OSPAR COMMISSION

Assessment of the environmental impact of underwater noise

Biodiversity Series

2009

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998.
La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l’Espagne.

Acknowledgement

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Cover photo provided by Frank Thomsen

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Executive Summary

For many marine organisms including most mammals, many fish, and perhaps even some invertebrates sound is important to communicate, to locate mates, to search for prey, to avoid predators and hazards, and for short- and long-range navigation. Anthropogenic sound emitted to the marine environment can potentially affect marine organisms in various ways. It can mask biologically relevant signals; it can lead to a variety of behavioural reactions; hearing organs can be affected in form of hearing loss, and at very high received levels, sound can injure or even kill marine life. Man-made sound sources of primary concern with regards to disturbance of marine life are explosions, shipping, seismic surveys, offshore construction (for example offshore wind farms or hydrocarbon production and transport facilities), and offshore industrial activities (dredging, drilling *etc.*), sonar of various types, and acoustic deterrent devices. Documented effects on marine life vary greatly from very subtle behavioural changes, avoidance reaction, hearing loss, injury and death in extreme cases. There are gaps in our understanding of the scale of noisy activities within the OSPAR maritime area. Due to the nature of the potential pressures, assessing the scale of the potential effects is challenging. The available data indicates, however, that pressures due to underwater noise emissions might be relatively high in OSPAR Regions II and III due to the comparably high amount of human activities therein. This might increase in the foreseeable future as these regions undergo further development, for example, with the plans for offshore wind farms in Germany, the Netherlands and the United Kingdom in particular. Looking at the various activities, it is also important to identify some key ones, most likely to be problematic for marine life, for example the ones with highest acoustic energy emitted into the environment and sort out those where relatively low level noise is a mere by-product of the activity, for example placement of structures near shore or placement of artificial reefs. Very little information on the level of noise emitted into the marine environment is currently available, for example, from some exploration and production (E&P) industry activities (except Regions II and III), sonar uses, and shipping. Any future assessment should aim at providing further data from a variety of activities to aid in a more comprehensive assessment of the impacts of underwater noise on marine life in the OSPAR maritime area. These have already affected marine life in parts of these regions. These and other potential effects should be further monitored and investigated. Increased efforts should be made to develop and apply effective mitigation measures to reduce the impact of underwater noise (of any source) on the marine environment in all OSPAR regions.

Some noise generating activities such as, oil and gas developments, sand and gravel extraction and construction of offshore wind farms are regulated by the Environmental Impact Assessment Directive (85/337/EEC (as amended by 97/11/EC)). This Directive requires Member States to perform an Environmental Impact Assessment (EIA) if projects are likely to have significant effects on the environment. In the case of the oil and gas industry and offshore wind farms, several guidance documents have been published to assist developers and regulators in the consenting process. Mitigation measures have been developed and implemented for offshore wind farm construction and the prospecting of hydrocarbons. They include, the avoidance of undertaking work during specific periods, the application of a soft start-procedure (gradually increasing the sound level to provide animals with time to leave the impact area), and the use of observers that scan a safety zone where no marine mammals should be present prior to the commencement of activities. Yet, the application of these measures is likely to be very varied within the OSPAR area. Information on regulation of offshore oil and gas exploration is patchy. Within the United Kingdom it is a legal requirement that new oil and gas developments are supported by an EIA or Petroleum Operations Notice 15 (PON 15) application approved, both of which are regulated under EIA regulations. Within an application an assessment of the potential impacts from noise has to be undertaken. In the United Kingdom seismic surveys require a permit and cannot be undertaken unless an assessment of the impacts has been undertaken. The same might be expected from other OSPAR countries. There are a variety of

mitigation measures currently in place to reduce potential effects from mid-frequency active sonar used by the Navy in the United Kingdom, Norway, Netherlands and Italy. Since 2004, the Spanish Ministry of Defence has maintained a moratorium on the use of sonar at less than 50nm from the Canary Islands.

It is currently difficult to provide an evaluation of the effectiveness and adequacy of the measures taken and planned for the protection of the marine environment against effects from underwater noise. Aside the EC EIA Directive (85/337/EEC) and Habitats Directives (92/43/EEC) there are very few other regulations specifically addressing noise in the marine environment. One of the reasons for this is that there are still gaps in our understanding on the effects of underwater noise on marine life. There is evidence that certain activities can generate noise levels that have the potential to be harmful to marine mammals, fish and possibly marine invertebrates, yet, the exact nature of the effects (temporary threshold shift, masking, behavioural response) are not totally understood. The poor understanding of effects means that any regulation and mitigation measures are likely to be based on precaution. This makes it urgent to gather data on the effects of underwater noise in order to apply appropriate regulation / and or mitigation measures.

Underwater noise has the potential to affect marine life in various ways and in some cases over relatively large areas and time scales. It is difficult to assess to what degree the introduction of man-made noise affects the overall quality status as there is little data to allow us to quantify noise levels across the whole OSPAR area. However, most of the intensities of anthropogenic sounds exceed by several order of magnitude the ambient sounds in the marine environment that occur naturally, such as sounds that are induced by rain, wind and waves. Underwater noise can have a range of impacts on marine life such as injury, permanent or temporary hearing loss, behavioural responses and masking of biological relevant signals. However, there are many uncertainties in assessing effects of noise due to the difficulties in observing individual level effects, let alone population level consequences of acoustic disturbance. From a conservation perspective, it is important to assess whether anthropogenic sound has a significant effect on populations. This is also important in assessing the impacts of noise in relation / or addition to other stressors (for example bycatch in cetaceans) either to assess cumulative impacts and / or to focus protection efforts. All factors impacting on populations are cumulative and must be assessed together by discussing the significance of effects. There is currently no information available on the cumulative effects of the factors listed above. No agreed assessment framework for cumulative effects of diverse human activities exists yet.

To improve our understanding of the effects of underwater sound on marine life, research including behavioural and auditory studies, monitoring of the distribution (both of the noise sources and of relevant species) and investigation of anthropogenic sound budgets will be needed. Furthermore, there is an urgent need for standardisation of methodologies to study the impact of sound on marine species over larger spatial scales. OSPAR can assist in the sharing of knowledge and understanding between Contracting Parties and other international organisations (for example International Maritime Organisation), the coordination of data and measures specific to the OSPAR regions (appropriate to future Quality Status Reports (QSR)) and the Marine Strategy Framework Directive (2008/56/EC) standardisation of measurements (for example guidelines on data collection methodologies). One of the first priorities should be to update the information provided here in further assessments, including data on important contributors to underwater noise such as military sonar and shipping. Increased efforts should be made to develop and apply effective mitigation measures to reduce the impacts of underwater noise (of any source) on marine life. The most effective mitigation measures are geographical and seasonal restrictions to avoid ensonification of sensitive species and habitats. Sound-producing activities may be designed to avoid areas and/or times where/when sensitive marine mammals and other species are usually engaged in susceptible activities such as mating, breeding, feeding, or migration.

Récapitulatif

Pour un grand nombre d'organismes marins - dont notamment la plupart des mammifères, de nombreux poissons et peut-être même certains invertébrés - le son est important et permet de communiquer, de s'accoupler, de rechercher des proies, de prévenir des prédateurs et des dangers. Il sert également pour la navigation à courte et longue distance. Les bruits anthropiques émis en milieu marin peuvent agir sur les organismes marins de manières différentes. Ils peuvent masquer des signaux biologiquement pertinents. Ils peuvent entraîner diverses réactions comportementales. Ils peuvent diminuer l'ouïe et, à des niveaux très élevés, ces bruits peuvent blesser ou même tuer des organismes marins. Parmi les sources de bruits anthropiques les plus préoccupantes figurent les explosions, la navigation, les études sismiques, la construction en offshore (par exemple les parcs d'éoliennes ou la production d'hydrocarbures et les installations de transport) et les activités industrielles en offshore (dragage, forage, etc.), les divers types de sonar et les répulsifs acoustiques. Les effets relevés sur les organismes marins varient énormément. Ils vont de légères modifications du comportement à des réactions pour fuir le bruit, à une diminution de l'ouïe, à des blessures et, dans des cas extrêmes, à la mortalité. Nos connaissances sur l'étendue des activités émettant des bruits dans la zone maritime OSPAR ne sont pas complètes et la nature des pressions potentielles rend difficile l'évaluation des effets potentiels. Les données dont on dispose indiquent cependant que les pressions exercées par les émissions de bruits sous-marins risquent d'être relativement fortes dans les Régions II et III OSPAR car le nombre d'activités humaines est relativement élevé. Ceci risque d'augmenter à l'avenir car de nouveaux développements sont en cours dans ces régions. A noter, par exemple des projets de parcs d'éoliennes qui sont prévus en Allemagne, aux Pays-Bas et au Royaume-Uni. Lorsque l'on considère les diverses activités, il est également important de déterminer les plus importantes, à savoir les plus susceptibles de poser des problèmes pour les organismes marins. Il s'agit par exemple de celles qui émettent le plus de bruit, et celles dont l'émission de bruits relativement faibles représente un effet secondaire comme, par exemple, l'implantation de structures près du littoral ou de récifs artificiels. On dispose actuellement de peu d'informations sur le niveau de bruit causé, par exemple, par les activités d'exploration et de production dans le domaine de l'industrie (E&P) (à l'exception des Régions II et III), par l'utilisation de sonars et par la navigation. Toute évaluation future devrait s'efforcer de présenter des données supplémentaires provenant de diverses activités afin de permettre une évaluation plus exhaustive de l'impact des bruits sous-marins sur les organismes marins dans la zone maritime OSPAR. Ceux-ci affectent déjà les organismes marins dans certaines parties de ces régions. Il faudrait continuer à les surveiller et à les étudier ainsi que d'autres effets potentiels. Il faudrait mieux s'efforcer de développer et d'appliquer des mesures de mitigation efficaces permettant de réduire l'impact des bruits sous-marins (de toute source) sur le milieu marin dans toutes les régions OSPAR.

