement of animal relative to vessel, source characteristics, distance of onset of TTS and PTS*[2] *[1] *may need to compare between jurisdictions where shut-downs are and are not required* *[2] *from literature or studies*
	At what distance do animals divert from the source? **P**	Date, species, operational activity, closest distance of approach, time of closest approach, time soft start began, time full power reached, time source stopped, jurisdiction*, movement of animal relative to vessel, source characteristics * *in some cases may need to use only data from jurisdictions that do not require shut-downs*
	How effective is PAM at detecting marine mammals? **P**	Location, date, start and end time of PAM, PAM effort (duration of monitoring), vessel speed, environmental conditions (sea state, swell etc.), date and time of detection, species/ species group

Category	Key questions	Minimum data needed
Impacts of sound on marine mammals	What influence do operations have on distribution, abundance, behaviour, etc., and what are the species-specific responses to operations? **P**	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, closest distance of approach, movement of animal relative to vessel, behaviour, source characteristics, operational activity* * *may need to use data prior to initial start up as an unbiased control*
	What are the long term impacts of operations?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, closest distance of approach, movement of animal relative to vessel, behaviour, source characteristics, operational activity * *may need data prior to and following the survey to assess long term impacts*
	What are the cumulative impacts of operations?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species, closest distance of approach, movement of animal relative to vessel, behaviour, source characteristics, operational activity, cumulative operations* * *multiple seismic surveys and/ or other operations*
Biology of marine mammals	What is the distribution and abundance of animals in areas where knowledge gaps exist?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species
	What are the densities of marine mammal species in given areas?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, transect width, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species
	What is the occurrence of marine mammals within a given area (presence/ absence or relative abundance)?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species
	How does the relative abundance of marine mammals within an area change?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), date and time of sighting, species
	What are the environmental preferences of marine mammal species?	Location, date, start and end time of watch, effort (duration of watch), vessel speed, environmental conditions (sea state, swell, visibility etc.), environmental/ habitat characteristics (depth, water temperature, etc.), date and time of sighting, species
Impact on operations	What is the cost to industry of complying with regulations?	Survey reference, sighting reference, date, time of sighting, loss of production due to mitigating actions
General	What is the quality of the data?	Any of the above
	What is the level of variation within the results?	Any of the above

7. Modification of recording forms

Currently many of the countries with guidelines or regulations for minimising acoustic disturbance to marine mammals from seismic surveys have their own format for recording observations. JNCC was the first to introduce standard marine mammal recording forms for use on seismic surveys, with the original effort and sightings forms being produced in 1996 and an operations form added in 1998. These forms have been revised several times since then and the current versions, like those of other regulators, are available on the internet (Joint Nature Conservation Committee, 2007a,b,c). In Australia, DEWHA have a form for individual sightings or a spreadsheet for multiple sightings (Department of the Environment and Heritage, 2006), and the Australian Petroleum Production and Exploration Association (APPEA) has also developed a sighting form. IBAMA has forms for effort and sightings in Brazilian waters and a cover sheet (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, 2005b). Regulators in both New Zealand and Ireland have recording forms included in their guidelines (Department of Conservation, 2006; Department of the Environment, Heritage and Local Government, 2007), the former containing effort and sightings forms, and the latter containing effort, sightings and operations forms. In the Gulf of Mexico there is no specific reporting format, but operators and observers may design reporting forms in whatever format they deem convenient and appropriate, or may adopt the JNCC forms; however, the regulations in the Gulf of Mexico do contain a list of specified items for effort, sightings and operations that should be included in reports (Minerals Management Service, 2007).

A comparison was made of the data recording requirements of the regulators in various countries (Table 6); data recording practices in the waters off Sakhalin Island were included in the comparison, due to the similarities of the forms used by the various companies working in that area. Canada is the only country included in the comparison to have no specific requirements noted within their regulations for the recording of data. In the other countries compared, the data requested fall into four categories: operations, effort, sightings and general information. Some data (e.g. ship's name) are included in more than one category (duplicated items were excluded when summing the number of items requested).

A total of 131 items are requested in the data recording requirements of all the countries considered. Only one quarter of these are requested in more than half the countries considered, with just seven items being universally requested in countries where there are specific recording requests (Table 7). The diversity of recording formats and the variety of information contained within them does not facilitate collation of data into any central database and therefore limits the potential for pooling and using data from more than one source. It would be beneficial to have one standard recording format designed in conjunction with a central database for storage of multiple sets of data.

A universal recording format would enable data to be fed into a database and be ready and available for analysis to answer the key questions of concern (section 6). An additional benefit of having one standard recording format is that MMOs, many of whom

work in the waters of more than one country, would only need to become familiar with one format.

A set of standard recording forms has therefore been designed (Appendix 2). These forms are designed primarily for seismic surveys, but the design also aims to make them adaptable for other operations during which MMOs may be recording observations. They are also designed to be capable of being used anywhere in the world.

Existing recording formats were taken into consideration when designing the forms, but with particular attention being paid to the potential use of the data collected. One key need is for regulatory compliance to be able to be assessed using the data; the forms therefore contain appropriate fields to collect sufficient information to allow assessment of compliance, taking account of the diversity of regulations worldwide. For example, the forms allow for the recording of all types of mitigating actions (e.g. delaying commencement of the source, powering down the source, shutting down the source) even though only some of these actions may be required in some areas.

Collecting the information needed to enable key questions of interest to be answered (Table 5) was a priority when designing the forms. One particular area of interest, identified at the workshop on the potential utility of MMO data (section 6), is investigation of the effectiveness of the soft start. This has required the addition of several fields not included in any of the existing forms (first, closest and last observed distances during the soft start).

Existing recording practices already utilise three categories of data: operations, effort and sightings. These have been retained in the design of the new recording forms, and a supplementary form, the cover page, has been added. This contains general information about the survey; such information has often been included within the text of MMO reports. Including this information on a form will standardise between surveys what general data are being collected and will enable these data to be easily used in analysis.

The ease of use of by MMOs was taken into account when designing the forms. The forms are in Excel spreadsheets; Excel was chosen because it is widely available and familiar to many MMOs (existing forms for Australia, Brazil and the UK are in Excel). An explanatory input message appears for many fields when a cell in that field is selected, providing guidance where necessary regarding what should be entered. If invalid data is entered an error message appears indicating the valid format(s) for that field. Some existing effort forms ask for blocks transited during the watch, rather than a start and end position - this has been changed to start and end latitude and longitude, which is more readily available to MMOs. Speed of data entry is enhanced by the use of abbreviations where there are several options to choose from; these abbreviations are usually only one character in length and are in the lower case. In recognition of the fact that many MMOs use paper forms to record hand-written observations initially while on deck, and then transcribe these later into an electronic format, printer-friendly deckforms have also been produced (Appendix 3). These contain the same information as on the Excel spreadsheets, but arranged in a layout suitable for printing onto A4 paper and then

writing on. These deckforms are intended simply to be an aide memoire to ensure that MMOs recording hand-written observations are prompted to record all the information necessary to complete the Excel spreadsheets later - the deckforms are not intended for submission to regulators, rather it is the Excel spreadsheets that should be submitted. Some MMOs have expressed a desire for a way of drawing attention to a particular event that does not involve them interpreting whether or not there has been compliance with guidelines/ regulations. Each form in the Excel spreadsheets therefore has the facility to flag a record. Hints on completion of the spreadsheets are contained within a guide to using the forms (Appendix 4).

Quality and consistency of the data was also a consideration. Where possible drop-down boxes have been used to limit entries to one of a list of appropriate options, thereby eliminating the possibility of invalid entries for these fields and ensuring a consistent format. In other fields, data validation has been used to reduce the potential for erroneous entries where possible; for example, fields for minutes of latitude or longitude will only accept numbers less than 60. The explanatory input messages and error messages should also help to reduce the potential for erroneous entries.

The forms have also been designed to minimise the resources needed to proceed to the stage of analysing the data. The Excel spreadsheets are in a simple format of rows and columns that could be easily imported into a database without the need for excessive manipulation. Fields where text would be entered, e.g. description of animals, have an appropriate limit on the number of characters that can be entered so that the spreadsheets can be imported into an appropriately structured database without loss of data.

With the use of standard recording forms, there is the potential for the collation of very large sets of data for analysis. Ease of analysis was therefore also a consideration. Drop-down boxes and data validation provide a consistent format for some fields, thereby allowing easy analysis. Some previous forms contained diagrams recording the movement of the animals relative to the survey vessel - while this provides a clear representation of the animals' response when examining individual sightings, it does not lend itself to analysis of multiple sightings. Where this information has been analysed over multiple sightings (e.g. Stone and Tasker, 2006) it has had to be manually translated into various categories of movement, which is a time-consuming process and hinders easy importation of data into a database. Such diagrams have therefore been replaced on the recording forms with appropriate categories of movement.

The potential for inclusion of UK (and possibly other European) MMO data within the Joint Cetacean Protocol (JCP) (section 9) was also considered when designing the recording forms. Start and end position in latitude and longitude were used (rather than blocks transited) to render the data compatible with the likely requirements of the JCP. Separating effort records where the source was active from those where the source was inactive (by starting a new line on the effort form if source activity changes) will enable potential bias due to source activity to be identified. These features, as well as increasing the potential for inclusion within the JCP, also enable easier and more detailed analysis of the data.

Where regulators require the submission of reports, the choice of acceptable reporting format is a matter for those regulators to decide. A draft of the recording forms was distributed amongst regulators for comment.

Those regulators who were supportive of the forms and indicated that they would accept their use included JNCC (UK), NPWS (Ireland), DOC (New Zealand) and MMS (Gulf of Mexico; MMS cannot require a form unless it is a government form, but allow any format so long as it provides the required information).

In Brazil IBAMA were undecided, but expressed concerns that Brazilian MMOs might perceive that having a worldwide standard, including information not necessarily applicable to Brazilian regulations, would compromise the ease of use of the forms. DEWHA (Australia) is in the process of developing its own standardised reporting system.

Table 6 Items requested when recording data in various countries

Item requested	UK	Ireland	Gulf of Mexico	Australia	New Zealand	Canada	Brazil	Sakhalin
Operations								
Survey reference/ licence no.	Y	Y	Y					
Ship	Y	Y	Y					
Client	Y	Y						
Contractor	Y	Y						
Survey type	Y		Y					
Airgun volume	Y							
Type of soft start	Y							
Date	Y	Y	Y					
Reason for firing	Y							
Time soft start began	Y	Y	Y					
Time of full power	Y	Y	Y					
Time of start of line	Y							
Time of end of line	Y							
Time output reduced	Y							
Time airguns stopped	Y	Y	Y					
Who carried out search	Y	Y						
Time pre-shooting search began	Y	Y	Y					
Time search ended	Y	Y						
Reasons why animals may have been missed	Y	Y	Y					
Were hydrophones used	Y	Y						
Were animals present before soft start	Y	Y	Y					
Were animals seen during soft start			Y					
Were animals seen at full power			Y					
Time animals were last seen	Y	Y						
What action was taken	Y	Y	Y					
Borehole number			Y					
Effort								
Ship	Y	Y	Y		Y			Y
Ship type	Y	Y						
Survey type	Y	Y	Y					Y
Survey reference/ licence no.	Y	Y	Y					
Departure date					Y			
Port of departure					Y			
Date	Y	Y	Y		Y		Y	Y
Observer	Y	Y	Y		Y			Y

Item requested	UK	Ireland	Gulf of Mexico	Australia	New Zealand	Canada	Brazil	Sakhalin
Observer's affiliation			Y					
Time watch began	Y	Y	Y		Y		Y	Y
Time watch ended	Y	Y	Y		Y		Y	
Duration of watch	Y	Y					Y	
Duration of shooting	Y	Y			Y		Y	
Predominant status of activity during observation							Y	
Times of soft start							Y	
Reasons adversely affecting sightings							Y	
Blocks transited	Y	Y						
Start position			Y		Y			Y
End position			Y		Y			
Ship's heading								Y
Wind force	Y	Y	Y					Y
Wind direction	Y	Y	Y					
Sea state	Y	Y	Y				Y	
Swell	Y	Y	Y				Y	
Visibility	Y	Y	Y				Y	Y
Wind force at start					Y			
Wind direction at start					Y			
Sea state at start					Y			
Swell at start					Y			
Visibility at start					Y			
Wind force at end					Y			
Wind direction at end					Y			
Sea state at end					Y			
Swell at end					Y			
Visibility at end					Y			
Sunglare amount								Y
Sunglare position								Y
Daylight								Y
Sightings								
Date	Y	Y	Y	Y	Y		Y	Y
Time	Y	Y	Y	Y	Y		Y	Y
Survey reference/ licence no.	Y	?	Y					
Survey type			Y					Y
Sighting no.	Y	Y		Y			Y	
How did sighting occur	Y	Y	Y					
Sighting cue								Y

Item requested	UK	Ireland	Gulf of Mexico	Australia	New Zealand	Canada	Brazil	Sakhalin
Animal seen from				Y				
Ship	Y	Y	Y		Y			Y
Observer	Y	Y	Y	Y	Y			Y
Organisation				Y				
Company conducting survey					Y			
Postal address				Y				
Phone number				Y	Y			
E-mail				Y				
Observer's activity				Y				
Location				Y				
Position	Y	Y	Y	Y	Y		Y	Y
Bearing of vessel			Y				Y	Y
Bearing to animal at first sighting			Y		Y			Y
Subsequent bearing to animal								Y
Range to animal at first sighting			Y		Y			Y
How range was estimated								Y
Depth	Y	Y	Y		Y		Y	
Species	Y	Y	Y	Y	Y		Y	Y
Certainty of identification	Y	Y	Y	Y			Y	
Number	Y	Y	Y	Y	Y			Y
Group							Y	
Number of adults	Y	Y					Y	
Number of juveniles	Y	Y	Y		Y		Y	
Approximate length of calves					Y			
Description	Y	Y	Y				Y	
Approximate length of animals					Y			
Body colour					Y			
Baleen visible					Y			
Baleen colour					Y			
Shape of blow					Y			
Photo taken	Y	Y		Y			Y	
Direction relative to ship	Y	Y	Y				Y	Y
Direction compass	Y	Y	Y		Y			
Behaviour	Y	Y	Y	Y	Y		Y	Y
Pace of movement								Y
Other animals present				Y				
Ship activity	Y	Y	Y		Y			
No. airguns firing					Y			

Item requested	UK	Ireland	Gulf of Mexico	Australia	New Zealand	Canada	Brazil	Sakhalin
Volume of airguns					Y			
Frequency					Y			
Intensity					Y			
Interval					Y			
Streamer length					Y			
Source depth					Y			
Airguns firing	Y	Y	Y				Y	
Closest distance	Y	Y	Y		Y		Y	
Wind force					Y			Y
Wind direction					Y			
Sea state				Y	Y		Y	
Cloud cover				Y				
Swell							Y	
Visibility				Y			Y	Y
Water temperature					Y			
Sunglare amount								Y
Sunglare position								Y
Daylight								Y
Subsequent action					Y			
Whether delay necessary							Y	
Whether shut down not necessary							Y	
Shut down requested							Y	
Time of shut down request							Y	
Shut down enacted							Y	
Time shut down enacted							Y	
Total time activity interrupted							Y	
Behaviour before shut-down			Y					
Behaviour after shut-down			Y					
Length of time to subsequent ramp-up			Y					
Whether survey resumed as soon as possible			Y					
Any irregularity in performance							Y	
Observer's signature							Y	
General information								
Date of survey	Y			Y				
Start date							Y	
End date							Y	
Location of survey	Y			Y			Y	
Start time of survey				Y				

Item requested	UK	Ireland	Gulf of Mexico	Australia	New Zealand	Canada	Brazil	Sakhalin
End time of survey				Y				
Type of survey							Y	
Number and types of vessels involved	Y							
Ship							Y	
Number of guns	Y							
Volume of guns	Y						Y	
Frequencies used	Y							
Intensity	Y							
Shot-point interval	Y							
Pressure of airguns							Y	
Any other acoustic sources used	Y							
Any problems encountered	Y							
Location, times & reasons when weather hampered observations				Y				
Location and times of any delays				Y				
Location and times of any power downs				Y				
Location and times of any shut-downs				Y				
Distance of any whale sighting				Y				
Observer's name							Y	
Observer's signature							Y	

Table 7 Items commonly requested when recording data in various countries (countries subject to comparison in Table 6)

Items universally requested	Items not universally requested, but requested in more than half of the countries considered
Date	Ship
Observer	Survey type
Visibility	Start date of survey
Time of sighting	Time soft start began
Position of sighting	Time of full power
Species	Time watch began
Behaviour	Time watch ended
	Location of watch
	Length of time shooting during the watch
	Reasons why animals may have been missed
	Wind direction
	Wind force
	Sea state
	Swell
	Depth
	Sighting number
	Number of animals
	Number of juveniles
	Description of animals
	Certainty of identification
	Photograph taken
	Animal's heading
	Direction of animals relative to ship
	Closest distance of approach
	Ship activity at time of sighting
	Whether airguns were firing at the time of sighting

8. Creation of database

The information contained in the MMO forms represents a significant amount of intellectual capital. It would be a waste of this if it were not fully utilised either through a lack of analysis tools, or lack of communication of the collected information. This section of the report looks at the potential flow of information from MMOs to a centrally managed database, and its analysis and dissemination to a selected audience.

The data flow

The flow of data from the source to final publication follows the steps outlined in Figure 1.