Certaines activités émettant des bruits, telles que les installations gazières et pétrolières, l'extraction du sable et du gravier et la construction de parcs d'éoliennes offshore sont réglementées par la Directive concernant l'évaluation des incidences sur l'environnement (85/337/CEE) (telle qu'amendée par 97/11/CE). Cette directive exige que les états membres réalisent une évaluation des incidences sur l'environnement (EIA) si des projets sont susceptibles d'avoir des incidences notables sur l'environnement. Divers documents d'orientation ont été publiés pour assister les promoteurs et régulateurs dans le processus de consentement dans le domaine de l'industrie gazière et pétrolière et des parcs d'éoliennes offshore. Des mesures de mitigation ont été élaborées et mises en oeuvre pour l'implantation de parcs d'éoliennes offshore et la prospection des hydrocarbures. Il s'agit notamment d'éviter d'entreprendre des travaux lors de périodes spécifiques, d'appliquer une procédure soft start (l'intensification progressive du bruit permettant à la faune de s'éloigner de la zone d'impact), et de faire appel à des observateurs chargés de détecter une zone de sécurité exempte de mammifères marins avant le début des activités. L'application de ces mesures est cependant susceptible de varier dans la zone OSPAR. Les informations sur la réglementation de l'exploration pétrolière et gazière offshore sont incomplètes. Au Royaume-Uni, selon les exigences légales, les nouvelles installations pétrolières et gazières font l'objet d'une EIA ou sont autorisées par une demande de Petroleum Operations Notice 15 (PON 15), toutes deux dans le cadre de la réglementation de l'EIA. Il faut entreprendre une évaluation de l'impact potentiel du bruit pour chaque installation. Au Royaume-Uni les études sismiques sont assujetties à une autorisation et ne peuvent pas être entreprises sans une évaluation préalable des impacts. On pourrait prévoir la même démarche pour d'autres pays OSPAR. Diverses mesures de mitigation sont actuellement en place afin de réduire les effets potentiels des sonars actifs à moyenne fréquence utilisés par la marine au Royaume-Uni, en Norvège, aux Pays-Bas et en Italie. Le Ministère espagnol de la défense conserve, depuis 2004, un moratoire sur l'utilisation de sonars à moins de 50 miles marins des Iles Canaries.

Il est actuellement difficile d'évaluer l'efficacité et la pertinence des mesures prises et prévues sur la protection du milieu marin contre les effets des bruits sous marins. En dehors de la Directive sur l'EIA (85/337/CEE) et des Directives sur les habitats (92/43/CEE) peu d'autres règlementations traitent spécifiquement du bruit dans le milieu marin car, entre autres, nos connaissances des effets des bruits sous marins sur les organismes marins ne sont pas complètes. On dispose de preuves que certaines activités sont responsables de bruits à des niveaux potentiellement dangereux pour les mammifères marins, le poisson et éventuellement des invertébrés marins. Cependant la nature précise de ces effets (modification temporaire des seuils, masquage, réactions comportementales) n'est pas complètement comprise. Toutes mesures de mitigation et de réglementation sont susceptibles de se fonder sur la précaution car les effets sont mal compris. Il est donc urgent de recueillir des données sur les effets des bruits sous-marins afin d'appliquer des mesures pertinentes de réglementation et ou de mitigation.

Les bruits sous-marins sont capables d'affecter les organismes marins de diverses manières et ce, dans certains cas, sur des étendues et des périodes relativement importantes. Il est difficile d'évaluer dans quelle mesure l'introduction de bruits anthropiques affecte l'état de santé dans son ensemble car nous disposons de peu de données nous permettant de quantifier les niveaux acoustiques dans l'ensemble de la zone OSPAR. Cependant la plupart des bruits anthropiques ont une intensité supérieure de plusieurs ordres de grandeur à celle des bruits ambiants présents naturellement dans le milieu marin, tels que les bruits causés par la pluie, le vent et les vagues. Les bruits sous-marins peuvent avoir une série d'impacts sur les organismes marins. Il s'agit notamment de blessures, de surdité permanente ou temporaire, de réactions comportementales et de masquage de signaux biologiques pertinents. L'évaluation des effets du bruit présente cependant de nombreuses incertitudes car il est difficile d'observer les effets aux niveaux individuels, sans compter les incidences de la perturbation acoustique sur les niveaux des populations. Du point de vue de la conservation, il est important d'évaluer si les bruits anthropiques ont une incidence importante sur les populations. Ceci est également important lors de l'évaluation de l'impact des bruits par rapport / en plus d'autres facteurs de stress (par exemple les captures accidentelles de cétacés) lorsqu'il s'agit d'évaluer l'impact cumulatif et/ou de focaliser les démarches de protection. Tous les facteurs ayant un impact sur les populations sont cumulatifs et doivent être évalués ensemble en discutant de l'importance des effets. On ne dispose actuellement d'aucune information sur les effets cumulatifs des facteurs énumérés ci- avant. Il n'existe actuellement aucun cadre d'évaluation convenu pour les effets cumulatifs des diverses activités humaines.

Il sera nécessaire d'effectuer des recherches, notamment sur les études comportementales et acoustiques, de surveiller la distribution aussi bien des sources de bruits que des espèces pertinentes et étudier les budgets des bruits anthropiques afin de mieux comprendre les effets des bruits sous marins sur les organismes marins. De plus, il est urgent de normaliser les méthodologies pour l'étude de l'impact du bruit sur les espèces marines à des échelles spatiales plus étendues. OSPAR peut aider les Parties contractantes et autres organisations internationales (l'Organisation maritime international par exemple) à échanger leurs connaissances et leurs raisonnements. Elle peut aussi les aider à coordonner les données et les mesures spécifiques aux régions OSPAR (pertinentes aux futurs Bilans de santé (QSR) et à la normalisation des analyses selon la Directive cadre de stratégie marine (2008/56/EC) (par exemple des lignes directrices sur les méthodologies de recueil des données). L'une des premières priorités devrait être l'actualisation des informations présentées ici dans les évaluations ultérieures, notamment des données sur les contributeurs importants aux bruits sous marins tels que les sonars militaires et la navigation. On devrait mieux s'efforcer de développer et d'appliquer des mesures de mitigation efficaces afin de réduire l'impact des bruits sous marins (de toute source) sur les organismes marins. Les mesures de mitigation les plus efficaces sont les restrictions géographiques et saisonnières permettant d'éviter l'insonification des espèces et habitats sensibles. On pourrait concevoir des activités émettant du bruit en évitant les zones et/ou les périodes d'accouplement, d'alimentation ou de migration des mammifères marins et autres espèces sensibles.

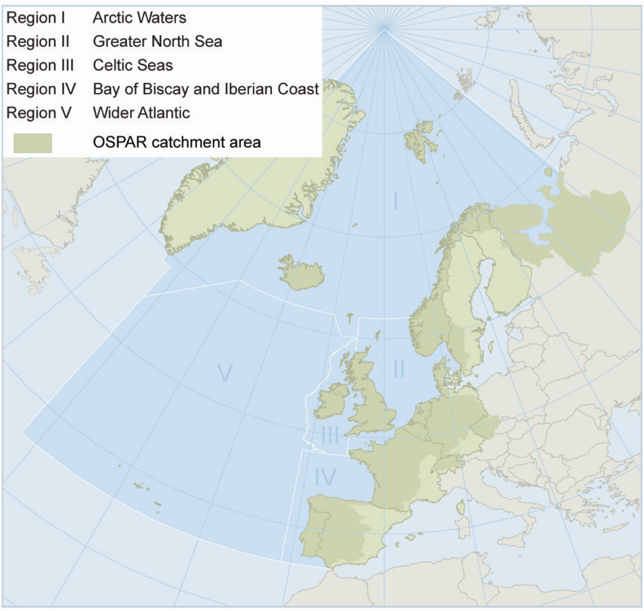
Introduction

For many marine organisms, including most mammals, many fish, and perhaps even some invertebrates sound is important to communicate, to locate mates, to search for prey, to avoid predators and hazards, and for short- and long-range navigation. Anthropogenic sound emitted to the marine environment can potentially affect marine organisms in various ways. It can mask biologically relevant signals; it can lead to a variety of behavioural reactions; hearing organs can be affected in form of hearing loss, and at very high received levels, sound can injure or even kill marine life. However, there are many uncertainties remaining in the assessment of noise related impact. This paper aims in providing a first assessment of the environmental impacts of underwater noise on marine life in the OSPAR regions and is a contribution to the series of assessments of human under the OSPAR Joint Assessment and Monitoring Programme (JAMP) and to the Quality Status Report 2010.

The current report is following the Overview of the impacts of anthropogenic underwater sound in the marine environment (OSPAR, 2009a), which provides a detailed account on the effects of noise/sound from various activities on marine life.

The purpose of the JAMP is to provide a quantitative (or if not possible a qualitative) assessment of the scale of effect at the OSPAR region level. In order to achieve this, we used the existing activity JAMP assessments to provide an indication of the nature and scale of activities per region. The information provided concerns:

- the level of any noise generating activity per region;
- a very preliminary assessment of the impacts with regards to underwater noise based on the findings in the background document(OSPAR, 2009a);
- a first overview whether noisy activities are subject to regulations, site investigations and EIA in all OSPAR Contracting Parties, and;
- recommendations on further work needed on assessment, reporting, mitigation and monitoring (at an OSPAR level).



The OSPAR maritime area and its five Regions

Information used in compiling the assessment:

Background documents

➥ Overview of the impacts of anthropogenic underwater sound in the marine environment (OSPAR 2009a)(and the various sources therein)

QSR assessments (see box with electronic navigator)

- ➥ Sand and gravel extraction (OSPAR, 2009d)
- ➥ Dredging for navigational purposes (OSPAR, 2008b)
- ➥ Dumping of wastes (OSPAR, 2009b)
- ➥ Dumped munitions (OSPAR, 2009c)
- ➥ Offshore oil and gas industry (OSPAR, 2009i)
- ➥ Shipping (OSPAR, 2009k)
- ➥ Offshore wind-farms (OSPAR, 2008a)
- ➥ Placement of structures (other than oil and gas and wind-farms) (OSPAR, 2008d)
- ➥ Cables (OSPAR, 2008e)
- ➥ Artificial reefs (OSPAR, 2009f)
- ➥ Coastal defence structures (OSPAR 2009g)
- ➥ Tourism (OSPAR, 2008c)
- ➥ Mariculture (OSPAR, 2009h)
- ➥ Trends in human activities (OSPAR, 2009j)

As some of the information in the JAMP assessments was vital for this paper, important figures and text were directly copied from the original documents. Text in most cases was edited to address noise related issues.

Databases

- USF Mitigation and monitoring database (United Kingdom), draft version, January 2009). This is a database under development of the Sound Forum from within the Inter Agency Committee for Marine Science and Technology, United Kingdom.

What are the problems?

Brief overview of underwater noise

There are a wide variety of noise-generating human activities in the marine environment. Underwater explosions, ships, seismic exploration, offshore construction (for example wind farms and hydrocarbon production activities) and industrial activities, sonar of various types and acoustic devices designed to deter mammals from approaching (so called acoustic harassment or deterrent devices, AHD's, ADD's) are of primary concern in impact assessments. Emitted frequencies range from low frequency engine noise of only several Hz to very high frequency echo sounders of several hundred kHz. Source levels also vary widely and can reach more than 250 dB re 1µPa peak at one meter in the case of some offshore construction activities, seismic exploration and explosives (Richardson *et al.,* 1995; Thomsen *et al.,* 2006; Nowacek *et al.,* 2007).

Table 1 provides an overview of the acoustic properties of major man-made sounds. It can be seen that there are a variety of activities such as pile driving, seismic exploration and sonar that can produce relatively high source levels. There are also sources that are less noisy such as operational wind farms, small ships, drilling for oil and gas and presumably also wave and tidal generators.

Table 1. *Overview of the acoustic properties of some anthropogenic sounds. * Nominal source, ** Higher source levels from drill ships use of bow thrusters, *** Projection based on literature data levels back-calculated at 1m (these are examples of sound sources and their levels, not all sources occur in all of the OSPAR-regions)*

Sound	Source level (dB re 1µPa-m)*	Bandwidth (Hz)	Major amplitude (Hz)	Duration (ms)	Directionality	Source citations in module
Offshore construction						
TNT (1 – 100 lbs)	272 – 287 Peak	2 – 1000	6 – 21	~ 1 – 10	Omnidirectional	4
Pile driving	228 Peak / 243 – 257 P-to-P	20 – >20 000	100 – 500	50	Omnidirectional	4
Offshore industrial activities						
Dredging	168 – 186 rms	30 – > 20 000	100 – 500	Continuous	Omnidirectional	4
Drilling	145 – 190 rms**	10 – 10 000	< 100	Continuous	Omnidirectional	4
Wind turbine	142 rms	16 – 20 000	30 – 200	Continuous	Omnidirectional	4
Shipping						
Small boats and ships	160 – 180 rms	20 – >10 000	> 1000	Continuous	Omnidirectional	5
Large vessels	180 – 190 rms	6 – > 30 000	> 200	Continuous	Omnidirectional	5
Sonar						
Military sonar low-frequency	215 Peak	100 – 500	-	600 – 1000	Horizontally focussed	6
Military sonar mid-frequency	223 – 235 Peak	2800 – 8200	3500	500 – 2000	Horizontally focussed	6
Echosounders	235 Peak	Variable	Variable 1500 – 36 000	5 – 10 ms	Vertically focussed	6
Seismic surveys						
Airgun array	260 – 262 P-to-P	10 – 100 000	10 – 120	30 – 60	Vertically focussed*	7
Other activities						
Acoustic deterrent / harassment devices	132 – 200 Peak	5000-30 000	5000 – 30 000	Variable 15 – 500ms	Omnidirectional	8
Tidal and wave energy devices***	165 – 175 rms***	10 – 50 000	-	Continuous	Omnidirectional	8

A detailed overview of the issue is provided by the background document (OSPAR 2009a). The background document is made up of eight modules:

1) Introduction and terms of reference;
2) Background on underwater sound;
3) Background on impacts of sound on aquatic life;
4) Offshore constructions and industrial activities;
5) Shipping;
6) Sonar;
7) Seismic surveys and;
8) Other activities.

The second module provides a comprehensive background on underwater sound, dealing with issues that are closely related to the overview:

a. the nature of sound and basic concepts;
b. measurement of sounds;
c. physical units;
d. biological units;
e. sound vs. noise;
f. source level measurements;
g. sound propagation and transmission loss and;
h. background noise.

The third module provides a background on general aspects of impact of sound on marine life and aims in setting the scene for the following modules. It outlines the approach of Richardson *et al.* (1995) in describing zones of noise influences (masking, behavioural response, injury, death) and discusses levels on which an impact assessment can be performed. In this context, the recently developed population consequences of acoustic disturbance is introduced and discussed (PCAD) model by the National Research Council (NRC) (2005) is introduced and discussed.

Each of the five latter modules deals with one activity or closely related activities and their documented acoustic impacts on marine life. It comprises a description of sound sources and a review of documented impacts. The impact review follows the outline put forward in module 3 of the background document by describing results looking at masking, behavioural responses, injury and death (Figure 1). Taxa looked upon are marine mammals (cetaceans and pinnipeds), marine fish, and other marine life (for example turtles, invertebrates). Whenever possible, the overview focuses on peer-reviewed papers and widely accessible reviews. This part is followed by a detailed description of mitigation measures that are suggested or already applied.

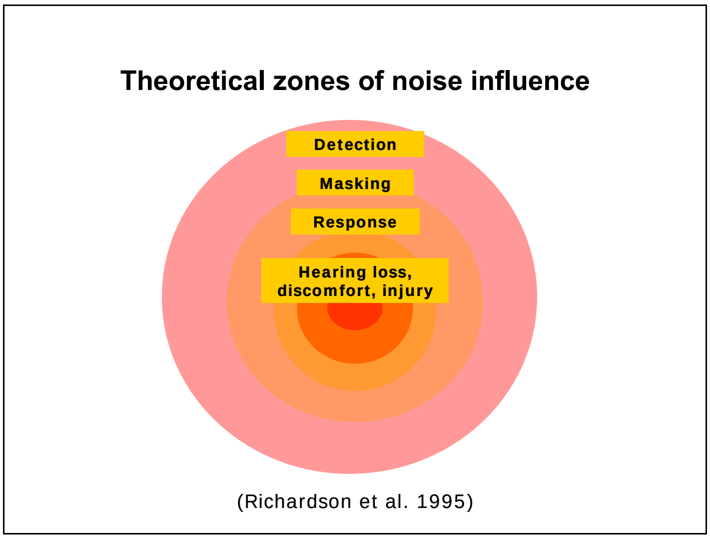


Figure 1: *Conceptual Zones of noise influence (Richardson et al. 1995)*[1].

[1] *This model has been used very often in impact assessments where the zones of noise influences are determined based on noise propagation modelling or sound pressure level measurements on the one hand, and information on the hearing capabilities of the species in question on the other. As sound spreads in principle omnidirectionally from the source, the zones of noise influences, given as distance from the source, indicate a radius rather than a straight line. It should be noted here that this model gives only a very rough estimate of the zones of influence as sound in the seas is always three-dimensional. The interference, reflection and refraction patterns within sound propagation will inevitably lead to much more complex sound fields than those based on the model by Richardson et al. 1995). This complexity may lead to effects such as increases of received sound energy with distance, especially when multiple sound sources are used simultaneously (i.e. seismic airguns).*

Assessment methodology

To assess activities, a very preliminary methodology was used. Levels of activity were assessed based on various parameters indicated by the JAMP assessments. It should be noted here that this comprises by no means any absolute assessment but merely a tool for a comparison of activities across regions. Types of expected effects were based on the information provided in the background document (OSPAR, 2009a), and as defined by Richardson *et al.* (1995):

- Behavioural response: behavioural reaction;
- Masking: Obscuring of sounds of interest (for example communication or echolocation signals) by interfering sounds, generally at similar frequencies;
- Temporary threshold shift (TTS): a temporary elevation of the hearing threshold due to noise exposure;
- Permanent threshold shift (PTS): a permanent elevation of the hearing threshold due to noise exposure;
- Injury: Further tissue damage due to noise exposure;
- Death.

It should be noted here that the assessment is concerned with potential effects based on information on documented responses and modelling exercises provided in the background document. The scale of these potential effects is assessed on a two-fold scale as either being short-range, that is happening only in the immediate vicinity of the source and / or within the area the activity is carried out (for example vicinity of a turbine and offshore wind farm area) or long-range, that is occurring beyond that. It should be emphasised that this is a very preliminary and rather subjective measure that needs further amendment. It is appreciated that noise can have potential effects on a wide range of distances, up to several kilometres. Yet, zones of noise influences are so diverse and depending on so many variables, that a further split in spatial scales of effects was deemed not to be feasible at this stage.