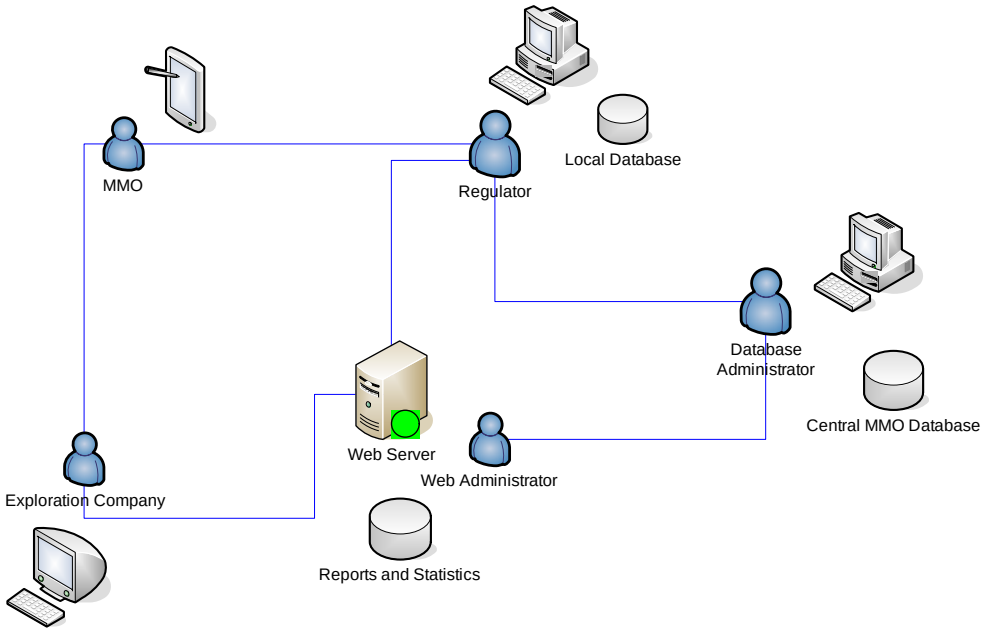

Figure 1 Data flow of MMO data

1. Collection of the information by MMOs
2. Transfer to regulators
3. Transfer to central database
4. Database administration
5. Analysis
6. Publication of results

The data element of each of these steps will be described in more detail below.

Collection of the information by MMOs

As with most field-based data collection, this is still best done with traditional pen and paper. There are ruggedized PDAs and laptops that allow for digital data collection but these are relatively expensive and still not as robust as traditional methods. In the absence

of direct entry into spreadsheets (or other form of database) on a PDA, MMO data will be entered using standard paper forms (Appendix 3), during watches, and then transcribed to digital format post-watch on a standard PC or laptop. This could be prone to transcription errors and adds to the time needed to collect the information, but it also adds a layer of data integrity checking as the observer has more time to check the information for consistency and completeness than (s)he would have during the watch.

A series of Microsoft Excel Spreadsheets (Appendix 2) have been designed to allow MMOs to enter the information into digital format. They have been designed with data integrity in mind by incorporating various field locks and consistency checks into the required cells. Such checks might be difficult to use if entering directly during the watch periods, but post-watch there is more time for data entry and these checks would help in consistent and correct data being entered.

There will be a single spreadsheet per voyage containing four worksheets (cover page, operations, effort and sightings) and all data for the entire period of the survey would be contained within this one file of four worksheets.

It is important to use a standard naming convention for these spreadsheets to avoid confusion after the voyage and when combining data from different voyages.

The suggested naming convention is:

RR_xxxxxx_ddmmyyyy.xls

Where:

RR is a region code – uniquely identifying the regulatory authority for example:

- UK – United Kingdom
- GM – Gulf of Mexico

Xxxxxx is the regulatory reference number for the voyage as recorded on the forms. The length of the references may change between regulatory authorities so this field can vary in length to accommodate this. There may only be an issue if the format of a reference number includes the "_" character which is unlikely.

Ddmmyyyy is the start date of the voyage in short format e.g. 27102008 for 27th October 2008

So a full example might look like this:

UK_81272827_27102008.XLS

Which translates to:

A voyage under the UK regulatory authority with the reference number 81272827 which commenced on the 27th October 2008.

Although the date is not strictly necessary it will allow for easier understanding and archiving when viewing many such spreadsheets in a directory.

Transfer to regulators

As the MMO's data have been captured in digital form using industry standard spreadsheets, it is fairly trivial to transfer these to regulators, either via e-mail or mailed on a CD. The standardized naming convention will help the regulators file this data, and the use of spreadsheets will provide an easy means for regulators to combine information for their own analyses should they wish to do so.

The regulators may choose to carry out their own analyses on the MMO data collected in their region using spreadsheet tools, standard statistical packages, or their own bespoke packages. Alternatively they could use the database tools developed as part of this project for their own analyses either running a local copy of the database using only their information, or using the central database giving access to worldwide information. These tools will be described more fully below.

Transfer to central database

There are several ways in which the MMO data can be transferred to a central database such as e-mail, CD, or internet upload of the raw spreadsheet information.

Sending via e-mail is quick and simple and users are generally familiar with the procedure of e-mailing attachments but there are several issues that make this process less than optimal for the following reasons:

- Anti-virus systems are notorious for detecting attachments that could contain malicious code, and spreadsheets are typical examples of such having the ability to include macros that could cause damage to operating environments. As an e-mail passes through various systems from the regulators to the final destination, it is very likely that the spreadsheet attachments will be stripped out.
- E-mail also requires (usually) the manual processing of attachments. An operator will need to export these and then import them into the central database. The standard naming convention would assist in the correct filing and tagging, but there still needs to be effort expended to achieve this.
- Excel documents offer great flexibility, but with that comes the danger of them being altered in some way by users somewhere in the chain from MMOs to central database. While this is not an issue if the documents are in their final form, it would create problems if they were used to automatically import information into a database as the location of key cells may change. This can be mitigated to some

extent by locking-down certain parts of the spreadsheet but this hampers flexibility in data collection and the protection can always be overridden.

Sending the data on CD will remove the issue of anti-virus stripping the e-mailed attached spreadsheets, but is a cumbersome practice and adds to the time and effort required to assemble and process the received information.

Internet upload of raw data has the advantages of not requiring email or CD submission with their inherent issues, and not requiring user interaction to receive the information and file it as that part can be automated.

The optimum solution is perhaps to create a web-based portal for organisations to upload their MMO data (current and legacy). By far the most significant advantage of this method is the ability of the web-portal to check the incoming data for consistency during the import process so that any errors can be highlighted to the person uploading the data for them to correct before re-trying. Once the imported information passes these data integrity checks, the system can then archive the data and import it into the database without requiring human intervention (and thus cost).

Unfortunately this solution does not solve the problem of incorrectly formatted spreadsheets, nor does it provide a solution for the import of legacy information that would be stored in a number of different formats and systems (some spreadsheet, some paper-based, some database, and others Word files). The tool required to solve this is a standard data Interchange Format for MMO data. If MMO data can be transformed into this standard format, then the web portal will be able to recognize and thus import the information into the database.

If the Interchange Format is simple enough, then it would be straightforward for organisations holding the legacy data to write transformation tools to convert their data to the new format and thus add it to the central database.

A tool could be written to convert the standard spreadsheets proposed in this report into the Interchange Format. Organisations would then be able to convert their spreadsheets and import the correctly formatted data into the web portal. This would catch issues with changes of format at an early stage and offer the opportunity for organisations to correct these issues at source. The tool would be distributed with the spreadsheets on the web portal.

A full description of a suitable Interchange Format is outwith the scope of this document, but it would almost certainly be based on the XML standard – a text-based standard which is human readable and lends itself to structured data such as the MMO data. It is a trivial exercise to create XML files programmatically and so it would be straightforward for organisations to create converters to export legacy information into the MMO Interchange Format, and thus transfer it into the MMO central database.

Database administration

There is a role for an entity (organisation or person) to host and maintain the central database. There are several aspects to this:

- Maintaining the structure and integrity of the database. Ensuring that the data does not become corrupted or inconsistent. Backing up the data and restoring it on finding errors.
- Maintaining the web portal front-end of the database to ensure high availability. Ensuring that the web operating environment is suitable for the number of users and their bandwidth requirements.
- Designing and implementing new queries and reports.
- Maintaining access control of the database. Ensuring that the appropriate users have access to controlled information.

These roles may easily be split, with the first two given to a technical resource used to managing generic web-based front-ends and databases, and the latter two to a resource with knowledge of MMO data analysis.

The anticipated traffic levels on the database will be low so the maintenance cost would be proportionally low.

Analysis

The database will store every piece of information collected by the MMOs in a relational structure normalised to reduce duplicated data. This structure and operation of the database is described in a later section. In order to analyse this information you will need a good understanding of the habits of marine mammals, an understanding of statistical techniques, and a knowledge of SQL to formulate database queries. Obviously many potential users of the system will not have all of these skills and so the database must be designed to be accessible to the lay user, but powerful enough for 'power users' to be able to query and report on the data.

There are precedents for this type of application that we can draw upon for direction. As an example the United Kingdom's Office of National Statistics, which produces independent information to help understand the UK's economy, uses a web-based application to publish its results (www.statistics.gov.uk). The database underpinning the published data is very large and very complex, and there are people with knowledge of statistics, economics, and database queries who will use the database to derive information for public consumption. The data are published as a mixture of reports and summary tabular information that can be consumed by the general public at a level they can easily understand. Subsets of the data can even be exported and used in external applications for users with a little more experience.

This model lends itself well to the MMO data. If complex data such as marine mammal observations are being collected, it is important to provide tools to query these data looking for trends or to test ideas, but it is equally important to make this information

available to a wide audience to try to maximise the usage of data that have cost a lot of time and money to collect.

The proposed design of the MMO database uses a portal model which will provide a front-end which is easy to keep updated, provides a user-friendly and familiar interface, and will support many of the required functions 'out of the box' such as user registration, document libraries and so on. Built into this portal will be data query and management functions.

The database will act as a repository of information and offer some basic query and reporting tools. There is little point in adding sophisticated data analysis functions to this system when they are already plentiful externally. A basic query tool will be part of this system allowing users with the required level of privilege to query the raw MMO data. A Query Builder will be available with options to drag object attributes and operators onto a query canvas to form standard SQL-92 syntax. Queries can be saved for later use, and can be made public, for example it would be possible to produce a query that selects a sub-set of data that did not include sensitive information such as location or contractor details. This would allow many of the data to be made available to all registered users of the system without fear of releasing commercially sensitive data. As a safeguard, queries containing columns that are marked in the database as potentially sensitive will not be allowed to be made public.

To allow analysts to build accurate queries, the database portal will provide a full description of the database structure and detailed descriptions of each data field.

The database would provide functions to export information to common formats such as comma- or tab-separated text files. These may then be used by other analysis tools such as GIS and statistical analysis packages like SPSS to analyse the information and look for patterns.

The results of these external analyses can be recorded in the form of tables and reports and made available on the database's document portal.

The data collected by the MMOs can potentially be used to analyse the activities of operators. The database will need to ensure that operators are not disadvantaged in any way by submitting their data to the database. It should be possible for the exploration companies to flag that company identification is not transferred to the central database. Despite that safeguard, the database would not allow public queries to include this type of information. In addition to this safeguard, only registered users may access the site, so the information will not be made available to the general public.

Publication of results

The results of the analyses of the data will be published on the web-based database for access by all authenticated users.

Initial access to the home page will be available to everyone to give them an opportunity to find out about the project and to apply for an account; beyond the home page, users will need an account to access any other part of the database.

The results will be published under the Library section of the database in common, accessible, formats such as Microsoft Office Word and Excel, Rich Text Format, Jpeg, Tiff and PDF. The results may take the form of reports or tables of data. Each result will have some metadata describing the data, its source, its accuracy and how it was derived. This metadata, together with the text within reports, will be searchable from any page in the database to give quick and easy access to relevant information.

Design of the database

The database will consist of two parts:

- A content database
- MMO data database

Content database

The designed system would make use of an off the shelf Content Management System to handle much of the structure of the database. A system such as Joomla (http://www.joomla.org/) would provide the following functionality 'out of the box':

- User interface – styles, and presentation of elements of the database.
- User account management – handling the management of user accounts, their registration, and permission levels.
- Document management – handling the upload, publication, presentation, and search for documents.

Such a Content Management System stores all of its data in a relational database, the structure of which is not relevant to this research, but is documented elsewhere.

MMO data database

The MMO data would also be stored in a relational database (which could be the same one as the database storing the Content Management System data). The structure (schema) needed to handle the information that will be collected on the MMO recording forms is described below.

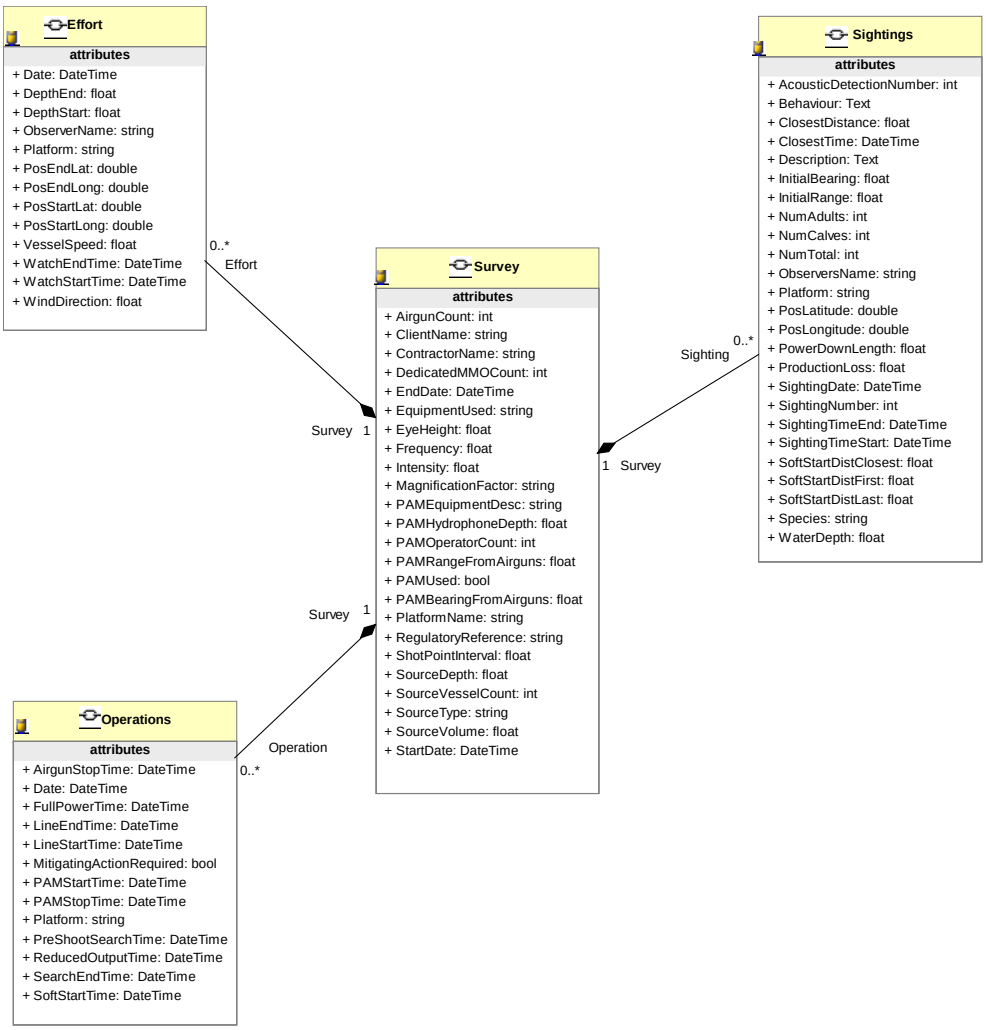

Figure 2 Overview of primary MMO Data Objects

Figure 2 gives an overview of the main Object types in the database. Each of these main objects will now be described in more detail below:

Survey

A Survey Object (Figure 3) is the base object for all other objects in the database, and represents a single marine mammal survey. There may be many Surveys per voyage. The attributes of a Survey are largely those found on the Marine Mammal Recording Forms Cover Page.

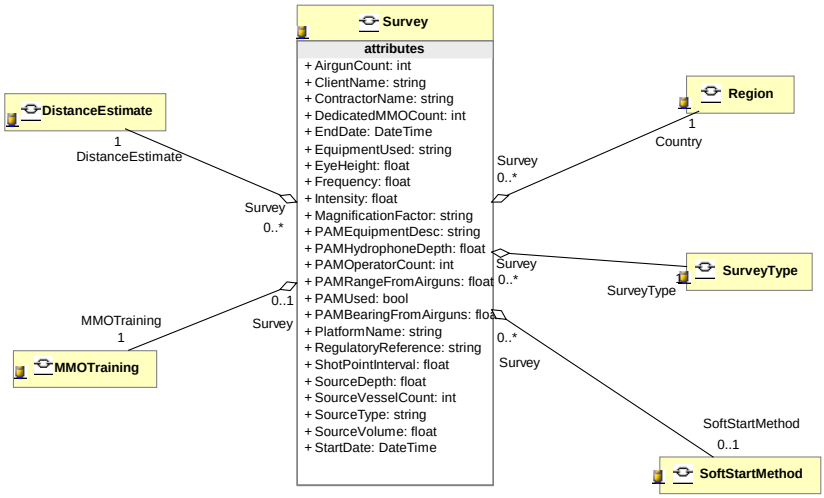

Figure 3 A Survey Object

Sightings

Each Sightings Object (Figure 4) represents the information gathered at each marine mammal sighting and stores the information recorded on the Sightings form. Each Survey may contain zero or more Sightings.

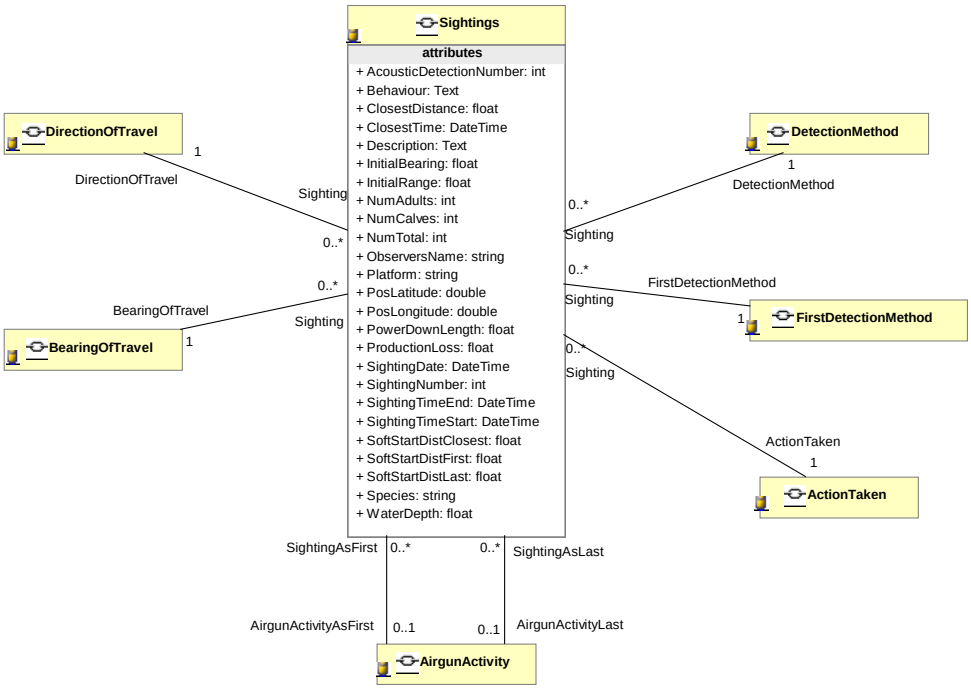

Figure 4 A Sightings Object

Effort

Each entry recorded on the Effort form is added as a new Effort Object (Figure 5). A Survey can contain zero or more of these records.

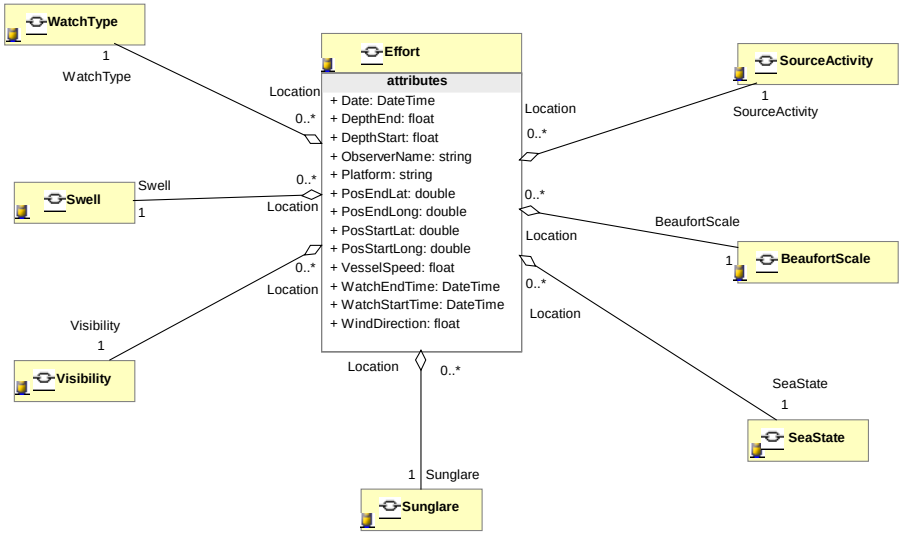

Figure 5 An Effort Object

Operations

An Operations Object (Figure 6) represents an entry in the Operations form. A Survey can contain zero or more Operation Objects.

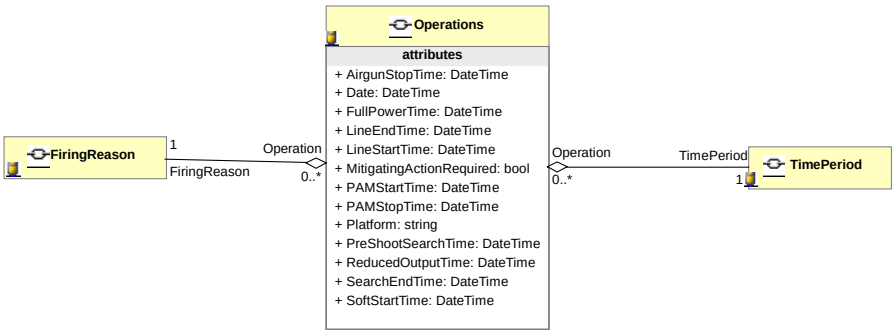

Figure 6 An Operations Object

The attributes of each Object will be one of the standard data types listed in Table 8 (based largely on c programming language definitions).

Table 8 Standard data types used for attributes

Data type	Description
Int	A 32 bit integer
Float	A 32 bit floating point number (real number)
Double	A 64 bit floating point number (real number) used when higher precision is required over standard Float.
Bool	A Boolean (on/off or True/False) value.
DateTime	A structure that can store Date and Time information to the nearest millisecond.
String	A character array of up to 255 characters
Text	A very large array of characters used to contain longer descriptions (essentially no limit)

Choices

Some attributes may not be simple data types as described above but may contain pointers to other objects. For example the WatchType attribute of the Effort Object allows for two values (v = visual watch, and p = PAM). These will be set up in the database with pre-populated objects of type WatchType, and the WatchType attribute of the Effort Object will point to an instance of one of these. Figure 7 gives an overview of the available Choice Objects.

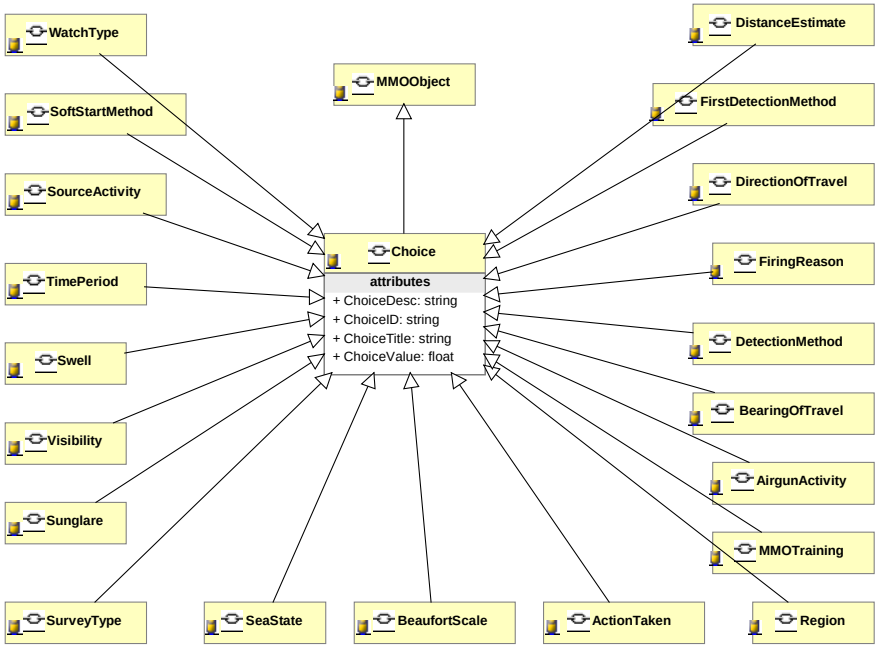

Figure 7 Choice definitions

Note that these choices will be read-only in the database. Once set up they will only be changeable by the system administrator. This ensures that all of the data are consistent and comparable.

Design of the web portal

An Application Functional Specification Document has been written to describe the design of a suitable web portal (Appendix 5). It describes in detail each form and page of the application together with a screen image annotated with notes. This document is accompanied by a prototype published on a website at http://www.rskorbital.com/mmason/MMO/. It is easier to read the Application Functional Specification Document in conjunction with using the prototype on the web.

The basic design of the web-based application is that of a portal that provides pages of information derived either directly from the MMO data, or indirectly through related research or reference information.

A huge advantage to a web-based approach is that it is accessible from anywhere and potentially by anyone (subject to authentication), with updates to the application and software being made at a single location but available to all.

This creates the possibility of replacing local copies of the database installed at the regulators' offices, with regulator-specific accounts whereby regulators may use their own sections of the web-based database to manage their own data. The database has been designed with this in mind.

The databases local to the regulators (Figure 1) can be replaced with user accounts on the central web-based system. When regulators upload information to the central application they may elect to make it private and not allow it to be accessed by other authenticated users. They themselves could then access it and treat it as their own database. If they choose to make the data public, it is simply a matter of changing its status to reflect this, and so there is no need to physically transfer the information to a central database thus overcoming the limitations of data transfer.

The data transfer actually takes place when the regulator uploads their data into their own account on the web application. It is during this phase of the data flow that the system checks for errors and inconsistencies within the data, so that only correct (or at least consistent) data are accepted into the system.

Being web-based, it is possible for anyone with web access to access the application. It is important therefore to limit such access to suitable information only.

It is proposed that, by default, all unauthenticated users may access the home page (first screen to be displayed), and a page that tells them about the database and who to contact for more information (the About page). In order for users to access more information they must obtain an account login. It is proposed that they use a form on a web page to submit their application, but that it is authorised by a system administrator who may decide to withhold permission to access the data.

The MMO data may contain sensitive information about the operators, contractors, operations, locations, and timings of survey activities. It is important therefore to protect this information from view to non-administrative users of the system. The proposed system does this by preventing certain fields of information being part of data queries and hence forming part of their output.

It may also be possible to strip out sensitive information from the database during the import process, or to replace names of operators etc. with pseudonyms. However, some of this information is essential if thorough and informed analyses are to be carried out. For example, even if a query is not concerned with where and when the animals occur, any potential bias due to temporal and spatial variation still needs to be taken into account for many questions that might be asked of the data.

What is needed therefore is a system that allows all of the relevant information to be available for viewing and query by selected, independent, individuals for their analyses efforts, but to be withheld from any organisation that could seek to get a competitive advantage from viewing such data. This is an issue that needs further debate and agreement.

9. Inclusion of UK MMO data in Joint Cetacean Protocol

In 2003 an atlas of cetacean distribution in north-west European waters was produced (Reid *et al.*, 2003), using data from the Joint Cetacean Database (JCD). The JCD was a product of collaboration between different organisations both within the UK and in Europe as a whole. The data sources used to compile the JCD were the European Seabirds at Sea (ESAS) database, the Sea Watch Foundation database and the 1994 Small Cetacean Abundance in the North Sea (SCANS) database. The ESAS database comprises seabird and marine mammal data from effort-related at-sea surveys conducted by JNCC and sister organisations in other European countries since 1979. Sea Watch Foundation has been collecting sightings data on marine mammals from UK and Irish waters since 1973 from opportunistic sightings and effort-related recording both from land and offshore. The EC-funded SCANS survey was co-ordinated by the Sea Mammal Research Unit and involved intensive line transect sampling throughout the North Sea, Skagerrak and Kattegat, the Western Baltic, the English Channel and the Celtic Sea. Data from these three sources were transformed into a common format consisting of sighting records and effort records.

A proposal to revise the JCD is being discussed between the UK and the Republic of Ireland. The aim is to establish by 2009 a new Joint Cetacean Protocol (JCP), a virtual, web-based solution that would demand little maintenance and would, if necessary, restrict access to data not properly in the public domain. The JCP is going to be a protocol for rendering different cetacean datasets comparable, rather than a database. The datasets will come from a variety of sources and, it is envisaged, will be available via a web-based portal. The JCP would play host to the data contained in those databases included in the JCD, updated where appropriate, as well as additional databases not included in the original JCD partnership, including data from the Irish Cetacean Database and SCANS II. The JCP also aims to host data from other European member states, some of which have already expressed interest through ASCOBANS. These individual datasets will continue to be maintained and controlled by the contributing providers (thus maintaining rights of access). A revised atlas would also ensue once the JCP is established.

As the JCP is going to be a protocol rather than a database, there is no structure available. However, prior to the JCD being formed and the atlas produced, a scoping report was written (Northridge, 1999) considering the data structure of the three datasets used, identifying common features and proposing a minimum data structure to be used (Table 9). A decision is yet to be made on which attributes should be selected to become the standard for the JCP, but the former proposal may provide an indication of the likely attributes.

Table 9 Former proposed minimum data structure for the JCD (from Northridge, 1999)

Effort Table	Sightings Table
Dataset origin	Database name
Observer/ team code	Observer/ team code
Date	Date
Leg or segment number	Leg
Time at start of leg	Sighting number in this leg
Time at end of leg	Time of sighting
Latitude at start of leg	Latitude and longitude
Longitude at start of leg	Species code
Latitude at end of leg	Number/ school size
Longitude at end of leg	Individual observer code
Beaufort sea state	Behaviour code
Field of view	Direction of movement
Number of observers	
Vessel code	

As with the Irish Cetacean Database, it is hoped that MMO data would be able to be included within the JCP. Incorporation of UK/ European MMO data into the JCP may enhance the JCP's coverage of some areas of European waters, and may lead to improved knowledge of the distribution of some species within these areas, especially those species found in relatively low numbers. Gaining further knowledge of the biology of marine mammals, e.g. distribution, migration, habitat usage, etc., is perhaps one area where the existing European MMO data are underused at the moment.

Incorporation of MMO data into the JCP would therefore increase the value of MMO data whilst at the same time enhancing the JCP. The revised recording forms have been designed with consideration of the potential for inclusion of MMO data within the JCP or similar protocols/ databases.

Informal discussions and correspondence with JNCC, a key partner in the JCP, have highlighted some of the issues involved in incorporating MMO data within the JCP. Due to the operational nature of the platforms used for collecting MMO data, there is potential for bias in the distribution or abundance of marine mammals observed from such platforms, therefore there would need to be some way of flagging these records or attaching a weighting. Similarly, source activity would need to be recorded in order to identify records where such bias may occur. The way that location is recorded in the existing JNCC Marine Mammal Recording Forms (Joint Nature Conservation Committee, 2007b) would hinder inclusion within the JCP as blocks transited are currently recorded rather than a precise position. To address these specific issues, the revised recording forms (section 7) include a start and end position of the watch in latitude and longitude, and separate watches according to source activity, enabling future data to be more compatible with the JCP.

10. Plan for future work

Any future phase of this project would include development of the initial database according to the design proposed. Agreements for the release of MMO data from the identified potential sources would be secured, and further sources investigated. The database would then be populated with appropriate data sets - this would probably involve considerable time and therefore resources to render different data sets compatible, and may involve manual entry of data in some cases. Some further development of the database may be required to support the importation of different formats. It is anticipated that due to the variety of recording methods currently and previously employed, some data sets may require much more effort (and therefore cost) than others to incorporate into the database; this may require decisions to be made on a case-by-case basis regarding the inclusion of each data set within the database, considering the cost: benefit ratio in each case. Once the Joint Cetacean Protocol is established, work to include UK (and possibly other European) MMO data within the protocol could proceed.

Once a populated MMO database is in existence appropriate analyses could then be performed to answer some of the identified key questions. It is envisaged that only some of the key questions would be addressed at this stage, selecting some of those seen as a priority, e.g. the effectiveness of mitigation measures such as the soft start. Depending on the analyses performed there may be a need for further refinement of the database. The results of such analyses, where appropriate, could be submitted for publication in a peer-reviewed journal. At the end of a future phase it is envisaged that a populated database would be available for any further analyses required, with the database capable of continual growth as incoming data recorded on the revised recording forms become available for importation.

A proposed estimated time scale for the various aspects of any future phase is shown in Table 10. It is envisaged that tasks A and B would run concurrently, bringing the total duration of a future phase to two years.

Table 10 Estimated time scale for future phase of the project

Task	Description of task	Duration
A	Development of the initial database	2 months*
B	Securing release of MMO data from identified sources + investigation of further sources of data	2 months*
C	Population of database with appropriate data sets + inclusion of UK MMO data within JCP	16 months
D	Perform analyses	4 months
E	Writing report + preparation of paper for peer-reviewed journal	2 months
Total duration		**2 years**

* these tasks would run concurrently

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12. References

Department of Conservation. 2006. *Guidelines for minimising acoustic disturbance to marine mammals from seismic survey operations*. Department of Conservation, Wellington, New Zealand. [Available at http://www.doc.govt.nz/upload/documents/conservation/native-animals/marine-mammals/marine-mammal-acoustic-disturbance-code.pdf]

Department of Fisheries and Oceans. 2007. *Statement of Canadian practice with respect to the mitigation of seismic sound in the marine environment*. [Available at http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismic-sismique/index_e.asp]

Department of the Environment and Heritage. 2006. *Whale and dolphin sighting report summary*. [Available at http://data.aad.gov.au/aadc/whales/Whale_and_Dolphin_sightings_report_summary_v2.xls]

Department of the Environment and Water Resources. 2007. *EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales*. [Available at http://www.environment.gov.au/epbc/publications/pubs/seismic-whales.pdf]

Department of the Environment, Heritage and Local Government. 2007. *Code of practice for the protection of marine mammals during acoustic seafloor surveys in Irish waters*. [Available at http://www.npws.ie/en/media/Media,5176,en.pdf]

Gailey, G., Würsig, B. and McDonald, T.L. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:75-91.

Gilders, M., Yetskalo, V., Johnson, S. and Yazvenko, S. 2007. *Marine mammal monitoring during exploratory drilling and seismic exploration near Sakhalin Island, Sea of Okhotsk, Russia, June-November 2006.* LGL Rep. EA1875-2, from LGL, Sidney, B.C., for Elvary Neftegaz JSC, Zapad-Shmidt Neftegaz JSC, and Vostok-Shmidt Neftegaz JSC, Yuzhno-Sakhalinsk, Russia, 133pp.

Goold, J.C. and Fish, P.J. 1998. Broadband spectra of seismic survey air-gun emissions, with reference to dolphin auditory thresholds. *J. Acoust. Soc. Am.* 103:2177-2184.