The results of the overall assessment are provided in Table 4. This assessment is based on the information that is currently available in the various JAMP assessments. It should be noted here that, due to time constraints, only such information that was provided by the Contracting Parties, with the addition of some reports undertaken from within the United Kingdom, could be utilised. This resulted in considerable data gaps which should be filled in subsequent updates to this report. It can be seen that for some activities in certain regions, for example oil and gas exploration and production in Regions I, IV & V, shipping and sonar, no or little information was available to provide even a rough first assessment. The information on seismic surveys, for all but Regions II & III, is not readily available (Thomsen *et al.,* 2008). Information on platforms was found in Thomsen *et al.* (2008). Information on shipping and military activities was not provided, although in the latter case much of this information (especially in relation to military sonar) – whether for the overall assessment or specific OSPAR regions – is and may continue not to be publicly available. What follows is a summary of the results for noisy activities and potential effects per region.

Region I (Arctic waters)

Type and scale of activities present

As can be seen in Table 4, there are a variety of activities present in Region I that produce underwater noise. Sand and gravel extraction, dredging for navigational purposes, dumping of wastes, and dumped munitions have a low or medium level of activity, compared to other regions. Yet, it has to be mentioned that information on a spatial scale is sparse. For example, only very small quantities of marine aggregates for land fill and construction have been extracted in Norway. However, the exact location of the dredging sites is not provided, so the activity can not be assessed.

Information on the E&P industry is sparse. There are a number of oil and gas platforms located off Trondheim (Norway) and off the northern Norwegian coast that we could assign provisionally as a medium level production activity (Figure 2 and Table 2).

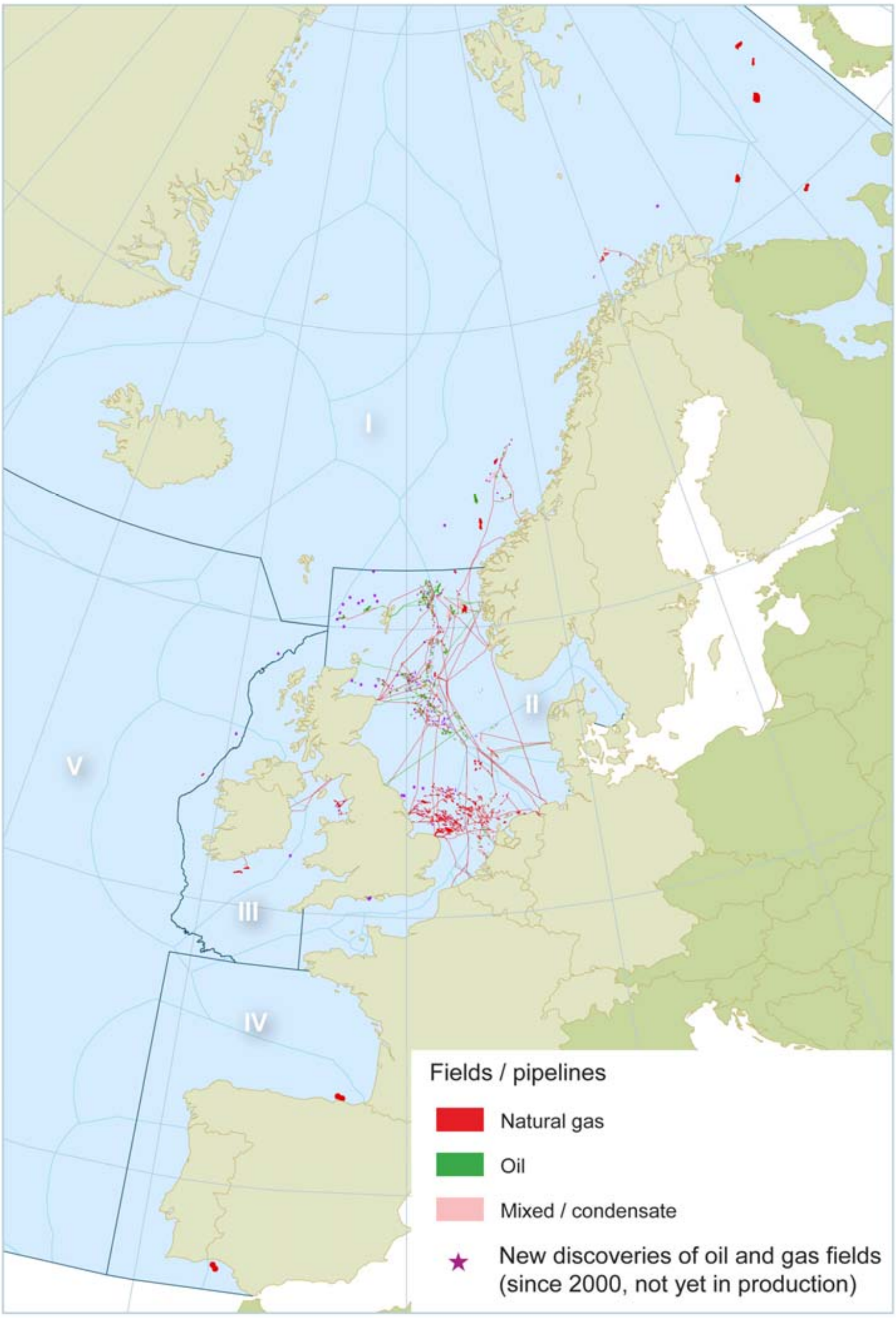


Figure 2. *Overview of hydrocarbon activities in the OSPAR maritime regions.*

Seismic surveys have been documented off the Lofoten (northern Norway) and further South (Cefas data) but the data is not sufficient enough to provide an estimate of the activity level for seismic surveys in Region I.

Table 2 *Number of installations in the OSPAR maritime area (all OSPAR regions).*

Table 1: Number of installations in the OSPAR maritime area

Table 1a: Number of installations in the OSPAR maritime area with discharges to the sea, or emissions to the air 1984-2007*

Country	1984	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Denmark	7	20	20	20	10.5	8	8.23	9	12	15	16
France [1]	0	0	0	0	0	0	0.1	0	0	0	0
Germany	1	3	3	4	2	1	1	2	2	2	3
Ireland	1	2	2	2	0	0	0	4	5	2.2	2.5
Netherlands	30	63	60	88	97	103.5	114.93	113.8	106.3	104.1	105
Norway [2]	13	24	25	34	93	90	83	61	53	54	59
Spain	1	1	1	1	1	1.5	9	5	2	0	0
UK [3]	90	79	79	79	81	152	169	193	164	218	186
Total	**143**	**192**	**190**	**228**	**284.5**	**356**	**385.26**	**387.8**	**344.3**	**395.3**	**371.5**

Country	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	16	19	17	19	20	17	18	19
France [1]	0	0	0	0.1	0	0	0	0
Germany	3	3	2	2	3	4	3	3
Ireland	2.5	4	4	NI	6	6	7	7
Netherlands	108	114	114	123	124	129	128	130
Norway [2]	60	65	67	63	103	108	109	125
Spain	1	1	1	1	1	1	1	1
UK [3]	298	332	381	383	396	407	416	444
Total	**488.5**	**538**	**586**	**592**	**653**	**671**	**683**	**730**

Table 1b [4]: Total number of installations in the OSPAR maritime area, 1984-2007**

	1984	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	NI	NI	NI	NI	320	438	459	554	520	560	587

	2000	2001	2002	2003	2004	2005	2006	2007
Total	591	NI	1070	1131 [3]	1130	1130	1281	1281

[1] France had 1 exploratory well in 1995, and 1 in 2003.

[2] The fact that Norway reports subsea installations for the first time in 2004 leads to an artificial significant increase in the total.

[3] UK has revised its criteria for counting subsea installations as from 2000.

[4] The increase of the number of installations from year 2002 is mainly due to the change of rules in counting the installations. The numbers given for 2003 and 2004 reflect the current OSPAR database on offshore installations set up in accordance with OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations

* These data are taken from table 1 of Part A of the report.

** These data are taken from the OSPAR inventory on offshore installations

Offshore wind farm activity in Region I was zero as of February 2008 (three wind farms with 334 turbines applied for). The planned sites are relatively near shore (OSPAR, 2008a)). Mariculture production values are high compared to other regions and seal scarers are commonly used at least in fish farms in Norwegian water (www.lofitech.no).

There was no information provided by the Contracting Parties on shipping or activities generating sonar for Region I.

Type and scale of effect expected

Table 4 provides a first assessment of the effects that might be expected with regards to disturbance form underwater noise of the various activities. This is based on the review of observed effects, theoretical considerations and modelling exercises in modules 4 – 8 of the background document (OSPAR, 2009a). A further important source was provided by a recent paper on underwater noise by the Marine Board ESF (ESF, 2008). What follows is a quick outline of the concluding chapters of the respective modules of the background document.

Types of effects from offshore construction and industrial activities (for example construction and operation of oil and gas platforms, offshore wind farms and aggregate extraction) are addressed in module 4 of the background document. Documented effects on marine mammals are variable and include a range of behavioural reactions but relevant studies often do not describe the noise, even at relatively high received sound pressure levels. Investigations on injuries in marine life due to marine construction are too limited to draw any conclusions yet. Investigations on the effects of fish are even patchier and few generalisations can be drawn from the studies undertaken to date. Injuries and death due to pile driving and explosions are documented in a variety of fish species. Behavioural effects in fish due to construction activity have not been investigated fully.

Based on what has been outlined in module 5 of the background document, marine ambient noise as a result of shipping may be increased on both acute and chronic time scales above natural conditions; in some areas there appears to be an increasing trend associated with increases in commercial shipping. There is uncertainty as to the exact biological significance of effects arising from shipping noise and it is particularly uncertain to whether critical points in terms of impacts to populations of marine animals have been reached. However, it is certain that there is some level of adverse effect of many tens of thousands of vessel noise sources and minimizing or reducing their incidentally-radiated noise would be generally environmentally beneficial.