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2005a. *Guia de monitoramento da biota marinha em atividades de aquisição de dados sísmicos (Guide to monitoring the marine biota in activities of seismic data acquisition).* [Available at http://www.ibama.gov.br/licenciamento/modulos/arquivo.php?cod_arqweb=biota]

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2005b. *Projeto de Monitoramento da Biota Marinha*. [Available at http://www.ibama.gov.br/licenciamento/modulos/arquivo.php?cod_arqweb=planbiota]

Jacques Whitford Environment Ltd. 2002. *Canadian Superior Energy Inc. environmental observations during and post-drilling of exploration well Marquis L-35.*

Joint Nature Conservation Committee. 2004. *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys.* [Available at http://www.jncc.gov.uk/pdf/Seismic_survey_guidelines_200404.pdf]

Joint Nature Conservation Committee. 2007a. *Marine mammal recording form - record of operations*. [Available at http://www.jncc.gov.uk/docs/Record_of_Operations_240507.xls]

Joint Nature Conservation Committee. 2007b. *Marine mammal recording form - location and effort data*. [Available at http://www.jncc.gov.uk/docs/Location_and_Effort_230507.xls]

Joint Nature Conservation Committee. 2007c. *Marine mammal recording form - record of sighting*. [Available at http://www.jncc.gov.uk/docs/Record_of_Sighting_230507.xls]

Joint Nature Conservation Committee. 2008a. *Statutory nature conservation agency protocol for mitigation of wind farm piling noise at sea – March 2008.* [Available at http://www.jncc.gov.uk/pdf/consultation_epsAnnexA.pdf]

Joint Nature Conservation Committee. 2008b. *JNCC guidelines for minimising acoustic disturbance to marine mammals when using explosives - March 2008*. [Available at http://www.jncc.gov.uk/pdf/consultation%20_epsAnnexB.pdf]

Kastalein, R. and Wartzok, D. 2004. *Prioritizing information needs for risk assessment and mitigation strategies. In:* MMC/ JNCC International Policy Workshop on Sound and Marine Mammals, London, 28-30 September 2004. [Available at http://www.mmc.gov/sound/internationalwrkshp/pdf/smallgroup1d.pdf]

LGL Limited. 2004. *Marine mammal monitoring of Marathon Canada Petroleum's #D seismic program on the Scotian Slope, 2003.*

Meier, S.K., Lawson, J., Yazvenko, S.B., Perlov, A., Maminov, M., Johnson, S.R., Yakovlev, Y., Newcomer, M., Wainwright, P., Moroz, I., Aschepkov, A., Piskunov, I. and Propp, M. 2002. *Vessel-based marine mammal monitoring during the 2001 3-D seismic survey of the Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia.* Report by LGL Limited Environmental Research Associates, Sidney, BC, for Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia, 38pp. + appendices.

Meier, S.K., Yazvenko, S.B., Blokhin, S.A., Wainwright, P., Maminov, M.K., Yakovlev, Y.M. and Newcomer, M.W. 2007. Distribution and abundance of western gray whales off northeastern Sakhalin Island, Russia, 2001–2003. *Environ. Monit. Assess.* 134:107-136.

Minerals Management Service. 2007. *Notice to lessees and operators (NTL) of federal oil, gas, and sulphur leases in the outer continental shelf, Gulf of Mexico OCS region: implementation of seismic survey mitigation measures and protected species observer program.* [Available at http://www.gomr.mms.gov/homepg/regulate/regs/ntls/2007NTLs/07-g02.pdf]

Moulton, V.D., Mactavish, B.D. and Buchanan, R.A. 2005. *Marine mammal and seabird monitoring of Chevron Canada Resources' 3-D seismic program on the Orphan Basin, 2004.* LGL Rep. SA817, report by LGL Limited, St. John's, NL, for Chevron Canada Resources, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB, 90pp. + appendices.

Moulton, V.D., Mactavish, B.D., Harris, R.E. and Buchanan, R.A. 2006. *Marine mammal and seabird monitoring of Chevron Canada Limited's 3-D seismic program on the Orphan Basin, 2005.* LGL Rep. SA843, report by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB, 109pp. + appendices.

National Research Council. 2000. *Marine mammals and low-frequency sound: progress since 1994*. National Academies Press, Washington, DC, 160pp.

National Research Council. 2003. *Ocean noise and marine mammals.* National Academies Press, Washington, DC, 204pp.

National Research Council. 2005. *Marine mammal populations and ocean noise: determining when noise causes biologically significant effects.* National Academies Press, Washington, DC, 142pp.

Nieukirk, S.L., Stafford, K.M., Mellinger, D.K., Dziak, R.P. and Fox, C.G. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. *J. Acoust. Soc. Am.* 115:1832-1843.

Northridge, S. 1999. *Technical evaluation of building a cetacean distribution database.* Final report to Seabirds and Cetaceans Branch of the JNCC, Project XGL:J01, University of St. Andrews, 23pp.

Reid, J.B., Evans, P.G.H. and Northridge, S.P. 2003. *Atlas of cetacean distribution in north-west European waters.* JNCC, Peterborough, 76pp.

Stone, C.J. 1997. Cetacean observations during seismic surveys in 1996. *JNCC Report,* No. 228. [Available at http://www.jncc.gov.uk/pdf/cetaceous observations 1996.pdf]

Stone, C.J. 1998. Cetacean observations during seismic surveys in 1997. *JNCC Report,* No. 278. [Available at http://www.jncc.gov.uk/pdf/jncc278.pdf]

Stone, C.J. 2000. Cetacean observations during seismic surveys in 1998. *JNCC Report,* No. 301. [Available at http://www.jncc.gov.uk/pdf/jncc301.pdf]

Stone, C.J. 2001. Marine mammal observations during seismic surveys in 1999. *JNCC Report*, No. 316. [Available at http://www.jncc.gov.uk/pdf/jncc316.pdf]

Stone, C.J. 2003a. Marine mammal observations during seismic surveys in 2000. *JNCC Report,* No. 322. [Available at http://www.jncc.gov.uk/pdf/jncc322.pdf]

Stone, C.J. 2003b. The effects of seismic activity on marine mammals in UK waters, 1998-2000. *JNCC Report*, No. 323. [Available at http://www.jncc.gov.uk/pdf/jncc323.pdf]

Stone, C.J. 2008 (in press). Marine mammal observations during seismic surveys in 2001 and 2002. *JNCC Report,* No. 359.

Stone, C.J. and Tasker, M.L. 2006. The effects of seismic airguns on cetaceans in UK waters. *J. Cetacean Res. Manag.* 8(3):255-263.

Weir, C.R. 2006a. First confirmed records of Clymene dolphin *Stenella clymene* (Gray, 1850) from Angola and Congo, South-east Atlantic Ocean. *African Zoology* 41(2):297-300. [Available at http://www.ketosecology.co.uk/WEIR [Clymene dolphins in Angola].pdf]

Weir, C.R. 2006b. Sightings of beaked whales (Cetacea: Ziphiidae) including first confirmed Cuvier's beaked whales *Ziphius cavirostris* from Angola. *African Journal of Marine Science* 28(1):173-175. [Available at http://www.ketosecology.co.uk/Weir 2006 [Beaked whales in Angola].pdf]

Weir, C.R. 2006c. *The temporal and spatial distribution of marine mammals, turtles and other marine fauna off northern Angola, September 2003 – March 2006.* Report by Ketos Ecology for BP (Angola) Exploration Ltd., May 2006, 157pp.

Weir, C.R. 2007. Observations of marine turtles in relation to seismic airgun sound off Angola. *Marine Turtle Newsletter* 116:17-20. [Available at http://www.ketosecology.co.uk/Weir 2007 [Turtles and seismic].pdf]

Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. *Aquatic Mammals* 34(1):71-83. [Available at http://www.ketosecology.co.uk/Weir 2008_seismic paper.pdf]

Yazvenko, S.B., McDonald, T.L., Blokhin, S.A., Johnson, S.R., Meier, S.K., Melton, H.R., Newcomer, M.W., Nielson, R.M., Vladimirov, V.L. and Wainwright, P.W. 2007a.

Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:45-73.

Yazvenko, S.B., McDonald, T.L., Blokhin, S.A., Johnson, S.R., Melton, H.R., Newcomer, M.W., Nielson, R. and Wainwright, P.W. 2007b. Feeding of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:93-106.

13. Bibliography

Aguilar Soto, N., Johnson, M., Madsen, P.T., Tyack, P.T., Bocconcelli, A. and Borsani, J.F. 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? *Mar. Mamm. Sci.* 22:690–699.

Andre, M., Kamminga, C. and Ketten, D. 1997. Are low-frequency sounds a marine hazard: a case study in the Canary Islands. *In: Proceedings of the Underwater Bio-Sonar Systems and Bioacoustics Symposium, Loughborough University, Leicestershire, UK, 16–17 December 1997, Institute of Acoustics, Hertfordshire, UK.*

Arnold, B.W. 1996. *Visual monitoring of marine mammal activity during the Exxon 3-D seismic survey, Santa Ynez Unit, offshore California, 9 November to 12 December 1995.* Report from Impact Sciences Inc., San Diego, CA, for Exxon Co. U.S.A., Thousand Oaks, CA. 25pp.

Au, W.W.L., Nachtigall, P.E. and Pawloski, J.L. 1997. Acoustic effects of the ATOC signal (75Hz, 195 dB) on dolphins and whales. *J. Acoust. Soc. Am.* 101(5):2973-2977.

Awbrey, F.T., Thomas, J.A. and Kastelein, R.A. 1988. Low frequency underwater hearing sensitivity in belugas, *Delphinapterus leucas*. *J. Acoust. Soc. Am.* 84(6):2273-2275.

Bain, D.E. and Dalheim, M.E. 1994. Effects of masking noise on detection thresholds of marine mammals. In: Laughlin, T.R. (ed.), *Marine Mammals and the Exxon Valdez*, Academic, New York, pp. 243-256.

Balcomb, K.C., III and Claridge, D.E. 2001. A mass stranding of cetaceans caused by naval sonar in the Bahamas. *Bahamas J. Sci.* 8(2):2-12.

Barlow, J. 2004. Mitigating the potentially harmful effects of sound on marine mammals. *In: MMC/ JNCC International Policy Workshop on Sound and Marine Mammals, London, 28-30 September 2004.* [Available at http://www.mmc.gov/sound/internationalwrkshp/internationalwrkshp.html]

Barlow, J. and Gisiner, R. 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. *J. Cetacean Res. Manag.* 7:239–249.

Barlow, J. and Richardson, J. 2004. Evaluating effectiveness of mitigation. *In: MMC/ JNCC International Policy Workshop on Sound and Marine Mammals, London, 28-30 September 2004.* [Available at http://www.mmc.gov/sound/internationalwrkshp/internationalwrkshp.html]

Barton, C.J.S. 2003. *MMO guidance document: standards for MMOs, MMO instructors and MMO training courses.* Report to Joint Nature Conservation Committee, 24pp.

Barton, C.J.S. 2005. *Review/ audit of marine mammal observer programme.* Report to Sakhalin Energy Investment Company Limited, 54pp.

Bejder, L., Samuels, A., Whitehead, H. and Gales, N. 2006*a*. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Anim. Behav.* 72:1149–1158.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J. and Flaherty, C. 2006*b*. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conserv. Biol.* 20:1791–1798.

Biassoni, N., Miller, P.J.O. and Tyack, P.L. 2001. Humpback whales, *Megaptera novaeangliae*, alter their song to compensate for man-made noise. *In: 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada.*

Blokhin, S.A., Doroshenko, N.V. and Marchenko, I.P. 2003. The abundance, distribution and movement patterns of gray whales (*Eschrichtius robustus*) in coastal waters off the northeast Sakhalin Island coast in 2002 based on the aerial survey data. *Report on the Research Project, Russian Federation State Committee on Fisheries, Federal Unitarian Enterprise TINRO-Center,* 67pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2002_aerial.pdf]

Blokhin, S.A., Doroshenko, N.V. and Yazvenko, S.V. 2004. Distribution, abundance and movement patterns of western gray whales (*Eschrichtius robustus*) off the coast of northeastern Sakhalin Island in June-December 2003 based on aerial survey data. *Research Program Annual Report, State Fisheries Committee Russian Federation, Federal State Unitary Enterprise Pacific Research Institute of Fishery and Oceanography (FGUP TINRO-Center),* 151pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2003_aerial.pdf]

Blokhin, S.A., Vladimirov, V.L., Doroshenko, N.V., Maminov, M.K. and Perlov, A.S. 2003. Abundance, distribution and behavior of gray whales (*Eschrichtius robustus*) offshore north-eastern Sakhalin in 2002. *Study Report, Russian Federation Fisheries Committee, Federal National Unitary Enterprise Pacific Research Fisheries Centre (TINRO-Center),* 11pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2002_study.pdf]

Borggaard, D., Lien, J. and Stevick, P. 1999. Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). *Aquatic Mammals* 25:149-161.

Bowles, A.E., Smultea, M., Würsig, B., DeMaster, D.P. and Palka, D. 1994. Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island feasibility test. *J. Acoust. Soc. Am.* 96(4):2469-2484.

Bowles, A. and Stewart, B.S. 1980. Disturbances to the pinnipeds and birds of San Miguel Island, 1979-1980. *In:* Jehl, J.R. Jr. and Cooper, C.F. (eds.), *Potential effects of space*

shuttle sonic booms on the biota and geology of the California Channel Islands: Research Report. Tech. Rep 80-1. Report from the Center for Maritime Studies, San Diego State University and the Hubbs/Sea World Research Institute, San Diego, CA for U. S. Air Force, Space Division, pp.99-137.

Bryant, P.J., Lafferty, C.M. and Lafferty, S.K. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. *In:* Jones, M.L. *et al.* (eds.), *The Gray Whale, Eschrichtius robustus*, Academic Press, Orlando, Florida, pp.375-387.

Burgess, W.C. and Greene, C.R. Jr. 1999. Physical acoustics measurements. *In*: Richardson, W.J. (ed.) 1998. *Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998.* LGL Rep. TA22303. Rep. from LGL, King City, Ont., and Greene-ridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD., pp.3-1 - 3-63.

Calambokidis, J., Chandler, T.E., Costa, D.P., Clark, C.W. and Whitehead, H. 1998. Effects of the ATOC sound source on the distribution of marine mammals observed from aerial surveys off central California. *In: The World Marine Mammal Science Conference, Monaco, 20-24 January 1998, Society for Marine Mammalogy and the European Cetacean Society, Centre de Recherche sur les Mammifères Marins, La Rochelle, France*.

Calambokidis, J., Schlender, L. and Quan, J. 1998. *Marine mammal observations and mitigation associated with USGS surveys in the southern California Bight in 1998.* Report from Cascadia Research, Olympia, WA, for U.S. Geological Survey, Menlo Park, CA. 14pp.

Castellote, M. 2007. General Review of Protocols and Guidelines for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Surveys. *J. Int. Wildl. Law Policy* 10(3-4):273-288.

Compton, R., Goodwin, L., Handy, R. and Abbott, V. 2008. A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys. *Marine Policy* 32(3):255-262.

Costa, D.P., Crocker, D.E., Gedamke, J., Webb, P.M., Houser, D.S., Blackwell, S.B., Waples, D., Hayes, S.A. and Le Boeuf, B.J. 2003. The effect of a low-frequency sound source (ATOC) on the diving behavior of juvenile northern elephant seals. *J. Acoust. Soc. Am.* 113:1155-1165.

Cox, T.M., Ragen, T.J., Read, A.J., Vos, E., Baird, R.W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., Crum, L., D'Amico, A., D'Spain, G., Fernández, A., Finneran, J., Gentry, R., Gerth, W., Gulland, F., Hildebrand, J., Houser, D., Hullar, T., Jepson, P.D., Ketten, D., MacLeod, C.D., Miller, P., Moore, S., Mountain, D., Palka, D., Ponganis, P., Rommel, S., Rowles, T., Taylor, B., Tyack, P., Wartzok, D., Gisiner, R., Mead, J. and

Benner, L. 2006. Understanding the impacts of anthropogenic sound on beaked whales. *J. Cetacean Res. Manag.* 7:177–187.

Croll, D.A., Clark, C.W., Calambokidis, J., Ellison, W.T. and Tershy, B.R. 2001. Effect of anthropogenic low-frequency noise on the foraging ecology of *Balaenoptera* whales. *Anim. Conserv.* 4:13–27.

Crum, L.A., Bailey, M.R., Guan, J., Hilmo, P.R., Kargl, S.G., Matula, T.J. and Sapozhnikov, O.A. 2005. Monitoring bubble growth in supersaturated blood and tissue *ex vivo* and the relevance to marine mammal bioeffects. *Acoustic Research Letters Online* 6(3):214-220.

Crum, L.A. and 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.

Crum, L.A. and Mao, Y. 1996. Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. *J. Acoust. Soc. Am.* 99:2898-2907.

Cummings, J. 2007. Regulating ocean noise: entering uncharted waters. *J. Int. Wildl. Law Policy* 10(2):101-107.

David, J.A. 2006. Likely sensitivity of bottlenose dolphins to pile driving noise. *Water and Environment Journal* 20:48-54.

Deffenbaugh, M. 2002. Mitigating seismic impact on marine life: current practice and future technology. *Bioacoustics* 12:316–318.

Department of Conservation. 2006. *Reference Document: Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys.* Department of Conservation, Wellington, New Zealand.

Department of Conservation. 2006. *Guidelines for minimising acoustic disturbance to marine mammals from seismic survey operations*. Department of Conservation, Wellington, New Zealand. [Available at http://www.doc.govt.nz/upload/documents/conservation/native-animals/marine-mammals/marine-mammal-acoustic-disturbance-code.pdf]

Department of Fisheries and Oceans. 2003. *A framework to assist DFO consideration of requests for review of seismic testing proposals.* DFO Can. Sci. Advis. Sec. Habitat Status Report 2003/001.

Department of Fisheries and Oceans. 2004. *Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals.* DFO

Can. Sci. Advis. Sec. Habitat Status Report 2004/002. [Available at http://www.dfo-mpo.gc.ca/csas/Csas/status/2004/HSR2004_002_E.pdf]

Department of Fisheries and Oceans. 2007. *Statement of Canadian practice with respect to the mitigation of seismic sound in the marine environment*. [Available at http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismic-sismique/statement-enonce_e.asp]

Department of the Environment and Heritage. 2006. *Whale and dolphin sighting report summary*. [Available at http://data.aad.gov.au/aadc/whales/Whale_and_Dolphin_sightings_report_summary_v2.xls]

Department of the Environment and Water Resources. 2007. *EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales*. [Available at http://www.environment.gov.au/epbc/publications/pubs/seismic-whales.pdf]

Department of the Environment and Water Resources. 2007. *Background paper to EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales*. [Available at http://www.environment.gov.au/epbc/publications/pubs/seismic-whales-background.pdf]

Department of the Environment, Heritage and Local Government. 2007. *Code of practice for the protection of marine mammals during acoustic seafloor surveys in Irish waters*. [Available at http://www.npws.ie/en/media/Media,5176,en.pdf]

Dolman, S.J. 2007. Spatio-temporal restrictions as best practice precautionary response to ocean noise. *J. Int. Wildl. Law Policy* 10(3-4):219-224.

Dolman, S. J., Parsons, E.C.M. and Simmonds, M.P. 2002. Noise sources in the cetacean environment. *Paper SC/54/E7 Presented to the Scientific Committee of the International Whaling Commission, Shimonoseki, Japan*.

Dolman, S.J. and Simmonds, M.P. 2005. Noise pollution - some thoughts on mitigation and wider protection. *Paper SC/57/E9 presented to the Scientific Committee of the International Whaling Commission, Ulsan, Korea,* 6pp.

Dolman, S.J. and Simmonds, M.P. 2006. An updated note on the vulnerability of cetaceans to acoustic disturbance. *Paper SC/58/E22 presented to the Scientific Committee of the International Whaling Commission, St Kitts and Nevis, WI,* 11pp.

Dotinga, H.M. and Oude Elferink, A.G. 2000. Acoustic pollution in the oceans: the search for legal standards. *Ocean Development and International Law* 31:151-182.

Ellison, W.T., Weixel, K.S. and Clark, C.W. 1993. Variation in received level from man-made low-frequency underwater noise sources as a function of diving animal depth. *J. Acoust. Soc. Am.* 94(3):1850.

Engås, A., Løkkeborg, S., Ona, E. and Soldal, A.V. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). *Canadian Journal of Fisheries and Aquatic Science* 53:2238-2249.

Engel, M.H., Marcondes, M.C.C., Martins, C.C.A., O'Luna, F., Lima, R.P. and Campos, A. 2004. Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult humpback whales in Abrolhos Bank, northeastern coast of Brazil. *Paper SC/56/E28 Presented to the Scientific Committee of the International Whaling Commission, Sorrento, Italy,* 8pp.

Erbe, C. and Farmer, D.M. 2000a. A software model to estimate zones of impact on marine mammals around anthropogenic noise. *J. Acoust. Soc. Am.* 108:1327-1331.

Erbe, C. and Farmer, D.M. 2000b. Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. *J. Acoust. Soc. Am.* 108:1332-1340.

Evans, P.G.H. and Miller, L.A. (eds.). 2004. Proceedings of the Workshop on Active Sonar and Cetaceans, Las Palmas, Gran Canaria, 8 March 2003. *European Cetacean Society Newsletter* No. 42, Special Issue.

Evans, P.G.H. and Nice, H. 1996. *Review of the effects of underwater sound generated by seismic surveys on cetaceans.* Report to UKOOA, Oxford, Sea Watch Foundation.

Fernández, A., Arbelo, M., Deaville, R., Patterson, I.A.P., Castro, P., Baker, J.R., Degollada, E., Ross, H.M., Herráez, P., Pocknell, A.M., Rodríguez, F., Howie, F.E., Espinosa, A., Reid, R.J., Jaber, J.R., Martin, D.W., Cunningham, A.A. and Jepson, P.D. 2004. Whales, sonar and decompression sickness - Reply. *Nature (Lond.)* 428(6984):1–2.

Fernández, A., Edwards, J.F., Rodriquez, F., de los Monteros, A.E., Herráez, P., Castro, P., Jaber, J.R., Martin, V. and Arbelo, M. 2005. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family Ziphiidae) exposed to anthropogenic sonar signals. *Vet. Pathol.* 42(4):446-457.

Findley, K.J., Miller, G.W., Davis, R.A. and Greene, C.R. 1990. Reactions of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, to ice-breaking ships in the Canadian high Arctic. *Canadian Journal of Fisheries and Aquatic Sciences* 224:97-117.

Finneran, J.J. 2003. Whole-lung resonance in a bottlenose dolphin (*Tursiops truncatus*) and a white whale (*Delphinapterus leucas*). *J. Acoust. Soc. Am.* 114:529-535.

Finneran, J.J., Carder, D.A., Schlundt, C.E. and Ridgway, S.H. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. *J. Acoust. Soc. Am.* 118(4):2696–2705.

Finneran, J.J., Dear, R., Carder, D.A. and Ridgway, S.H. 2003. Auditory and behavioral responses of California sea lions (*Zalophus californianus*) to single underwater impulses from an arc-gap transducer. *J. Acoust. Soc. Am.* 114:1667-1677.

Finneran, J.J., Schlundt, C.E., Carder, D.A., Clark, J.A., Young, J.A., Gaspin, J.B. and Ridgway, S.H. 2000. Auditory and behavioral responses of bottlenose dolphins *Tursiops truncatus* and a beluga whale *Delphinapterus leucas* to impulsive sounds resembling distant signatures of underwater explosions. *J. Acoust. Soc. Am.* 108:417–431.

Finneran, J.J., Schlundt, C.E., Dear, R., Carder, D.A. and Ridgway, S.H. 2000. Masked temporary threshold shift (MTTS) in odontocetes after exposure to single underwater impulses from a seismic watergun. *J. Acoust. Soc. Am.* 108:2515.

Finneran, J.J., Schlundt, C.E., Dear, R., Carder, D.A. and Ridgway, S.H. 2002. Temporary shift in masked hearing thresholds MTTS in odontocetes after exposure to single underwater impulses from a seismic watergun. *J. Acoust. Soc. Am.* 111(6):2929–2940.

Firestone, J. and Jarvis, C. 2007. Response and responsibility: regulating noise pollution in the marine environment. *J. Int. Wildl. Law Policy* 10(2):109-152.

Frankel, A.S. and Clark, C.W. 2000. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. *J. Acoust. Soc. Am.* 108:1930–1937.

Frankel, A.S. and Clark, C.W. 2002. ATOC and other factors affecting the distribution and abundance of humpback whales off the north shore of Kauai. *Mar. Mamm. Sci.* 18:644-662.

Frantzis, A. 1998. Does acoustic testing strand whales? *Nature (Lond.)* 392(6671):29.

Frantzis, A. and Cebrian, D. 1999. A rare mass stranding of Cuvier's beaked whales: cause and implications for the species biology. *European Research on Cetaceans* 12: 332-335.

Freitas, L. 2004. The stranding of three Cuvier's beaked whales *Ziphius cavirostris* in Madeira archipelago. *In:* Evans, P.G.H. and Miller, L.A. (eds.), Proceedings of the Workshop on Active Sonar and Cetaceans, Las Palmas, Gran Canaria, 8 March 2003. *European Cetacean Society Newsletter* No. 42, Special Issue. pp.28–32.

Fristrup, K.M., Hatch, L.T. and Clark, C.W. 2003. Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts. *J. Acoust. Soc. Am.* 113:3411-3424.

Gailey, G., Sychenko, O. and Würsig, B. 2004. Western gray whale behavior and movement patterns: shore-based observations off Sakhalin Island, July-September 2003. *Report to Sakhalin Energy Investment Company Ltd.,* 74pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2003_behavior.pdf]

Gailey, G., Würsig, B. and McDonald, T.L. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:75-91.

Gentry, R. (ed.). 2002. *Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans, Silver Spring, MD, April 2002.* National Marine Fisheries Service 19pp. [Available at http://www.nmfs.noaa.gov/pr/pdfs/acoustics/cetaceans.pdf]

Gilders, M., Yetskalo, V., Johnson, S. and Yazvenko, S. 2007. *Marine mammal monitoring during exploratory drilling and seismic exploration near Sakhalin Island, Sea of Okhotsk, Russia, June-November 2006.* LGL Rep. EA1875-2, from LGL, Sidney, B.C., for Elvary Neftegaz JSC, Zapad-Shmidt Neftegaz JSC, and Vostok-Shmidt Neftegaz JSC, Yuzhno-Sakhalinsk, Russia, 133pp.

Gill, J.A., Norris, K. and Sutherland, W.J. 2001. Why behavioural responses may not reflect the population consequences of human disturbance. *Biol. Conserv.* 97:265–268.

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.

Goold, J.C. 1996. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying. *J. Mar. Biol. Ass. UK* 76(3):811-820.

Goold, J.C. and Coates, R.F.W. 2006. Near source, high frequency air-gun signatures. *Paper SC/58/E30 presented to the Scientific Committee of the International Whaling Commission, St Kitts and Nevis, WI,* 7pp.

Goold, J.C. and Fish, P.J. 1998. Broadband spectra of seismic survey air-gun emissions, with reference to dolphin auditory thresholds. *J. Acoust. Soc. Am.* 103(4):2177-2184.

Gordon, J.C.D., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M. and Swift, R. 1998. The effects of seismic surveys on marine mammals. *In:* Tasker, M.L. and Weir, C.R. (eds.), *Proceedings of the Seismic and Marine Mammals Workshop, London, 23–25 June 1998.*

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M., Swift, R. and Thompson, D. 2004. The effects of seismic surveys on marine mammals. *Mar. Technol. Soc. J.* 37(4):16-34.

Gordon, J. and Moscrop, A. 1996. Underwater noise pollution and its significance for whales and dolphins. *In:* Simmonds, M.P. and Hutchinson. J.D. (eds.) *The Conservation of Whales and Dolphins*, Wiley and Sons, New York, pp.281-319.

Green, D.M., DeFerrari, H.A., McFadden, D., Pearse, J.S., Popper, A.N., Richardson, W.J., Ridgway, S.H. and Tyack, P.L. 1994. *Low Frequency Sound and Marine Mammals: Current Knowledge and Research Needs.* National Academy Press, Washington, DC.

Greene, C.R. Jr., Altman, N.S. and Richardson, W.J. 1999. The influence of seismic survey sounds on bowhead whale calling rates. *J. Acoust. Soc. Am.* 106:2280.

Greene, C.R. Jr., Norman, R., Hanna, J.S. and Blaylock, R.W. 1998. Physical acoustics measurements. *In*: Richardson, W.J. (ed.) 1998. *Marine mammal and acoustical monitoring of BP Exploration (Alaska)'s open-water seismic program in the Alaskan Beaufort Sea, 1997.* LGL Rep. TA2150-3. Rep. from LGL, King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. pp.3-1 - 3-64.

Greene, C.R. Jr. and Richardson, W.J. 1988. Characteristics of marine seismic survey sounds in the Beaufort Sea. *J. Acoust. Soc. Am.* 83(6):2246-2254.

Gulland, J.A. and Walker, C.D.T. 1998. Marine seismic overview. *In:* Tasker, M.L. and Weir, C.R. (eds.), *Proceedings of the Seismic and Marine Mammals Workshop, London, 23–25 June 1998.*

Haren, A.M. 2007. Reducing noise pollution from commercial shipping in the Channel Islands National Marine Sanctuary: a case study in Marine Protected Area management of underwater noise. *J. Int. Wildl. Law Policy* 10(2):153-173.

Harris, R.E., Miller, G.W. and Richardson, W.J. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. *Marine Mammal Science* 17(4):795-812.

Heinemann, D. 1981. A range finder for pelagic bird censusing. *Journal of Wildlife Management* 45(2):489-493

High Energy Seismic Survey. 1999. *Review process and interim operational guidelines for marine surveys offshore southern California*. Report from the High Energy Seismic Survey team for the California State Lands Commission and the US Minerals Management Service Pacific Outer Continental Shelf Region, California.

Hildebrand, J. 2004. Impacts of anthropogenic sound on cetaceans. *Paper SC/56/E13 Presented to the Scientific Committee of the International Whaling Commission, Sorrento, Italy,* 30pp.

Hildebrand, J.A. 2005. Impacts of anthropogenic sound. *In:* Reynolds, J.E. III, Perrin, W.F., Reeves, R.R., Montgomery, S. and Ragen, T.J. (eds.) *Marine mammal research: conservation beyond crisis.* Johns Hopkins University Press, Baltimore, Md., pp.101-124.

Horowitz, C. and Jasny, M. 2007. Precautionary management of noise: lessons from the U.S. Marine Mammal Protection Act. *J. Int. Wildl. Law Policy* 10(3-4):225-232.

Houser, D.S., Howard, R. and Ridgway, S. 2001. Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals? *J. Theor. Biol.* 213:183-195.

Independent Scientific Review Panel. 2005. Impacts of Sakhalin II Phase 2 on western north Pacific gray whales and related biodiversity. *Report of the Independent Scientific Review Panel,* 131pp. [Available at http://www.iucn.org/dbtw-wpd/edocs/2005-005.pdf]

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2005a. *Guia de monitoramento da biota marinha em atividades de aquisição de dados sísmicos (Guide to monitoring the marine biota in activities of seismic data acquisition).* [Available at http://www.ibama.gov.br/licenciamento/modulos/arquivo.php?cod_arqweb=biota]

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2005b. *Projeto de Monitoramento da Biota Marinha*. [Available at http://www.ibama.gov.br/licenciamento/modulos/arquivo.php?cod_arqweb=planbiota]

Inter-Agency Committee on Marine Science and Technology. 2006. *Report of the IACMST working group on underwater sound and marine life.* IACMST Working Group Report No. 6, 19pp.

International Association of Geophysical Contractors. 2006. *Statement of Principles: Marine Mammal Protection*. [Available at http://www.iagc.org/iagcwebdata/public/sops/IAGC_SOP_2F_marine mammal protection_rd02_2006_01.pdf]

International Council for the Exploration of the Sea. 2005. Report of the ad-hoc group on the impact of sonar on cetaceans and fish (AGISC). *ICES C.M. 2005/ACE:01.*

International Union for Conservation of Nature. 2006. Report of the interim independent scientists group (IISG) on mitigation measures to protect western gray whales during

Sakhalin II construction operations in 2006. *Workshop convened by the IUCN, Vancouver, British Columbia, 3-5 April 2006.*

Jacques Whitford Environment Ltd. 2002. *Canadian Superior Energy Inc. Environmental Observations during and post-drilling of Exploration Well Marquis L-35.*

Jasny, M., Reynolds, J., Horowitz, C. and Wetzler, A. 2005. Sounding the depths II: the rising toll of sonar, shipping and industrial ocean noise on marine life. Natural Resources Defense Council, November 2005. [Available at http://www.nrdc.org/wildlife/marine/sound/sound.pdf]

Jepson, P.D., Arbelo, M., Deaville, R., Patterson, I.A.P., Castro, P., Baker, J.R., Degollada, E., Ross, H.M., Herráez, P., Pocknell, A.M., Rodríguez, F., Howie, F.E., Espinosa, A., Reid, R.J., Jaber, J.R., Martin, V., Cunningham, A.A. and Fernández, A. 2003. Gas-bubble lesions in stranded cetaceans. *Nature (Lond.)* 425(6958):575-576.

Jepson, P.D., Deaville, R., Patterson, I.A.P., Pocknell, A.M., Ross, H.M., Baker, J.R., Howie, F.E., Reid, R.J., Colloff, A. and Cunningham, A.A. 2005. Acute and chronic gas bubble lesions in cetaceans stranded in the United Kingdom. *Vet. Pathol.* 42:291–305.

Jochens, A.E. and Biggs, D.C. (eds.). 2003. *Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1.* U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 pp.

Jochens, A., Biggs, D., Engelhaupt, D., Gordon, J., Jaquet, N., Johnson, M., Leben, R., Mate, B., Miller, P., Ortega-Ortiz, J., Thode, A., Tyack, P., Wormuth, J. and Würsig, B. 2006. *Sperm whale seismic study in the Gulf of Mexico; summary report, 2002-2004.* U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-034. 352 pp. [Available at http://www.gomr.mms.gov/homepg/regulate/environ/studies/2006/2006-034.pdf]

Johnson, M., Tyack, P., Nowacek, D. and Shorter, A. 2000. A digital acoustic recording tag for measuring the response of marine mammals to sound. *J. Acoust. Soc. Am.* 108(5):2582-2583.

Johnson, S.R., Richardson, W.J., Yazvenko, S.B., Blokhin, S.A., Gailey, G., Jenkerson, M.R., Meier, S.K., Melton, H.R., Newcomer, M.W., Perlov, A.S., Rutenko, S.A., Würsig, B., Martin, C.R. and Egging, D.E. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:1-19.

Joint Nature Conservation Committee. 2004. *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys.* [Available at http://www.jncc.gov.uk/pdf/Seismic_survey_guidelines_200404.pdf].

Joint Nature Conservation Committee. 2007a. *Marine mammal recording form - record of operations*. [Available at http://www.jncc.gov.uk/docs/Record_of_Operations_240507.xls]

Joint Nature Conservation Committee. 2007b. *Marine mammal recording form - location and effort data*. [Available at http://www.jncc.gov.uk/docs/Location_and_Effort_230507.xls]

Joint Nature Conservation Committee. 2007c. *Marine mammal recording form - record of sighting*. [Available at http://www.jncc.gov.uk/docs/Record_of_Sighting_230507.xls]

Joint Nature Conservation Committee. 2008a. *Statutory nature conservation agency protocol for mitigation of wind farm piling noise at sea - March 2008.* [Available at http://www.jncc.gov.uk/pdf/consultation_epsAnnexA.pdf]

Joint Nature Conservation Committee. 2008b. *JNCC guidelines for minimising acoustic disturbance to marine mammals when using explosives - March 2008*. [Available at http://www.jncc.gov.uk/pdf/consultation_epsAnnexB.pdf]

Kastak, D. and Schusterman, R.J. 1996. Temporary threshold shift in a harbor seal. *J. Acoust. Soc. Am.* 100:1905-1908.

Kastak, D., Schusterman, R.J., Southall, B.L. and Reichmuth, C.J. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. *J. Acoust. Soc. Am.* 106:1142-1148.

Kastalein, R. and Wartzok, D. 2004. Prioritizing information needs for risk assessment and mitigation strategies. *In: MMC/ JNCC International Policy Workshop on Sound and Marine Mammals, London, 28-30 September 2004.* [Available at http://www.mmc.gov/sound/internationalwrkshp/pdf/smallgroup1d.pdf]

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. *In:* Kastelein, R.A., Thomas, J.A. and Nachtigall, P.E. (eds.), *Sensory systems of aquatic mammals,* De Spil Publishers, Woerden, The Netherlands. pp.391–407.

Ketten, D.R. 1998. Marine mammal auditory systems: a summary of audiometric and anatomical data and its implications for underwater acoustic impacts. *NOAA Technical Memorandum NMFS SWFSC-256.*

Ketten, D.R., Lien, J. and Todd, S. 1993. Blast injury in humpback whale ears: Evidence and implications. *J. Acoust. Soc. Am.* 94(3):1849-1850.

Koschinski, S., Culik, B.M., Henriksen, O.D., Tregenza, N., Ellis, G., Jansen, C. and Kathe, G. 2003. Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2 MW windpower generator. *Mar. Ecol. Prog. Ser.* 265:263–273.