According to module 6 of the background document, the full effects of sonar on cetaceans are not well known, mostly due to the difficulty of studying the interaction, and to a lesser extent because details of sonar equipment and usage are not easy to obtain. The use of high-intensity mid frequency sonar has led to the deaths of a number of cetaceans in some places, but population level consequences due to these mortalities are completely unknown. From our very limited knowledge, it appears that beaked whales are the most affected species, in particular Cuvier's beaked whale (possibly as this species appears to be the commonest and most widely dispersed beaked whale). Yet, according to Carwardine (1995), the species distribution doesn't overlap with Region I of the OSPAR maritime area.

As stated in module 7 of the background document, seismic surveys – for mapping of features beneath the ocean floor – are used for oil and gas exploration, but also for academic research, and for gathering data for the purpose of delineating Economic Exclusive Zone (EEZ) extensions under the United Nations Convention of the Law of the Sea (UNCLOS). There have been a few cases of stranding of beaked whales and giant squids coinciding with academic seismic surveys. However, there is no conclusive evidence of a link between sounds of seismic surveys and the mortality of any marine mammals. Furthermore, there is limited information on possible physical injury (permanent or temporary threshold shift). There is a considerable volume of research concerning behavioural responses to intense sounds generated by seismic airguns. While many of these studies have reported changes of behaviour in a range of species, no universal conclusions can be drawn. Moreover, where responses have been observed in individual animals or small groups of animals, it is not known whether these reactions are significant at the population level for the species investigated. Studies investigating sound-induced effects on fish are relatively scarce compared with those on marine mammals, and the results are variable. Studies have been performed on the effects of seismic surveys on marine organisms and the results show that harm to individual fish and increased mortality from firing airguns can occur at distances up to 5 m, with most frequent and serious damages up to 1.5 m. Fish in the early life stages are most vulnerable. The extent of seismic-induced mortality for commercial species in Norwegian waters was estimated to be so low that it was considered not to have significant negative impacts on recruitment to the populations (DALEN *et al.,* 1996). Adult fish show behavioural responses to the sound waves from seismic activity. Based on the few existing studies, that showed a reduction in catch rates during noise exposure, behavioural response is indicated within a radius of several kilometres from the sound source. If fish that are on their way to the spawning grounds are exposed to this type of noise, or if they are exposed to the noise during the actual spawning, the effects can have an impact on the fish's spawning success and thereby the recruitment. Avoidance responses of sea turtles to low frequency sounds have been demonstrated.

Based on the review provided in module 8 of the background document, large scale habitat exclusion of odontocetes (a non-target species) has been demonstrated in response to commercially available acoustic harassment devices (AHDs) and should be considered a potential concern (if no mitigation measures are implemented). Although there is the potential that some pingers could exclude porpoise from their habitat, it should be highlighted that avoidance responses do not seem to extend over more than a few hundred metres from the device. Therefore, the benefits of reducing lethal by-catch may outweigh the impact on behaviour in some populations and habitats. Due to their high frequency content, both AHDs and pingers are less likely to affect fish behaviour, except for individuals within the immediate vicinity of the device. Hearing damage may only be caused by some of the high intensity noise sources in species with good hearing sensitivity. Depending on the assumptions made, predicted impact zones may vary markedly. Odontocetes exposed to a single emission of an AHD are unlikely to suffer hearing damage even when being close to the device. However, repeated exposure for extended amount of times (for example as a result of overlapping sound fields from different devices) may pose a substantial risk.

Region II (Greater North Sea)

Type and scale of activities present

Table 4 clearly shows that Region II comprises a relatively high amount of human activities that generate noise.

Sand and gravel extraction is undertaken in a variety of sub regions. The United Kingdom remains the main producer of sand and gravel for the manufacture of concrete, whilst the Netherlands produces and uses the largest quantity of sand. The construction industry's requirement for marine sand and gravel has remained fairly stable. A number of the new resources of sand and gravel that have been identified occur in deeper water (40 – 60 m), for example in the East English Channel. Aggregate dredging sites in Region II are off Denmark, the German West coast (Island of Sylt), along the southern North Sea coast (Netherlands, Belgium and France), in the Channel, and off the United Kingdom east coast.

Dredging for navigational purposes is carried out at a relatively high level, compared to other OSPAR regions. According to the respective JAMP assessment, the number of maintenance dredging sites per size category, as reported by the Contracting Parties, in the period 2003 – 2005, was 186, with most (~171) located in Region II or III of the overall OSPAR area. Known munitions dumpsites are located in Region II in coastal areas from Denmark to France in a medium number compared to other regions.

Region II is clearly one of the centres for the E&P industry in the Northeast Atlantic comprising a relatively high number of platforms and high level of seismic surveys being conducted. Production oil and gas exploration began on the United Kingdom Continental Shelf (UKCS) in 1964 with the first licenses being granted and the first well being drilled in the central North Sea soon after (see www.ukooa.uk). Exploration drilling continued and the first North Sea gas field began production in 1967 (BERR[2], 2008). Drilling activity has remained high in the North Sea peaking in 1990 with 159 exploration wells drilled. Development drilling activity has remained high in recent years with 201 wells drilled in 2006 after a development drilling peak of 289 wells in 1998 (BERR 2008). Figure *2* highlights the extent of hydrocarbon industries in Region II of the OSPAR area.

There are currently 284 oil and gas installations in production. The first platform installations were predominantly in the southern North Sea, followed later by increased activity in the northern North

[2] Department for Energy and Climate Change was formerly known as Department for Business and Regulatory Reform (BERR)

Sea, the Moray Firth and the Irish Sea. The largest increase in platform numbers occurred during the late 1980s, with over 80% of current platforms in production by 1997. Most recently, activity has moved into the central North Sea and to the west of the Shetland Islands. For example, there has been an increase in the number of platforms from one to three to the west of Shetland over the last ten years.

Seismic surveys have been carried out in the North Sea since 1963, with the majority being 2D line transects (for more information on seismic survey methodology, see module 7 of the background document). With the developing 3D technology, surveying began in 1978 with high numbers of 3D surveys concentrated in the southern North Sea and northern central North Sea. A quantitative assessment of seismic surveys undertaken in the North Sea can be found at ASCOBANS (www.ascobans.org and ASCOBANS, 2005, and 2006).

Region II is also a centre for offshore wind farm development in European waters. A very detailed account of offshore wind farms can be found in the respective JAMP assessment (OSPAR, 2008a). According to that paper there were 13 offshore wind farms operational in Region II and III as of February 2008, with a cumulative size of 800km^2 or 0.07% of the surface area of Region II and III combined. This might be viewed as rather small but there are a further 28 and 42 projects authorised and applied for respectively (total number of turbines ~5,600). Existing offshore wind farms are coastal, however, many license applications, for example in the German EEZ, are much further offshore (OSPAR, 2008a).

Placement of structures, cables and pipelines, coastal defence structures and tourism might be all viewed to comprise a relatively high level of activity, compared to other OSPAR regions. Twelve of the 48 artificial reefs found in all of the OSPAR maritime area occur in Region II which leads to a medium level of activity. Based on the questionnaires, Table 3 gives an overview of structures placed in some countries of the OSPAR maritime area.

Table 3. *Summary of returns to the questionnaire detailing types of structures and numbers of installations within national boundaries.*

	Germany	**Netherlands**[(12)]	**Norway**[(10)]	**Spain**	**UK**[(11)]
Harbours and marinas	202	34	[(6)]	207	407
Outfalls	>15	27	[(7)]	17	95
Piers and jetties	>3	82	[(6)]	163	137
Land reclamation	1	3	0	467	74
Flood defence and sea walls	>4[(2)]	17	0	144	24
Coast protection	>1700[(3)]	22	0	0	309
Artificial reefs	0	0	28	23	1
Cables and pipelines	>29[(4)]	67	163[(8)]	ND	133
Slipways and causeways	>4	11	[(9)]	ND	53
Scour protection	unknown	13	0	ND	77
Beach nourishment	>1[(5)]	13	0	86	68
Bank stabilisation	7	14	0	155	39
Measuring poles	0	9	0	0	0

2) in addition to the number given:
- Schleswig-Holstein: 364 km of primary seawalls, 44 km of secondary seawalls
- Niedersachsen: 610 km primary sea wall length

(3) including fascines and scour protection, 8 km of revetments, 1.3 km of walls

(4) Schleswig-Holstein: variety of cables and some pipelines between Holms/Islands and mainland including telecommunication, water supply and a total of 11 operational power cables

(5) In addition to number given Schleswig-Holstein – about 1 million m^3 per year

(6) Norway has around 800 public fishery harbours (480 out of these have breakwaters), around 60 public/national traffic terminals, 10 large offshore bases, and a countless number of private harbours and marinas, with or without breakwaters. All these on the coast.
(7) all are within the coastal zone.
(8) 3 cables @ 420 kV, 6 cables @ 300 kV, 2 cables @ 220 kV, 40 cables @ 132 kV, 46 cables @ 45 kV, 3 cables @ 33 kV and 39 cables @ 22 kV. Out of these, 5 cables are more than 1 mile off the coast.
(9) along the Norwegian coast there is a countless number of small and large slipways. No national overview. All causeways are within the coastal zone.
(10) the total coastline of Norway is 83281 lm long, and the local governments give permission to the overall amount of structures in the coastal zone. The national overview is therefore very limited.
(11) data for England and Wales between 2000 and 2006 only
(12) data for 2007 only – includes North Sea, Westerschelde and Wadden Sea

Sonar activity can not be assessed to date as information on military activities within Region II was not provided by the Contracting Parties.

Shipping activity might be very provisionally assessed in Region II. There is neither a JAMP assessment dealing specifically with this issue nor any other paper attempting to quantify shipping activity in the North Sea. However, Region II comprises of numerous lanes for a variety of carriers and it could be said that the activity level is high (see Figure 3).

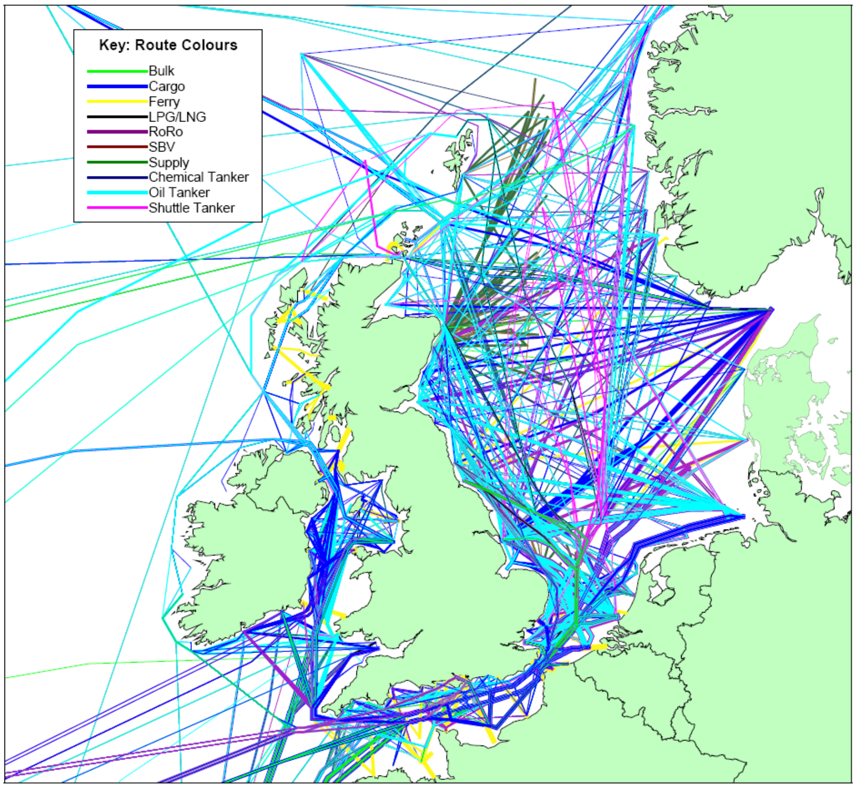


Figure 3: *Major shipping lanes in the North Sea. Source: Rijkswaterstaat, the Netherlands*

More specific information on vessel traffic in area II (Dutch EEZ and adjacent waters is given by Ainslie *et al*., 2009) as in Figure 4).

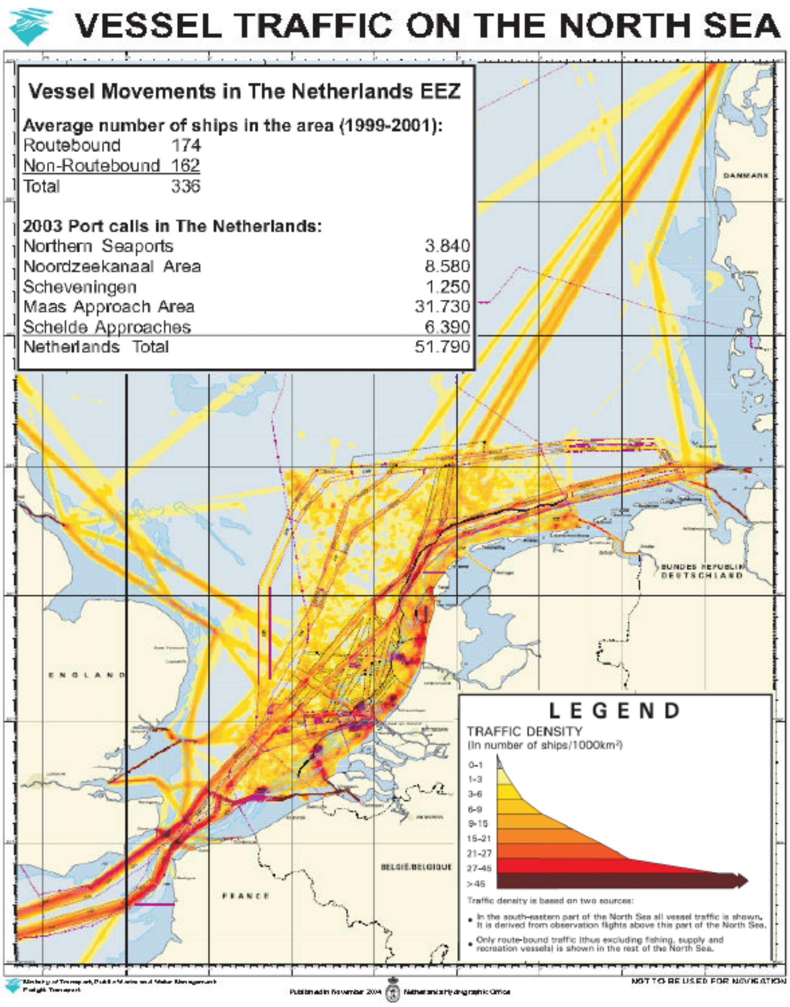


Figure 4.8. Overview of the vessel traffic on the North Sea. Map published by the Netherlands Hydrographic Office in 2004.

Figure 4: *Overview of the vessel traffic in the Dutch EEZ and adjacent waters (Ainslie et al., 2009)*

Other activities that generate noise in Region II are mariculture (AHDs on some fish farms off the United Kingdom East Coast) and the “Acoustic Communication Network for Monitoring of Underwater Environment in Coastal Areas (ACME)” (see module 8 of the background document for more details).

Type and scale of effect expected

Depending on the activity, the effects outlined for Region I on page 13 – 15 of this document and as outlined in module 4 – 8 of the background document, a variety of potential effects due to exposure of underwater noise are to be expected. These are summarised in Table 4. There is not enough data to date to make any more than very basic assumptions on the scale of potential effects.

Region III (Celtic Seas)

There are several sites for sand and gravel extraction off the United Kingdom West Coast, albeit the areas are less and smaller than compared with the East Coast. There was no further information on other locations of sites for aggregate dredging in the respective JAMP assessment (OSPAR, 2009d). According to the JAMP assessment on the impacts of dredging for navigational purposes (OSPAR, 2008b), there were eight areas dredged in maintenance dredging activities reported in the Celtic Seas off Ireland in the period 2003 – 2005, and 102 areas reported by the United Kingdom in the Celtic

Seas and greater North Sea. The activity might therefore be viewed as having a high level, pending more detailed information on the exact distribution of dredging sites.

According to the JAMP assessment on dumping of waste material (OSPAR, 2009b), activities related to this category (dumping according to number of dumpsites, capital dredging) are relatively high in Region III. The number of munitions dumped was smaller than that in Region II.

The E&P industry is active in Region III, both in terms of oil and gas platforms. There are five oil and gas platforms in Liverpool Bay and eight in the Eastern Irish Sea. Seismic surveys have been undertaken, in the United Kingdom part of Region III in May – June 2004 and May – August and October 2005 (ASCOBANS, 2005; ASCOBANS, 2006). However, the information is not sufficient to assess an activity level.

The JAMP assessment on the impacts of offshore wind farms gives a detailed analysis of this activity (for combined values on number of existing platforms and area size, see page 16). Nonetheless, it should be noted that plans for offshore wind farms in Region III have been rather confined to specific areas (Liverpool Bay and two near shore sites off the Irish East Coast), leading us to assess the activity level as medium.

Placement of structures, cables and pipelines, coastal defence structures and tourism have been given provisionally medium to high levels of activity in Region III but it should be noted that regional specific information was rarely supplied (see Table 3).

Based on the numbers of arrivals, Region III has more visitors to the coast each year than Region V and I, but less than II and IV (OSPAR, 2008c).

Mariculture is used in Region III by Ireland, France and the United Kingdom. The precise amount produced in this particular region can not be assessed, but activity levels can be very provisionally defined as high compared with other regions.

There is currently no quantifiable information on sonar and shipping activities within Region III. As can be seen however in Figure 3, there are a number of major shipping lanes placed in Region III indicating a high activity level for shipping.

Type and scale of effect expected

Depending on the activity, the effects outlined for Region I on page 13 – 15 of this document and as outlined in module 4 – 8 of the background document, a variety of potential effects due to exposure of underwater noise are to be expected. These are summarised in Table 4. There is not enough data yet to make any more than very basic assumptions on the scale of potential effects.

Region IV (Bay of Biscay and Iberian Coast)

Region IV can be characterised as diverse with regards to noisy activities, with some of them carried out at a comparably lower level than in other regions (especially Region II and III); others – mostly where noise is not the central issue (for example placement of artificial reefs) – are relatively high, and for a number of activities, no quantitative information was provided.

Sand and gravel extraction has a low-medium level of activity compared to other OSPAR regions: In France, extraction of marine aggregates only represents a small part, 1%, of the total national production. The amount of marine aggregates extracted has remained stable in recent years and is about 3 Mm^3/year. Extraction is restricted to a limited number of dredging areas in Normandy (Region II), Brittany and along the Atlantic coast (Region III). In Spain, beach nourishment is the only end-use for which extraction of marine sand from the Spanish continental shelf is permitted. Over 15Mm^3 of marine sediment has been dredged for this purpose along the North Atlantic Spanish coast between 1990 and 2005 including the Canary Islands. According to the JAMP assessment on the impacts of dredging for navigational purposes, there were 15 areas dredged in maintenance dredging activities reported in the Bay of Biscay and the Iberian Coast.