Lawson, J.W. and Becker, E.A. (eds.) 2002. *Marine mammal and acoustical monitoring of target missile launches on San Nicolas Island, August 2001 - March 2002.* LGL Report TA2630-2, Report from LGL Ltd., King City, Ontario and Greeneridge Sciences Inc, Santa Barbara, CA for Naval Air Warfare Center Weapons Division, Point Magu, CA and NMFS, Silver Spring, MD, 74 pp.

Lawson, J.W., Davis, R.A., Richardson, J. and Malme, C.I. 2000. *Assessment of noise issues relevant to key cetacean species (northern bottlenose and sperm whales) in the Sable Gully Area of Interest*. LGL Report TA2446-2, LGL Ltd, Ontario, Canada.

LGL Limited. 2003a. *Environmental assessment of a marine seismic survey by the R/V Maurice Ewing in the southeast Caribbean Sea and adjacent Atlantic Ocean.* LGL Rep. TA2822-13. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and Nat. Sci. Found., Arlington, VA., 99pp.

LGL Limited. 2003b. *Marine mammal monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the Northern Gulf of Mexico, 2003.* LGL Rep. TA2822-12. Rep. from LGL, King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD., 76pp.

LGL Limited. 2003c. *Environmental assessment of a marine seismic survey by the R/V Maurice Ewing off the Northern Yucatan Peninsula, Gulf of Mexico, March-April 2004.* Prepared for Lamont-Doherty Earth Observatory and National Science Foundation by LGL Limited.

LGL Limited. 2003d. *Environmental assessment of a planned low-energy marine seismic survey by the Scripps Institution of Oceanography vessel R/V Roger Revelle in the southern Gulf of California, May 2004.* Prepared for Scripps Institution of Oceanography and National Science Foundation by LGL Limited.

LGL Limited. 2004a. *Marine mammal monitoring of Marathon Canada Petroleum's #D seismic program on the Scotian Slope, 2003.*

LGL Limited. 2004b. *Assessment of regulatory practices governing the limits of sound energy produced during seismic operations (draft).* LGL Limited, environmental research associates, Report TA4014-1.

LGL Limited. 2004c. *Environmental assessment of a marine seismic survey by the R/V Maurice Ewing in the Gulf of Alaska, late summer/early autumn 2004.* Prepared for Lamonth-Doherty Earth Observatory and National Science Foundation by LGL Limited.

LGL Limited. 2006a. *Assessment of potential effects on marine mammals related to the exploratory drilling in the Kaigansko-Vasykanskya and West Schmidt license blocks, Sakhalin, Russia.* Prepared for BP Sakhalin by LGL Limited.

LGL Limited. 2006b. *Assessment of potential effects on marine mammals related to a 3-D seismic survey, East Schmidt, Russia*. Prepared for BP Sakhalin by LGL Limited.

Lien, J., Todd, S., Stevick, P., Marques, F. and Ketten, D. 1993. The reaction of humpback whales to underwater explosions: orientation, movements and behaviour. *J. Acoust. Soc. Am.* 94(3):1849.

Ljungblad, D.K., Würsig, B., Swartz, S.L. and Keene, J.M. 1988. Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. *Arctic* 41:183-194.

Madsen, P.T. 2005. Marine mammals and noise: problems with root mean square sound pressure levels for transients. *J. Acoust. Soc. Am.* 117:3952–3957.

Madsen, P.T., Johnson, M., Miller, P.J.O., Aguilar Soto, N., Lynch, J. and Tyack, P. 2006. Quantitative measures of air-gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. *J. Acoust. Soc. Am.* 120:2366–2379.

Madsen, P.T. and Møhl, B. 2000. Sperm whales (*Physeter catodon* L. 1758) do not react to sounds from detonators. *J. Acoust. Soc. Am.* 107:668–671.

Madsen, P.T., Møhl, B., Nielsen, B.K. and Wahlberg, M. 2002. Male sperm whale behaviour during exposures to distant seismic survey pulses. *Aquat. Mamm.* 28(3):231–240.

Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Mar. Ecol. Prog. Ser.* 309:279–295.

Malme, C.I. 1993. Prediction of potential disturbance of baleen whales by low-frequency acoustic transients. *J. Acoust. Soc. Am.* 94(3):1850.

Malme, C.I., Miles, P.R., Clark, C.W., Tyack, P. and Bird, J.E. 1983. *Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior.* Rep. No. NTIS PB86-174174 of Bolt Beranek & Newman, Inc., Cambridge, Mass., to U.S. Minerals Management Service, Anchorage, Alaska.

Malme, C.I., Miles, P.R., Clark, C.W., Tyack, P. and Bird, J.E. 1984. *Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Phase II: January 1984 migration.* Rep. No. NTIS PB86-218377 of Bolt Beranek & Newman, Inc., Cambridge, Mass., to U.S. Minerals Management Service, Anchorage, Alaska.

Martín, V., Servidio, A. and García, S. 2004. Mass strandings of beaked whales in the Canary Islands. *In:* Evans, P.G.H. and Miller, L.A. (eds.), *Proceedings of the Workshop on Active Sonar and Cetaceans, Las Palmas, Gran Canaria, 8 March 2003, European Cetacean Society Newsletter No. 42, Special Issue,* pp.33–36.

Mate, B.R., Stafford, K.M. and Ljungblad, D.K. 1994a. A change in sperm whale (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. *Proceedings of the 128th Meeting of the Acoustical Society of America, Texas.*

Mate, B.R., Stafford, K.M. and Ljungblad, D.K. 1994b. A change in sperm whale (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. *J. Acoust. Soc. Am.* 96:3268-3269.

Maybaum, H.L. 1990. Effects of a 3.3 kHz sonar system on humpback whales, *Megaptera novaeangliae*, in Hawaiian waters. *EOS* 71:92.

Maybaum, H.L. 1993. Responses of humpback whales to sonar sounds. *J. Acoust. Soc. Am.* 94:1848-1849.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. 2000a. Marine seismic surveys - a study of environmental implications. *Appea Journal* 2000:692-708.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. 2000b. *Marine seismic surveys: Analysis of airgun signals and effects of air gun exposure on humpback whales, sea turtles, fishes and squid.* Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188pp.

McCauley, R.D., Jenner, M-N., Jenner, C., McCabe, K.A. and Murdoch, J. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. *Appea Journal* 1998:692-707.

McDonald, M.A., Hildebrand, J.A., Webb, S., Dorman, L. and Fox, C. 1993. Vocalizations of blue and fin whales during a midocean ridge airgun experiment. *J. Acoust. Soc. Am.* 94(3):1849.

Meier, S.K., Lawson, J., Yazvenko, S.B., Perlov, A., Maminov, M., Johnson, S.R., Yakovlev, Y., Newcomer, M., Wainwright, P., Moroz, I., Aschepkov, A., Piskunov, I. and Propp, M. 2002. *Vessel-based marine mammal monitoring during the 2001 3-D seismic survey of the Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia.* Report by LGL Limited environmental research associates, Sidney, BC, for Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia, 38pp. + appendices.

Meier, S.K., Yazvenko, S. B., Blokhin, S.A., Wainwright, P., Maminov, M.K., Yakovlev, Y.M. and Newcomer M.W. 2007. Distribution and abundance of western gray whales off northeastern Sakhalin Island, Russia, 2001–2003. *Environ. Monit. Assess.* 134:107-136.

Melnikov, V.V. and Starodymov, S.P. 2003. *Results of onshore route observations of the Okhotsk-Korean gray whale population from July to October 2003.* Far East Branch of Russian Academy of Sciences, V.I. Ilichev, Pacific Oceanological Institute (Febras Poi), 95pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2003_vehicle.pdf]

Miller, G.W., Moulton, V.D., Davis, R.A., Holst, M., Millman, P. and MacGillivray, A. 2005. Monitoring seismic effects on marine mammals - southeastern Beaufort Sea, 2001-2002. *In:* Armsworthy, S. L., Cranford, P. J. and Lee, K. (eds.), *Offshore oil and gas environmental effects monitoring: Approaches and technologies,* Columbus, OH: Battelle Press, pp.511-542.

Miller, P.J., Biassoni, N., Samuels, A. and Tyack, P.L. 2000. Whale songs lengthen in response to sonar. *Nature (Lond.)* 405(6789):903.

Mills, J.H., Osgithorpe, J.D., Burdick, C.K., Patterson, J.H. and Mozo, B. 1983. Temporary threshold shifts produced by exposure to low frequency noises. *J. Acoust. Soc. Am.* 73:918–923.

Minerals Management Service. 2007. *Notice to lessees and operators (NTL) of federal oil, gas, and sulphur leases in the outer continental shelf, Gulf of Mexico OCS region: implementation of seismic survey mitigation measures and protected species observer program.* [Available at http://www.gomr.mms.gov/homepg/regulate/regs/ntls/2007NTLs/07-g02.pdf]

Moore, P.W.B., Finneran, J.J. and Houser, D.S. 2004. Hearing loss and echolocation signal change in dolphins. *J. Acoust. Soc. Am.* 116:2503A.

Moore, S.E. and Clarke, J.T. 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). *J. Cetacean Res. Manag.* 4:19-25.

Morton, A.B., Gale, J.C. and Prince, R.C. 1986. Sound and behavioral correlations in captive *Orcinus orca*. *In:* Kirkevold, B.C. and Lockard, J.S. (eds.) *Behavioral Ecology of Killer Whales,* Alan R. Liss, New York, pp. 303-333.

Morton, A.B. and Symonds, H.K. 2002. Displacement of *Orcinus orca* by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science* 59:71-80.

Moscrop, A. and Simmonds, M. 1994. *The threats posed by noise pollution and other disturbances to the health and integrity of cetacean populations around the UK.* A report for the Whale and Dolphin Conservation Society.

Moulton, V.D., Mactavish, B.D. and Buchanan, R.A. 2005. *Marine mammal and seabird monitoring of Chevron Canada Resources' 3-D seismic program on the Orphan Basin, 2004.* LGL Rep. SA817, rep. by LGL Limited, St. John's, NL, for Chevron Canada Resources, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB, 90pp. + appendices.

Moulton, V.D., Mactavish, B.D., Harris, R.E. and Buchanan, R.A. 2006. *Marine mammal and seabird monitoring of Chevron Canada Limited's 3-D seismic program on the Orphan Basin, 2005.* LGL Rep. SA843, rep. by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB, 109pp. + appendices.

Moulton, V.D. and Miller, G.W. 2005. Marine mammal monitoring of a seismic survey on the Scotian Slope, 2003. *In:* Lee, K., Bain, H. and Hurley, G.V. (eds.), *Acoustic monitoring and marine mammal surveys in The Gully and outer Scotian Shelf before and during active seismic programs*, Environmental Studies Research Funds Report No. 151 pp.29-40.

Nachtigall, P.E., Au, W.W.L., Lemonds, D. and Roitblat, H.L. 1998. Hearing and noise in odontocetes. *In: The World Marine Mammal Science Conference, Monaco, 20-24 January 1998, Society for Marine Mammalogy and the European Cetacean Society, Centre de Recherche sur les Mammifères Marins, La Rochelle, France*.

Nachtigall, P.E., Pawloski, J. and Au, W.W.L. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin *Tursiops truncatus*. *J. Acoust. Soc. Am.* 113(6):3425–3429.

Nachtigall, P.E., Supin, A., Pawloski, J.L. and Au, W.W.L. 2001. Measuring recovery from temporary threshold shifts with evoked auditory potentials in the bottlenosed dolphin *Tursiops truncatus*. *J. Acoust. Soc. Am.* 110:2749A.

Nachtigall, P.E., Supin, A., Pawloski, J. and Au, W.W.L. 2004. Temporary threshold shifts after noise exposure in the bottlenose dolphin *Tursiops truncatus* measured using evoked auditory potentials. *Marine Mammal Sci.* 20:673–687.

National Oceanographic and Atmospheric Administration and US Department of the Navy. 2001. *Joint interim report: Bahamas marine mammal stranding event of 15–16 March 2000.* US Department of Commerce, Washington, D.C., 59pp.

National Research Council. 2000. *Marine mammals and low-frequency sound: progress since 1994*. National Academies Press, Washington, DC, 160pp.

National Research Council. 2003. *Ocean noise and marine mammals.* National Academies Press, Washington, DC, 204pp.

National Research Council. 2005. *Marine mammal populations and ocean noise: determining when noise causes biologically significant effects.* National Academies Press, Washington, DC, 142pp.

Nedwell, J.R. 2005. *A metric for estimating the behavioural effects of noise on marine species.* Subacoustech Report no. 59R0303 presented at the National Physics Laboratory Seminar on Underwater Acoustics, Teddington, UK, October 2005. [Available at http://www.subacoustech.com/information/downloads/reports/59R0303.pdf]

Nedwell, J.R. and Edwards, B. 2002. *Measurements of underwater noise in the Arun River during piling at County Wharf, Littlehampton.* Subacoustech Report no. 513R0108, 26pp. [Available at http://www.subacoustech.com/information/downloads/reports/513R0108.pdf]

Nedwell, J.R. and Edwards, B. 2004. *A review of measurements of underwater man-made noise carried out by Subacoustech Ltd, 1993 - 2003.* Subacoustech Report no. 565R00109, to ChevronTexaco Ltd, TotalFinaElf Exploration UK PLC, DSTL, DTI and Shell UK Ltd, 131pp. [Available at http://www.subacoustech.com/information/downloads/reports/534R0109.pdf]

Nedwell, J.R., Edwards, B., Turnpenny, A.W.H. and Gordon, J. 2004. *Fish and marine mammal audiograms: a summary of available information.* Subacoustech Report no. 534R0214 to Cowrie, 278pp. [Available at http://www.subacoustech.com/information/downloads/reports/534R0214.pdf]

Nedwell, J. and Howell, D. 2004. *A review of offshore windfarm related underwater noise sources.* Subacoustech Report no. 544R0308 to COWRIE, 57pp. [Available at http://www.subacoustech.com/information/downloads/reports/544R0308.pdf]

Nedwell, J., Langworthy, J. and Howell, D. 2004a. *Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise.* Subacoustech Report no. 544R0424 to COWRIE, 68pp. [Available at http://www.subacoustech.com/information/downloads/reports/544R0424.pdf]

Nedwell, J., Langworthy, J. and Howell, D. 2004b. *Underwater noise and offshore windfarms.* Subacoustech Report no. 544R0503 presented at the BWEA Conference 2004 on behalf of COWRIE. [Available at http://www.subacoustech.com/information/downloads/reports/544R0503.pdf]

Nedwell, J.R., Lovell, J. and Turnpenny, A.W.H. 2005. Experimental validation of a species-specific behavioural impact metric for underwater noise. Subacoustech Report no. 59R0503, *Proceedings of the 50th meeting of the Acoustical Society of America / NOISE-CON 2005, 17-21 October 2005, Minneapolis, Minnesota, USA.* [Available at http://www.subacoustech.com/information/downloads/reports/59R0503.pdf]

Nedwell, J.R., Needham, K., Turnpenny, A.W.H. and Thompson, D. 1999. *Measurement of sound during a 3D seismic survey in blocks 14/14a of the North Sea.* Subacoustech Report no. 356R0108, 52pp. [Available at http://www.subacoustech.com/information/downloads/reports/356R0108.pdf]

Nedwell, J.R. and Parvin, S.J. 2007. *Improvements to passive acoustic monitoring systems.* Subacoustech Report no. 565R0810, to DTI, 18pp. [Available at http://www.subacoustech.com/information/downloads/reports/565R0810.pdf]

Nedwell, J.R., Turnpenny, A.W.H., Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L. and Howell, D. 2007. *A validation of the dB_{ht} as a measure of the behavioural and auditory effects of underwater noise.* Subacoustech Report no. 534R1231to Chevron Ltd, TotalFinaElf Exploration UK PLC, Department of Business, Enterprise and Regulatory Reform, Shell UK, ITF and JNCC, 74pp. [Available at http://www.subacoustech.com/information/downloads/reports/534R1231.pdf]

Nehls, G., Betke, K., Eckelmann, S. and Ros, M. 2007. *Assessment and costs of potential engineering solutions for the mitigation of the impacts of underwater noise arising from the construction of offshore windfarms.* BioConsult SH report, Husum, Germany, on behalf of COWRIE Ltd, 47pp. [Available at http://www.offshorewind.co.uk/Downloads/COWRIE-ENGFinal270907.pdf]

Nieukirk, S.L., Stafford, K.M., Mellinger, D.K., Dziak, R.P. and Fox, C.G. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. *J. Acoust. Soc. Am.* 115:1832-1843.

Northridge, S. 1999. *Technical evaluation of building a cetacean distribution database.* Final report to Seabirds and Cetaceans Branch of the JNCC, Project XGL:J01, University of St. Andrews, 23pp.

Nowacek, D.P., Johnson, M.P. and Tyack, P.L. 2004. North Atlantic Right Whales (*Eubalaena glacialis*) ignore ships, but respond to alerting stimuli. *Proc. Roy. Soc. Lond. Ser. B* 271:227-231.

Nowacek, D.P., Thorne, L.H., Johnston, D.W. and Tyack, P.L. 2007. Responses of cetaceans to anthropogenic noise. *Mammal Rev.* 37:81–115.

O'Brien, J., Berrow, S. and Wall, D. 2005. *The impact of multibeam on cetaceans: a review of best practise.* Irish Whale & Dolphin Group, Merchant's Quay, Kilrush, Co. Clare.

Parente, C.L. and de Araújo, M.E. 2005. Is the diversity of cetaceans in Brazil reduced by the intensification of the seismic surveys? *Paper SC/57/E6 presented to the IWC Scientific Committee, June 2005, Ulsan, Republic of Korea,* 15pp.

Parente, C.L., de Araújo, J.P. and de Araújo, M.E. 2007. Diversity of cetaceans as tool in monitoring environmental impacts of seismic surveys. *Biota Neotrop.* 7(1). [Available at http://www.biotaneotropica.org.br/v7n1/]

Parks, S.E., Clark, C.W. and Tyack, P.L. 2007. Short- and long-term changes in right whale calling behavior: the potential effects of noise on acoustic communication. *J. Acoust. Soc. Am.* 122(6):3725-3731.

Parsons, E.C.M., Birks, I., Evans, P.G.H., Gordon, J.G., Shrimpton, J.H. and Pooley, S. 2000. The possible impacts of military activity on cetaceans in West Scotland. *European Research on Cetaceans* 14:185-190.

Parvin, S.J., Harland, E. and Nedwell, J.R. 2007. *The target strength of marine mammals, and estimated performance of active acoustic monitoring systems.* Subacoustech Report no. 565R0608, to DTI, 13pp. [Available at http://www.subacoustech.com/information/downloads/reports/565R0608.pdf]

Parvin, S.J. and Nedwell, J.R. 2005. *Update on underwater noise and offshore wind farms.* Presented at the BWEA Conference 2005 on behalf of COWRIE. [Available at http://www.subacoustech.com/information/downloads/reports/UWNoisePresentation.pdf]

Parvin, S.J. and Nedwell, J.R. 2006a. *Underwater noise survey during impact piling to construct the Burbo Bank Offshore Wind Farm.* Subacoustech Report no. 726R0103 to COWRIE, 5pp. [Available at http://www.subacoustech.com/information/downloads/reports/726R0103.pdf]

Parvin, S.J. and Nedwell, J.R. 2006b. *Underwater noise survey during impact piling to construct the Barrow Offshore Wind Farm.* Subacoustech Report no. 544R0602 to COWRIE.

Parvin, S.J., Nedwell. J.R. and Harland, E. 2007. *Lethal and physical injury of marine mammals, and requirements for passive acoustic monitoring.* Subacoustech Report no. 565R0212, to DTI, 38pp. [Available at http://www.subacoustech.com/information/downloads/reports/565R0212.pdf]

Perry, C. 1998. A review of the impact of anthropogenic noise on cetaceans. *Paper SC/50/E9 Presented to the Scientific Committee of the International Whaling Commission, Muscat.*

Peterson, G. 2003. Whales beach seismic research. *Geotimes* January 2003:8-9. [Available at http://www.geotimes.org/jan03/NN_whales.html]

Pierson, M., Wagner, J., Langford, V., Birnie, P. and Tasker, M. 1998. Protection for, and mitigation of, the potential effects of seismic exploration on marine mammals. *In:* Tasker, M.L. and Weir, C.R. (eds.), *Proceedings of the Seismic and Marine Mammals Workshop, London, 23–25 June 1998.*

Pinatadosi, C.A. and Thalmann, E.D. 2004. Whales, sonar and decompression sickness - Reply. *Nature (Lond.)* 428(6984):1.

Popper, A.N. 1980. Sound emission and detection by delphinids. *In:* Herman, L.M. (ed.) *Cetacean Behaviour: Mechanisms and Processes.*

Potter, J.R., Thillet, M., Douglas, C., Chitre, M.A., Doborzynski, Z. and Seekings, P.J. 2007. Visual and passive acoustic marine mammal observations and high-frequency seismic source characteristics recorded during a seismic survey. *IEEE Journal of Oceanic Engineering* 32(2):469-483.

Quan, J. and Calambokidis, J. 1999. *Marine mammal observations and mitigation associated with USGS seismic surveys in the Southern California Bight in 1999.* Report from Cascadia Research, Olympia, WA, for U.S. Geological Survey, Menlo Park, CA. 15pp.

Rankin, S. and Evans, W.E. 1998. Effect of low frequency seismic exploration signals on the cetaceans of the Gulf of Mexico. *In: The World Marine Mammal Science Conference, Monaco, 20-24 January 1998, Society for Marine Mammalogy and the European Cetacean Society, Centre de Recherche sur les Mammifères Marins, La Rochelle, France,* p. 110.

Reeves, R.R., Ljungblad, D.K. and Clarke, J.T. 1984. Bowhead whales and acoustic seismic surveys in the Beaufort Sea. *Polar Record* 22:270-280.

Reid, J.B., Evans, P.G.H. and Northridge, S.P. 2003. *Atlas of cetacean distribution in north-west European waters.* JNCC, Peterborough, 76pp.

Rendell, L.E. and Gordon, J.C.D. 1999. Vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Ligurian Sea. *Mar. Mamm. Sci.* 15(1):198–204.

Richardson, W.J. (ed.) 1997a. *Northstar Marine Mammal Monitoring Program, 1996: Marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea.* LGL Report TA2121-2, prepared for BP Exploration (Alaska) Inc. and National Marine Fisheries Service by LGL Ltd., Ontario, Canada and Greenridge Sciences Inc., Santa Barbara CA.

Richardson, W. J. 1997b. Marine mammals and man-made noise: current issues. *Proceedings of the Institute of Acoustics* 19(9): 39-50.

Richardson, W.J. 1998. Reactions of bowhead whales and ringed seals to an open water seismic program in the Alaskan Beaufort Sea. *In:* Tasker, M.L. and Weir, C. (eds.), *Proceedings of the seismic and marine mammals workshop, London, 23-25 June 1998.*

Richardson, W.J. (ed.) 1999. *Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998.* LGL Report TA2230-3, prepared for Western Geophysical, Houston, TX, and NMFS, Anchorage, AK, and Silver Spring, MD, by LGL Ltd., Ontario, Canada and Greeneridge Sciences Inc., Santa Barbara, CA.

Richardson, W.J., Fraker, M.A., Würsig, B. and Wells, R.S. 1985. Behaviour of bowhead whales *Balaena mysticetus* summering in the Beaufort Sea: reactions to industrial activities. *Biol. Conservation* 32:195-230.

Richardson, W.J. and Greene, C.R. Jr. 1993. Variability in behavioral reaction thresholds of bowhead whales to man-made underwater sounds. *J. Acoust. Soc. Am.* 94:1848.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I. and Thompson, D.H. 1991. *Effects of noise on marine mammals*. OCS Study MMS 90–0093, LGL Rep. TA834-1, Report from LGL Ecological Research Associates Inc., Bryan, TX for U.S. Minerals Management Service, Atlantic OCS Reg., Herndon, VA. NTIS PB91-168914.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I. and Thomson, D.H. 1995. *Marine mammals and noise*. Academic Press, San Diego.

Richardson, W.J., Miller, G.W. and Greene, C.R. Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. *J. Acoust. Soc. Am.* 106:2281.

Richardson, W.J., Wells, R.S. and Würsig, B. 1985. Disturbance responses of bowheads and industrial activity, 1980- 84. *In:* Richardson, W.J. (ed.), *Behavior, disturbance responses and distribution of bowhead whales, Balaena mysticetus, in the eastern Beaufort Sea, 1980-84*, OCS Study MMS 85-0034, LGL Ecological Research Associates Inc., Bryan, Texas, pp.255-301.

Richardson, W.J. and Würsig, B. 1997. Influences of man-made noise and other human actions on cetacean behaviour. *Marine and Freshwater Behaviour and Physiology* 29:183-209

Richardson, W.J., Würsig, B. and Greene, C.R. Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. *J. Acoust. Soc. Am.* 79:1117-1128.

Richardson, W.J., Würsig, B. and Greene, C.R. Jr. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. *Mar. Environ. Res.* 29:135–160.

Ridgway, S.H. and Carder, D.A. 1997. Hearing deficits measured in some *Tursiops truncatus*, and discovery of a deaf/mute dolphin. *J. Acoust. Soc. Am.* 101:590–594.

Ridgway, S., Carder, D., Smith, R., Kamolnick, T. and Elsberry, W. 1998. A report on Project Deephear: toward a scientific basis for understanding noise effects on marine mammals. *In: The World Marine Mammal Science Conference, Monaco, 20-24 January 1998, Society for Marine Mammalogy and the European Cetacean Society, Centre de Recherche sur les Mammifères Marins, La Rochelle, France,* pp.112-113.

Ridgway, S.H., Carder, D.A., Smith, R.R., Kamolnick, T., Schlundt, C.E. and Elsberry, W.R. 1997. *Behavioral responses and temporary shift in masked hearing thresholds of bottlenose dolphins, Tursiops truncatus, to 1-second tones of 141–201 dB re 1 mPa.* Technical Report 1751, Naval Command, Control, and Ocean Surveillance Center, RDT&E Division, San Diego.

Romano, T.A., Keogh, M.J., Kelly, C., Feng, P., Berk, L., Schlundt, C.E., Carder, D.A. and Finneran, J.J. 2004. Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. *Can. J. Fish. Aquat. Sci.* 61:1124–1134.

Rutenko, A.N., Borisov, S.V., Gritsenko, A.V. and Jenkerson, M.R. 2007. Calibrating and monitoring the western gray whale mitigation zone and estimating acoustic transmission during a 3D seismic survey, Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:21-44.

Sakhalin Energy Investment Company. 2003a. Environmental Impact Assessment SEIC Phase II Development. *Sakhalin Energy Investment Company Limited,* 7 volumes.

Sakhalin Energy Investment Company. 2003b. *Western gray whale technical environmental impact assessment.* Prepared by LGL Limited for SEIC, 146pp.

Sakhalin Energy Investment Company. 2004. Marine mammal observers manual 2004. *Sakhalin Energy Investment Company Limited,* 33pp.

Sakhalin Energy Investment Company. 2005a. Marine mammal protection plan: a framework for mitigation and monitoring related to Sakhalin Energy oil and gas operations, Sakhalin Island, Russia. *Sakhalin Energy Investment Company Limited, Document no. 1000-S-90-04-P-0048-00-02,* 52pp.

Sakhalin Energy Investment Company. 2005b. Marine mammal observers manual 2005. *Sakhalin Energy Investment Company Limited,* 41pp.

Sakhalin Energy Investment Company. 2005c. Marine mammal emergency response plan - 2005. *Sakhalin Energy Investment Company Limited, Document no. 1000-S-90-04-P-0000-00,* 24pp.

Sakhalin Energy Investment Company. 2005d. *Western gray whale environmental impact assessment*. Prepared by LGL Ltd for SEIC.

Schlundt, C.E., Finneran, J.J., Carder, D.A. and Ridgway, S.H. 1999. Masked hearing thresholds and critical bandwidths for dolphins and a white whale at 20 and 30 kHz. *J. Acoust. Soc. Am.* 106:2190A.

Schlundt, C.E., Finneran, J.J., Carder, D.A. and Ridgway, S.H. 2000. Temporary shift in masked hearing thresholds MTTS of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. *J. Acoust. Soc. Am.* 107:3496–3508.

Shaffer, S A. and Costa, D.P. 2006. A database for the study of marine mammal behavior: gap analysis, data standardization, and future directions. *IEEE Journal of Oceanic Engineering* 31(1):82-86.

Shyu, H.-J. and Hillson, R. 2006. A software workbench for estimating the effects of cumulative sound exposure in marine mammals. *IEEE Journal of Oceanic Engineering* 31(1):8–21.

Simmonds, M. and Dolman, S. 1999. A note on the vulnerability of cetaceans to acoustic disturbance. *Paper SC/51/E15 Presented to the Scientific Committee of the International Whaling Commission, Grenada, WI,* 4pp.

Simmonds, M.P. and Lopez-Jurado, L.F. 1991. Whales and the military. *Nature (Lond.)* 351:448.

SMRU Ltd. 2007. *Assessment of the potential for acoustic deterrents to mitigate the impact on marine mammals of underwater noise arising from the construction of offshore windfarms.* Commissioned by COWRIE Ltd. (project reference DETER-01-07), 71pp. [Available at http://www.offshorewind.co.uk/Downloads/COWRIE_DETER_FINAL_01_10_2007.pdf]

Sobolevsky, E.I., Rutenko, A.N., Borisov, S.V., Gritsenko, A.V., Antonenko, D.V. and Ruznikova, N.P. 1999. Marine mammal studies offshore north east Sakhalin. *Final Report, Sakhalin Energy Investment Company Ltd.,* 166pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_1999_marine.pdf]

Southall, B.L. 2005. Shipping noise and marine mammals: a forum for science, management and technology. *Final Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium on Shipping Noise and Marine Mammals, 18-19 May 2004, Arlington, Virginia, USA,* 40pp.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene, C.R. Jr., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. and Tyack, P.L. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals* 33(4):411-521.

Southall, B.L., Schusterman, R.J. and Kastak, D. 2003. Auditory masking in three pinnipeds: aerial critical ratios and direct critical bandwidth measurements. *J. Acoust. Soc. Am.* 114:1660-1666.

Stewart, B.S. 1993. Behavioral and hearing responses of pinnipeds to rocket launch noise and sonic boom. *J. Acoust. Soc. Am.* 94(3):1828.

Stone, C.J. 1997. Cetacean observations during seismic surveys in 1996. *JNCC Report,* No. 228. [Available at http://www.jncc.gov.uk/pdf/cetaceous observations 1996.pdf]

Stone, C.J. 1998. Cetacean observations during seismic surveys in 1997. *JNCC Report,* No. 278. [Available at http://www.jncc.gov.uk/pdf/jncc278.pdf]

Stone, C.J. 2000. Cetacean observations during seismic surveys in 1998. *JNCC Report,* No. 301. [Available at http://www.jncc.gov.uk/pdf/jncc301.pdf]

Stone, C.J. 2001. Marine mammal observations during seismic surveys in 1999. *JNCC Report*, No. 316. [Available at http://www.jncc.gov.uk/pdf/jncc316.pdf]

Stone, C.J. 2003a. Marine mammal observations during seismic surveys in 2000. *JNCC Report,* No. 322. [Available at http://www.jncc.gov.uk/pdf/jncc322.pdf]

Stone, C.J. 2003b. The effects of seismic activity on marine mammals in UK waters, 1998-2000. *JNCC Report*, No. 323. [Available at http://www.jncc.gov.uk/pdf/jncc323.pdf]

Stone, C.J. 2008 (in press). Marine mammal observations during seismic surveys in 2001 and 2002. *JNCC Report,* No. 359.

Stone, C.J. and Tasker, M.L. 2006. The effects of seismic airguns on cetaceans in UK waters. *J. Cetacean Res. Manag.* 8(3):255-263.

Swift, R. 1994. *The effects of seismic airgun arrays on the acoustic behaviour and distribution of sperm whales and other cetaceans in the Northeast Atlantic/ Atlantic frontier.* Master's thesis, University of Edinburgh, Edinburgh, Scotland, 207pp.

Tasker, M.L. and Weir, C.R. (eds). 2001. Proceedings of the Seismic and Marine Mammals Workshop, London, 23-25 June 1998. [Available at http://smub.st-and.ac.uk/seismic/pdfs/1.pdf]

Taylor, B., Barlow, J., Pitman, R., Ballance, L., Klinger, T., DeMaster, D., Hildebrand, J., Urban, J., Palacios, D. and Mead, J. 2004. A call for research to assess risk of acoustic impact on beaked whale populations. *Paper SC/56/E36 presented to the IWC Scientific Committee, July 2004, Sorrento, Italy,* 4pp.

Thomas, J.A., Kastelein, R.A. and Awbrey, F.T. 1990. Behaviour and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. *Zoo Biology* 9:393-402.

Thompson, T.J., Winn, H.E. and Perkins, P.J. 1979. Mysticete sounds. *In:* Winn, H.E. and Olla, B.J. (ed.) *Behaviour of Marine Animals*, Volume 3: Cetaceans.

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. 2006. *Effects of offshore windfarm noise on marine mammals and fish.* Biola, Hamburg, Germany on behalf of COWRIE Ltd., 62pp. [Available from: http://www.offshorewind.co.uk/Downloads/BIOLAReport06072006FINAL.pdf]

Todd, S., Stevick, P., Lien, J., Marques, F. and Ketten, D. 1996. Behavioural effects to underwater explosions in humpback whales (*Megaptera novaeangliae*). *Can. J. Zool.* 74:1661–1672.

Tolstoy, M., Diebold, J., Webb, S., Bohnenstiehl, D. and Chapp, E. 2004a. Acoustic calibration measurements. *In:* W.J. Richardson (ed.), *Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003.* Revised ed. Rep. from LGL, King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD, Chapter 3.

Tolstoy, M., Diebold, J.B., Webb, S.C., Bohenstiehl, D.R., Chapp, E., Holmes, R.C. and Rawson, M. 2004b. Broadband calibration of R/V *Ewing* seismic sources. *Geophys. Res. Lett.* 31:L14310.

Tougaard, J., Carstensen, J., Skov, H., Teilmann, J. and Henriksen, O.D. 2003. *Effects from pile driving operations on harbour porpoises at Horns Reef offshore windfarm, monitored by T-PODs and behavioural observations.* Report by National Environmental Research Institute, Frederiksborgvej 399, DK-4000 Roskilde, Denmark.

Turl, C.W. 1993. Low-frequency sound detection by a bottlenose dolphin. *J. Acoust. Soc. Am.* 94:3006-3008.

Turnpenny, A.W.H. and Nedwell, J.R. 1994. *The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys.* Southampton, Fawley Aquatic Research Laboratories Ltd.

Turnpenny, A.W.H., Thatcher, K.P. and 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, October 1994.

Tyack, P. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. *Journal of Mammalogy* 89(3):549-558.

Tyack, P., Johnson, M. and Miller, P. 2003. Tracking responses of sperm whales to experimental exposures of airguns. *In:* Jochens, A.E. and Briggs, D.C. (eds.) *Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1.* U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069, 139pp.

Tyack, P., Thompson, D. and Gordon, J. 2004. Controlled-exposure experiments to determine the effects of noise on marine mammals. *Mar. Technol. Soc. J.* 37(4):39-51.

URS Australia. 2004. *Draft Report 8 July 2004: Draft Review of the DEH Guidelines on the Application of the EPBC Act to interactions between Offshore Seismic Operations and Larger Cetaceans.* A report prepared for the Department of the Environment and Heritage, Canberra, Australia.

Vonk, R. and Martin, V. 1989. Goosebeaked whales *Ziphus cavirostris* mass strandings in the Canary Isles. *European Research on Cetaceans* 3:73-77.

Wartzok, D., Popper, A.N., Gordon, J. and Merrill, J. 2004. Factors affecting the responses of marine mammals to acoustic disturbance. *Mar. Technol. Soc. J.* 37(4):6-15.

Weilgart, L.S. 2007a. The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Can. J. Zool.* 85(11):1091–1116.

Weilgart, L.S. 2007b. The need for precaution in the regulation and management of undersea noise. *J. Int. Wildl. Law Policy* 10(3-4):247-253.