According to the overview of the amount and distribution of dumpsites in the OSPAR region, from the data that was available, France, Spain and Portugal combined, account for ~20 – 25% of all dumpsites, (see Figure 5). Based on what is stated in the JAMP assessment on munitions (OSPAR, 2009c), there are a relatively high number of dumpsites for conventional munitions in region IV.

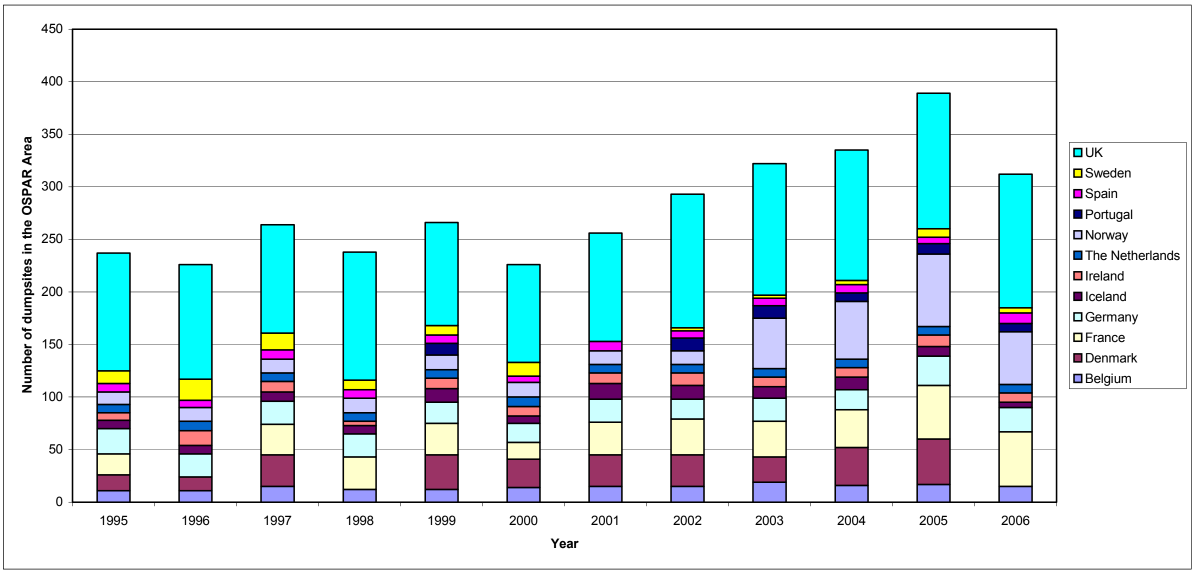


Figure 5. *Overview of the amount and distribution of dumpsites within the OSPAR area.*

Data on the E&P industry in region IV is sparse. There is currently no permanent platform in the Bay of Biscay, albeit there was one offshore drilling operation in 2007. Based on the information provided in Table 2, the activity level can be defined as low.

According to the respective JAMP assessment, there is currently no activity with regards to offshore wind farms in Region IV (OSPAR, 2008a).

Based on the information provided in Table 3, there are a relatively high number of structures and installations in region IV (OSPAR, 2008d). According to the respective JAMP assessment (OSPAR, 2009e), there are only a few submarine cables for telecommunications in Region IV and no power cables, however, the overview given is incomplete, constraining any comprehensive assessment on the level of activity for placement of underwater cables. There are 31 artificial reefs in Region IV (out of a total of 48). There seems to be only a small portion of the Spanish part of Region IV comprising coastal defence structures. Information on the use of coastal defence in the French part is lacking, so no assessment can be made.

Region IV welcomes the second highest number of visitors on its coasts from all OSPAR regions. The level of activity can, therefore, be viewed as relatively high.

Production values for mariculture are relatively high in Region IV. Still, there is no estimate on the use of deterrents in this region, hampering any conclusions on potential effects of underwater noise generated by mariculture.

Due to lack of data provided, no assessment on the activities of sonar and shipping with regards to Region IV can be made.

Type and scale of effect expected

Depending on the activity, the effects outlined for Region I on page 13 – 15 of this document and as outlined in module 4 – 8 of the background document, a variety of potential effects due to exposure to underwater noise are to be expected. These are summarised in Table 4. There is not enough data yet to make any more than very basic assumptions on the scale of potential effects.

Region V (wider Atlantic)

As indicated in Table 1, some human activities generating underwater noise in the other OSPAR regions are not carried out in Region V, for example sand and gravel extraction, dredging for navigational purposes, offshore wind farm construction and operation, deployment of artificial reefs, creation of coastal defence structures and mariculture. Others might be viewed as having a low level of activity compared with other OSPAR regions (for example tourism). So far, there is a lack of information on other noise generating activates (for example sonar, shipping, seismic surveys) that prohibit a comprehensive assessment of pressures with regards to underwater noise emission in region V. Depending on the activity, the effects outlined for Region I on page 13 – 15 of this document and as outlined in module 4 – 8 of the background document, a variety of potential effects due to exposure to underwater noise are to be expected. These are summarised in Table 4. There is not enough data yet to make any more than very basic assumptions on the scale of potential effects.

Conclusions and recommendation

From what has been stated above, it should be clear that there are gaps in our understanding of the scale of noisy activities within the OSPAR maritime area. It is also difficult to assess the scale of the potential effects of underwater noise. The above overview indicates, however, that pressures due to underwater noise emissions might be relatively high in Region II and III due to the comparably high amount of human activities therein. This might increase in the foreseeable future as these regions undergo even more development, for example, with the plans for offshore wind farms in Germany, the Netherlands and the United Kingdom in particular. It is important to identify the activities that are most likely to be problematic for marine life, for example the ones with highest acoustic energy emitted into the environment, and those where relatively low level noise is a mere by-product of the activity, such as placement of structures near shore or placement of artificial reefs. The activities analysed in the background document are of particular relevance here. Very little information is currently available on the overall level of activity, for example some E&P industry activities (except Regions II and III), sonar uses, and shipping. Updated assessment should aim at providing more data on a variety of noisy activities to aid in a more comprehensive assessment of the impacts of underwater noise on marine life in the OSPAR maritime area. It can be concluded however, that the Regions II and III seem to be most affected by noise-generating human activities. These have already affected marine life in parts of these regions. These and other potential effects should be further monitored and investigated. Increased efforts should be made to develop and apply effective mitigation measures to reduce the impact of underwater noise (of any source) on the marine environment in all regions.

What has been done?

What follows are excerpts from the respective chapters of the various JAMP assessments with regards to the regulation of human activities. These have been edited addressing noise related issues whenever information was available. In addition information on regulation and possible mitigation methods as given in the background document and other sources is provided.

Sand and gravel extraction (OSPAR, 2009d)

There are differences in approach for legislation and regulation of marine aggregate extraction in several countries. The general trend in legislation and regulation is that environmental issues are taken more and more into account in a formal way. The obligation to follow EIA procedures and to include EC directives in the managing of marine aggregate extraction is operational. Some countries have an overall marine legislation under which the marine aggregate extraction is regulated. Most countries have it regulated under national laws on extraction. Although legislation is national, in many countries regional authorities regulate extraction. Risk assessment is a promising instrument for regulation, but with regards to the extraction of marine sediments and the possible effects on the environment, it is still far from mature.

Dredging for navigational purposes (OSPAR, 2008b)

The respective JAMP assessment concludes that in most cases, the existing EU and national regulations will be sufficient to minimise adverse effects of dredging on marine species and habitats. Evaluation of the effectiveness of regulations and other measures, especially on protected areas, is recommended after the Contracting Parties have fully implemented the existing EU legislation. The JAMP assessment concludes that at present, there is no need to develop additional OSPAR measures to exercise, specifically, control on the effects of dredging operations on marine species and habitats.

Dumping of wastes (OSPAR, 2009b)

In general, dumping of dredged material is well managed by licences from national and local authorities. There are issues with regards to the impacts of material to be dumped, but these are largely irrelevant to the issue of disturbance due to underwater noise emission during the dumping process and during the transport (noise from vessels).

Exploration for oil and gas and placement of structures for the exploitation of oil and gas (correspondences and drafts)

The EC EIA Directive 85/337/EEC (as amended by 97/11/EC) requires Member States to adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects. According to the JAMP assessment on the extent, input and impact of offshore oil and gas activities (version 10/08), the OSPAR Commission has put in place a number of measures to reduce discharges from the oil and gas industry. However, there is little information on the applied regulation mechanisms during construction (pile driving) of oil and gas platforms. Information on regulation of seismic surveys is lacking from some Contracting Parties. In the United Kingdom EEZ, seismic surveys are regulated by the Department for Energy and Climate Change, and effects of underwater noise are taken into account in regulatory advice leading in some cases to seasonal and / or geographical restrictions (see background document, module 7, chapter 5). The Joint Nature Conservation Committee has further updated its guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (JNNC, 2009). The guidelines provide advice on the planning stage, on the application of a soft start procedure during surveys, the use of marine mammal observers and the application of passive acoustic monitoring techniques (PAM) as a mitigation measure.

In Norway seasonal restrictions on seismic surveys may be imposed in specific areas or included in the license conditions. Prior to each seismic survey the Norwegian Institute of Marine Research is doing a resource biological evaluation and recommendation and the Directorate of Fisheries is considering and advising in seasonal fishing periods in the area (see background document, module 7, chapter 5).

Offshore wind-farms (OSPAR, 2008a)

As for oil and gas, the EC EIA Directive 85/337/EEC (as amended by 97/11/EC) applies to offshore wind farms In line with the requirements of the Directive, an EIA is to be carried out in support of applications to develop certain types of project as listed in the Directive at Annexes I and II. Offshore wind farm developments are listed in Annex II as ‘installations for the harnessing of wind power for energy production (wind farms)’. Projects listed in Annex II shall be made subject to an assessment where Member States consider that their characteristics so require. Contracting Parties have decided that an EIA is necessary for the majority of offshore wind farm developments in the OSPAR area (OSPAR, 2007).