Weir, C.R. 2006a. First confirmed records of Clymene dolphin *Stenella clymene* (Gray, 1850) from Angola and Congo, South-east Atlantic Ocean. *African Zoology* 41(2):297-300. [Available at http://www.ketosecology.co.uk/WEIR [Clymene dolphins in Angola].pdf]

Weir, C.R. 2006b. Sightings of beaked whales (Cetacea: Ziphiidae) including first confirmed Cuvier's beaked whales *Ziphius cavirostris* from Angola. *African Journal of Marine Science* 28(1):173-175. [Available at http://www.ketosecology.co.uk/Weir 2006 [Beaked whales in Angola].pdf]

Weir, C.R. 2006c. *The temporal and spatial distribution of marine mammals, turtles and other marine fauna off northern Angola, September 2003 – March 2006.* Report by Ketos Ecology for BP (Angola) Exploration Ltd., May 2006, 157pp.

Weir, C.R. 2007. Observations of marine turtles in relation to seismic airgun sound off Angola. *Marine Turtle Newsletter* 116:17-20. [Available at http://www.ketosecology.co.uk/Weir 2007 [Turtles and seismic].pdf]

Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*)

to seismic exploration off Angola. *Aquatic Mammals* 34(1):71-83. [Available at http://www.ketosecology.co.uk/Weir 2008_seismic paper.pdf]

Weir, C.R. and Dolman, S.J. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. *J. Int. Wildl. Law Policy* 10:1–27.

Weir, C.R., Dolman, S.J. and Simmonds, M.P. 2006. Marine mammal mitigation during seismic surveys and recommendations for worldwide standard mitigation guidance. *Paper SC/58/E12 presented to the Scientific Committee of the International Whaling Commission, St Kitts and Nevis, WI,* 6pp. [Available at http://www.ketosecology.co.uk/MitigationSC58E12Final.pdf]

Welch, B.L. and Welch, A.S. 1970. *Physiological effects of noise*. Plenum Press, New York.

Weller, D.W., Burdin, A.M., Bradford, A.L., Ivashchenko, Y.V., Tsidulko, G.A., Lang, A.R. and Brownell, R.L. Jr. 2004. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2004. *International Whaling Commission Scientific Committee Report SC/57/BRG1.*

Weller, D.W., Burdin, A.M., Bradford, A.L., Tsidulko, G.A., Ivashchenko, Y.V. and Brownell, R.L. Jr. 2003. Gray whales off Sakhalin Island, Russia: June - September 2001; a joint US - Russia scientific investigation. *Final Report Sakhalin Energy Investment Company Ltd.,* 66pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2001_whales.pdf]

Weller, D.W., Ivashchenko, Y.V., Tsidulko, G.A., Burdin, A.M. and Brownell, R.L. Jr. 2002. Influence of seismic surveys on western gray whales off Sakhalin Island, Russia in 2001. *Paper SC/54/BRG14 presented to the IWC Scientific Committee, April 2002, Shimonoseki, Japan,* 12pp.

Weller, D.W., Rickards, S.H., Bradford, A.L., Burdin, A.M. and Brownell, R.L. Jr. 2006*a*. The influence of 1997 seismic surveys on the behavior of western gray whales off Sakhalin Island, Russia. *Paper No. SC/58/E4 presented to the International Whaling Commission Scientific Committee, Cambridge, UK.*

Weller, D.W., Tsidulko, G.A., Ivashchenko, Y.V., Burdin, A.M. and Brownell, R.L. Jr. 2006*b*. A re-evaluation of the influence of 2001 seismic surveys on western gray whales off Sakhalin Island, Russia. *Paper No. SC/58/E5 presented to the International Whaling Commission Scientific Committee, Cambridge, UK.*

Weller, D.W., Würsig, B., Bradford, A.L., Burdin, A.M., Blokhin, S.A., Minakuchi, H. and Brownell, R.L. Jr. 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia: seasonal and annual patterns of occurrence. *Marine Mammal Science* 15(4):1208-1227.

Weller, D.W., Würsig, B., Burdin, A.M., Reeve, S.H. and Bradford, A.L. 2000. Gray whales off Sakhalin Island, Russia: a joint U.S.-Russian scientific investigation. *Final Contract Report, Sakhalin Marine Mammal Monitoring and Research Program, Sakhalin Energy Investment Company Ltd.,* 65pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2000_gray.pdf]

Yakovlev, Y. and Tyurneva, O. 2004. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) population along the northeast coast of Sakhalin Island, Russia, 2003. *Final Report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Company Ltd.,* 52pp. [Available at http://www.sakhalinenergy.com/en/documents/doc_33_2003_photo.pdf]

Yazvenko S.B., McDonald, T.L., Blokhin, S.A., Johnson, S.R., Meier, S.K., Melton, H.R., Newcomer, M.W., Nielson, R.M., Vladimirov, V.L. and Wainwright, P.W. 2007. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:45-73.

Yazvenko, S.B., McDonald, T.L., Blokhin, S.A., Johnson, S.R., Melton, H.R., Newcomer, M.W., Nielson, R. and Wainwright, P. W. 2007. Feeding of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:93-106.

14. Appendices

Appendix 1 Questionnaire circulated to identify available MMO data
Appendix 2 Revised marine mammal recording forms - Excel spreadsheets
Appendix 3 Revised marine mammal recording forms - deckforms
Appendix 4 Revised marine mammal recording forms - guide
Appendix 5 Application functional specification document

Appendix 1 Questionnaire circulated to identify available MMO data

Name of Organisation:	**Contact person:**	**Contact address/ e-mail/ phone:**

	Seismic surveys	**Pile-driving**	**Drilling**	**Well-decommissioning**	**Dredging**	**Military acoustic trials**	**Other (please specify)**
Do you have MMO data from these operations? (yes/ no)							
Where is the data held?							
Do you submit data to another organisation (regulator, contracting company, other)? (please say where)							
Do you hold data submitted to you by others? (please say who)							
What format is the data? (paper/ electronic/ mixed)							
Which countries do you hold data for?							
Approximate quantity of data:							
Number of years of data held							
Approximate number of surveys/ reports per year							
How would you rate the quality of the data? (high/ medium/ low/ variable) (please expand, e.g. most observers are/ are not trained or experienced, data is/ is not collected in a standard format, etc.)							

	Seismic surveys	Pile-driving	Drilling	Well-decommissioning	Dredging	Military acoustic trials	Other (please specify)
What type of data is available? (please tick appropriate boxes; if standard recording forms are used please attach an example)							
Effort data:							
Date & times of watch	☐	☐	☐	☐	☐	☐	☐
Location of watch	☐	☐	☐	☐	☐	☐	☐
Observer's name	☐	☐	☐	☐	☐	☐	☐
Platform	☐	☐	☐	☐	☐	☐	☐
Weather during watch:							
wind	☐	☐	☐	☐	☐	☐	☐
sea state	☐	☐	☐	☐	☐	☐	☐
swell	☐	☐	☐	☐	☐	☐	☐
visibility	☐	☐	☐	☐	☐	☐	☐
other (please specify)	☐	☐	☐	☐	☐	☐	☐
Source activity during watch	☐	☐	☐	☐	☐	☐	☐
Operational data:							
Times sources active	☐	☐	☐	☐	☐	☐	☐
Times of soft start	☐	☐	☐	☐	☐	☐	☐
Visual clearing period	☐	☐	☐	☐	☐	☐	☐
Mitigating action	☐	☐	☐	☐	☐	☐	☐
Sighting data:							
Date & time of sighting	☐	☐	☐	☐	☐	☐	☐
Location	☐	☐	☐	☐	☐	☐	☐
Multiple locations and time per sighting	☐	☐	☐	☐	☐	☐	☐
Species	☐	☐	☐	☐	☐	☐	☐
Number	☐	☐	☐	☐	☐	☐	☐
Behaviour	☐	☐	☐	☐	☐	☐	☐
Distance from source	☐	☐	☐	☐	☐	☐	☐
Direction of travel	☐	☐	☐	☐	☐	☐	☐
Relative orientation	☐	☐	☐	☐	☐	☐	☐
Source active/ inactive	☐	☐	☐	☐	☐	☐	☐
Is any of the data entered into a database? (yes/ no)							
Specify format or database used to capture data							

Have any analyses been performed using these data? (yes/ no)

If yes, please state type of data used (e.g. seismic) and give brief description of subject of analysis (e.g. compliance with regulations, effects of noise):

Please specify the electronic format in which analyses were undertaken:

Cite reference of any publications or reports produced:

Do you plan to perform any analyses using these data in future? (yes/ no)

If yes, please give brief description of type of data (e.g. drilling) and subject of analysis (e.g. response to noise):

Appendix 2 Revised marine mammal recording forms - Excel spreadsheets

"Marine mammal recording forms_rev01

Appendix 3 Revised marine mammal recording forms - deckforms

Deckforms_rev01.doc

MARINE MAMMAL RECORDING FORM - COVER PAGE

Regulatory reference number (e.g. BERR no., MMS permit no., OCS lease no., etc.)	**Country**	**Ship/ platform name**
Client	**Contractor**	**Survey type** □ site □ 4C □ 2D □ VSP □ 3D □ WAZ □ 4D □ other □ OBC
Start date	**End date**	

Number of source vessels	**Type of source** (e.g. airguns)	**Number of airguns** (only if airguns used)	**Source volume** (cu. in.)
Source depth (metres)	**Frequency** (Hz)	**Intensity** (dB re. 1µPa or bar metres)	**Shot point interval** (seconds)
Method of soft start □ increase number of guns □ increase pressure (where permitted) □ increase frequency (where permitted) □ other			

Visual monitoring equipment used (e.g. binoculars, big eyes, etc.)	**Magnification of optical equipment** (e.g. binoculars)	**Height of eye** (metres)	**How was distance of animals estimated?** □ by eye □ with laser rangefinder □ with rangefinder stick/ calipers □ with reticle binoculars □ by relating to object at known distance □ other
Number of dedicated MMOs	**Training of MMOs** □ JNCC approved MMO induction course for UK waters □ PSO training course for the Gulf of Mexico □ MMO training course for Irish waters □ other □ none		

Was PAM used? □ yes □ no	**Number of PAM operators**
Description of PAM equipment	
Range of PAM hydrophones from airguns (metres)	**Bearing of PAM hydrophones from airguns** (relative to direction of travel)	**Depth of PAM hydrophones** (metres)

MARINE MAMMAL RECORDING FORM - OPERATIONS

Regulatory reference number .....…….. **Ship/ platform name** .....
(e.g. BERR no., MMS permit no., OCS lease no., etc.)

Complete this form every time the airguns are used, including overnight, whether for shooting a line or for testing or for any purpose.
Times should be in UTC, using the 24 hour clock.

Date	**Reason for firing** l = line t = test x = test followed immediately by line	**Time soft start/ ramp-up began**	**Time of full power**	**Time of start of line**	**Time of end of line**	**Time of reduced output** (if relevant)	**Time airguns/ source stopped**	**Time pre-shooting search began**	**Time search ended**	**Time PAM began**	**Time PAM ended**	**Was it day or night in period prior to firing?** d = day n = night w = dawn k = dusk	**Was any mitigating action required?** (yes/ no)

MARINE MAMMAL RECORDING FORM - EFFORT

Regulatory reference number .....…….. **Ship/ platform name** .....
(e.g. BERR no., MMS permit no., OCS lease no., etc.)

Please record the following for all watches, even if no marine mammals are seen.

									Start a new line on form if any one of these changes							
Date	**Visual watch or PAM** v = visual watch p = PAM	**Observer's/ operator's name(s)**	**Time of start of watch** (UTC, 24hr clock)	**Time of end of watch** (UTC, 24hr clock)	**Start position** (latitude and longitude)	**Depth at start** (m)	**End position** (latitude and longitude)	**Depth at end** (m)	**Speed of vessel** (knots)	**Source activity** f = full power s = soft start r = reduced power (not soft start) n = not active	**Wind direction**	**Wind force** (Beaufort scale)	**Sea state** g = glassy (like mirror) s = slight (no or few white caps) c = choppy (many white caps) r = rough (big waves, foam, spray) or Beaufort sea states (0 - 7+)	**Swell** o = low (< 2 m) m = medium (2-4 m) l = large (> 4 m)	**Visibility** (visual watch only) p = poor (< 1 km) m = moderate (1-5 km) g = good (> 5 km)	**Sunglare** (visual watch only) n = no glare w = weak glare s = strong glare v = variable

MARINE MAMMAL RECORDING FORM - SIGHTINGS

Regulatory reference number (e.g. BERR no., MMS permit no., OCS lease no., etc.)	**Ship/ platform name**	**Sighting number** (start at 1 for first sighting of survey)	**Acoustic detection number** (start at 500 for first detection of survey)
Date		**Time at start of encounter** (UTC, 24hr clock)	**Time at end of encounter** (UTC, 24hr clock)

Were animals detected visually and/ or acoustically?	**How were the animals first detected?**
□ visual □ acoustic □ both	□ visually detected by observer keeping a continuous watch □ visually spotted incidentally by observer or someone else □ acoustically detected by PAM □ both visually and acoustically before operators/ observers informed each other

Observer's/ operator's name	**Position** (latitude and longitude)	**Water depth** (metres)

Species/ species group	**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)
Bearing to animal (when first seen or heard)	**Range to animal** (when first seen or heard) (metres)

Total number	**Number of adults** (visual sightings only)	**Number of calves** (visual sightings only)

Behaviour (visual sightings only)

Direction of travel (relative to ship)

- □ towards ship
- □ away from ship
- □ parallel to ship in same direction as ship
- □ travelling in opposite direction to ship
- □ crossing ahead of ship
- □ variable
- □ milling
- □ other

Direction of travel (compass points)

- □ N
- □ NE
- □ E
- □ SE
- □ S
- □ SW
- □ W
- □ NW
- □ variable

Airgun (or other source) activity when animals first detected	**Airgun (or other source) activity when animals last detected**	**Closest distance of animals from airguns (or other source)** (metres)	**Time of closest approach** (UTC, 24hr clock)
□ full power □ not firing □ soft start □ reduced power (other than soft start)	□ full power □ not firing □ soft start □ reduced power (other than soft start)	**If seen during soft start give:** **First distance** **Closest distance** **Last distance** during soft start (metres)	

What action was taken? (according to requirements of guidelines/ regulations in country concerned)	**Length of power-down and/ or shut-down** (if relevant) (length of time until subsequent soft start, in minutes)	**Estimated loss of production (if relevant) due to mitigating actions** (km)
□ none required □ delay start of firing □ shut-down of active source □ power-down of active source □ power-down then shut-down of active source		

Appendix 4 Revised marine mammal recording forms - guide

"Marine mammal recording forms_guid

GUIDE TO USING MARINE MAMMAL RECORDING FORMS

The Marine Mammal Recording Forms are aimed primarily at seismic surveys, but could also be used for other operations. The forms are in Excel, with four spreadsheets contained within one workbook. The four spreadsheets are:

1). Cover page - contains general information about the survey
2). Operations - contains details of the use of the source
3). Effort - contains details of your watches for marine mammals
4). Sightings - contains details of sightings

Many of the fields (columns) within each spreadsheet have input messages that appear when you click on a cell in that field - these input messages contain guidance regarding the information that is required in each field. All fields have data validation that will only allow entries in an appropriate format to be made. In some cases the validation is simply a restriction on the maximum number of characters that can be entered, while in others there may be stricter limitations, e.g. numbers within a certain range, or a valid date or time. In some cases entries are restricted to a list of options; in these cases drop-down boxes are available to select one of the correct options. If an entry is made that is not valid an error alert will appear with guidance regarding the restrictions for that field.

Each spreadsheet has a field for comments and a field where a record can be flagged. Comments should be used only where important information cannot be conveyed within the other fields on the forms. A record should be flagged if an MMO wishes to draw attention to a particular event, for example for the relevant regulator to determine whether there has been compliance with guidelines or regulations.

Printer-friendly versions of the forms are available as Word documents known as Deckforms. These are intended for use when recording hand-written observations whilst on deck, and act as an aide memoire to ensure that MMOs collect all the necessary information for completing the Excel spreadsheets. Records made using the Deckforms should be transcribed to the Excel spreadsheets prior to submission of the forms. The Deckforms are not intended for submission to regulators.

General hints on completion of the spreadsheets:

Times should use the 24 hour clock, and should be in UTC. Times should be entered with a colon between the hours and minutes, i.e. hh:mm. Failure to use the separator will result in the entry not being recognised as a time and therefore being invalid.

Dates should be entered with slashes between day, month and year, i.e. dd/mm/yyyy (a two digit entry for year will automatically be changed to a four digit entry, e.g. 08 becomes 2008). Failure to use the separator when entering the date will result in the entry changing to an incorrect date.

On the Operations form, some fields may need to be left blank on some occasions, e.g. if a soft start began but was aborted before full power was reached, the time the soft start began and the time the airguns stopped would be entered, but the times of full power, start of line, end of line and reduced output would be left blank.

The Effort form can be used for recording periods of acoustic monitoring as well as visual monitoring.

For the Effort form, a new record should be entered on the form if vessel speed, source activity or weather conditions change during a watch.

Acoustic detections as well as visual sightings may be recorded on the Sightings form. Care should be taken not to duplicate records where animals have been detected both visually and acoustically.

Sightings of mixed species can be entered with each species as a separate record on the Sighting form, but sharing the same sighting or acoustic detection number.

Submission of forms:

The forms should be submitted to the relevant regulator in the country of operation. Addresses for those regulators who have indicated acceptance of these forms, and their timescales for submission of reports, are given below. For other regulators, reporting requirements should be checked before using these forms. The Excel spreadsheets (not the Word Deckforms) should be submitted electronically, avoiding the use of pdfs as this prevents easy importation of data into a database.

UK - Joint Nature Conservation Committee - seismic@jncc.gov.uk (after the survey has been completed)

Gulf of Mexico - Minerals Management Service - protectedspecies@mms.gov (1st and 15th of each month, with reports of whales within the exclusion zone that resulted in shut-down of the airguns required to be submitted within 24 hours of the shut-down)

Ireland - National Parks and Wildlife Service - offshore@environ.ie (within 30 days of completion of the survey)

New Zealand - Department of Conservation - marinemammals@doc.govt.nz (no later than 20 working days following survey completion)

Appendix 5 Application functional specification document

"MMO DB Functional Design.pdf"