By following the EIA process, OSPAR Contracting Parties have been able to consent and construct offshore wind farm within their national waters (OSPAR, 2007). In this context the existing measures at the international level for EIA are sufficient and have been shown to work. However, the importance of guidance in the identification and assessment of impacts at both the international and national level has been highlighted.

National guidance has been, and is being developed to assist developers and regulators in the assessment and consenting process; examples include:

- Standards for Environmental Impact Assessments of Offshore Wind Turbines on the Marine Environment (StUK 3). Issued by Bundesamt für Seeschifffahrt und Hydrographie, February 2007 (Germany);
- Offshore Wind Farms – Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements. Version 2 – June 2004 (United Kingdom);
- Nature Conservation Guidance on Offshore Windfarm Development – A guidance note on the implications of the EC Birds (79/409/EEC) and Habitats (92/43/EEC) Directives for developers undertaking offshore windfarm developments. March 2005. Defra (United Kingdom);
- “Development of a framework for Appropriate Assessments of Dutch offshore wind farms” Issued by Deltares, 2008. (Prins *et al.,* 2008) (The Netherlands);
- Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor surveys in Irish Waters (Version 1.1) Issued by DEHLG August 2007.

OSPAR is also developing guidance to assist Contracting Parties with the assessment and consenting of offshore wind farm developments, in particular those that have yet to embark on the process of establishing offshore wind energy schemes. Guidance on location, construction, operation and removal of offshore wind farms has/is being produced and is currently being consolidated into a single guidance document to cover the whole life-cycle of an offshore wind farm.

Mitigation measures in place for offshore wind farm construction are, for example the use of deterrent sounds to chase animals away from an area where noise related impacts are likely to be high, the application of a soft start-procedure (gradually increasing the sound level to provide animals with time to leave the impact area), and the use of observers that scan a safety zone where no marine life (in this case marine mammals) should be present prior to activities. The application of these measures is likely to be very varied within the OSPAR region.

Placement of structures (other than oil and gas and wind-farms) (OSPAR, 2008d)

The European Commission EIA Directive 85/337/EEC (as amended by 97/11/EC) and Directive 2003/35/EC applies to some of the activities listed in Table 3. An EIA is mandatory for projects in Annex 1, which includes trading ports and also inland waterways and ports for inland waterway traffic which permit the passage of vessels over 1350 tonnes. Projects listed under Annex 2 require an EIA at the discretion of the local/national regulatory authorities and include:

- reclamation of land from the sea for agriculture;
- shipyards (for processing of metals); harbours (including fishing harbours); yacht marinas;
- canalisation and flood relief works;
- coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example of, dykes, moles, jetties and other sea defence works.

According to the respective JAMP assessment, which also addresses underwater noise during pile driving for construction activities ('Environmental Impact of the Construction or Placement of Structures other than Oil and Gas and Wind farms and including Artificial Islands'), appropriate mechanisms seem to be in place to control this activity in terms of the location, techniques and environmental effects in all Contracting Parties in all zones (intertidal, 0 – 12 miles and 12 – 200 miles) except that Ireland and Norway do not control the construction or placement of installations or structures within the 12 – 200 nautical mile zone. However, Ireland is considering legislation for that zone and Norway says that it has no activity within the zone except oil and gas activities.

Cables and pipelines (OSPAR, 2009e)

The EC EIA Directive 85/337/EEC (as amended by Directive 97/11/EC) does not require an environmental impact assessment for the placement of submarine cables. Nevertheless, in various countries application procedures are in place that include the requirement to compile an environmental impact assessment. For example, in Germany in the framework of the application procedure an EIA has to be provided (www.bsh.de). The respective permission will include specifications concerning cable routing, placement time, burial, design of the cable (for example no monopolar systems) *etc*.

Artificial reefs (OSPAR, 2009f)

There are a number of international (London Convention and London Protocol) and regional (OSPAR) conventions addressing the placement of artificial reefs. A number of Contracting Parties have national legislation which, although not specific for that purpose, is used to regulate artificial reef development. In most cases this includes a requirement for an Environmental Impact Assessment. The available information is summarised in the JAMP assessment on artificial reefs (Table 2, Annex C)and it should be noted that the emission of underwater noise during placement of an artificial reefs is probably negligible.

Coastal defence structures (OSPAR, 2009g)

The authorities responsible for design, construction and maintenance of coastal defence structures can belong to different administrations or institutions, such as: ministries of public works, ministries of the environment (often, both are united in the same ministry or department), often in cooperation with local authorities and research institutes. In France and in the United Kingdom, the responsibilities for coastal defence are shared between national and regional authorities on the one hand and land owners on the other hand. In Ireland, the role of local authorities is paramount though national funding is accompanied by some control of the national authority. National laws or principles on coastal defence are applied in all the countries south and east of the North Sea and in Spain. In France, local partnerships are responsible for coastal defence schemes, but they are funded by the central state when they follow the national regulations. The references to applicable regulations and principles adopted by the legislation are given in the questionnaire replies available at the OSPAR Secretariat. The EU countries refer to the national or regional implementation of EC regulations such as the EC EIA (85/337/EEC), Birds (79/409/EEC) and Habitats (92/43/EEC) Directives, and general ecological management principles that have systematically been incorporated in national laws.

Tourism (OSPAR, 2008c)

As indicated in Table 4, the tourism industry can create underwater noise in the form of recreational boating, cruise travelling and whale watching. There are no regulations explicitly to mitigate against underwater noise disturbance due to whale watching, but some guidelines are in place that will also have an effect on underwater noise emissions during this activity. Under the auspices of the Convention for Migratory Species, two regional marine agreements specific to cetaceans have been concluded: the 1992 Agreement for Small Cetaceans of the Baltic and North Seas (ASCOBANS, which has been amended to include the Seas around Ireland, Portugal and Spain), and the 1996 Agreement on the Conservation of Cetaceans of the Black and Mediterranean Seas and Contiguous waters (ACCOBAMS). At the first meeting of ACCOBAMS parties, a resolution providing a detailed code of conduct for whale-watching was passed. The consequences in practice of the “soft law” provided by such resolutions can only be gauged over time. The guidelines for whale watching agreed by the ACCOBAMS parties are unusual in that they are provided as an exemplary regime for states in the agreement area to follow. Some countries have developed specific legislation at this regard, for example Spain has approved Royal Decree 1727/2007, of 21st December, establishing protective measures for cetaceans. This basic tool has been enacted on the basis of the obligations assumed with the Convention on Biological Diversity (CBD). In Ireland, the Department of Communications, Energy and Natural Resources issued Marine Notice No. 15 of 2005 providing clear guidelines to all vessel operators (including recreational and charter craft) on correct procedures when encountering whales and dolphins in Irish coastal waters.

Mariculture (OSPAR, 2009h)

There is no specific information whether or not an EIA – including the use of acoustic deterrent devices – has to be carried out in planning a mariculture project.

Sonar

Module 6 of the background document lists details of a variety of mitigation measures currently in place to reduce potential effects from mid-frequency active sonar used by the navy in the United Kingdom, Norway, Netherlands and Italy. Since 2004, the Spanish Ministry of Defence has maintained a moratorium on the use of sonar at less than 50 nm from the Canary Islands. (see background document, chapter 5.6, paragraphs 79-87; 91-93).

Shipping (OSPAR, 2009k)

There is a reasonably long and successful history of quieting both surface and sub-surface military vessels to reduce their acoustic signature and thus vulnerability to detection by enemy passive acoustics. Additionally, commercial applications of ship quieting technology, are rapidly advancing in such areas as acoustic research vessel design, ferries, and environmentally-sensitive cruise ships. There are some commonalities in both of these quieting contexts, based purely on the physics of sound and constraints of vessel design, and many of the associated technologies focus on aspects of the propeller or other components of the propulsion systems. Reducing the overall noise level on board might also be beneficial to the ship’s crew and passengers, while the reduction of structural vibrations might be beneficial to the integrity and lifetime of the vessel. Additionally, there may also be tangible benefits in terms of efficiency and reduced fuel consumption associated with reduced propeller cavitation, to the extent that may be achieved, it will also reduce the overall radiated noise signature. Efforts at reducing noise are most effective when incorporated into the design of ships, though retrofitting of vessels may also be successful to varying degrees, though generally at much greater cost. Minimizing propeller cavitation across the range of operating conditions is likely to remain the primary focus in efforts to quiet large vessels, given the fact that other noise sources (for example machinery) will likely be overwhelmed by cavitation noise until considerable quieting treatments were applied. Efforts to reduce structure-borne noise may be facilitated by advances in electrical propulsion systems which, provided that measures have been taken to reduce interference frequencies in the power supply, can enable the main engine room to be positioned away from the propeller shaft to a location where it can be acoustically isolated from transmitting underwater sound more easily. Additionally, operational measures (for example routing and speed restrictions) could have positive outcomes in terms of ambient noise reduction in some areas. However, these must be carefully considered in the light of potential related impacts arising from modifying traffic schemes (for example possibly increasing noise in specific areas and possible impacts on the likelihood of vessel strikes). The relative costs and environmental benefits of either technological or operational mitigation measures related to vessel noise output are not well-known. However, the United States has recently submitted a proposal to the Marine Environment Protection Committee of the International Maritime Organization to explicitly consider this international matter and consider a global strategy to address it.

Mitigation methods

As described above, a number of mitigation methods have been developed and applied or are being considered in the OSPAR Maritime Area to reduce potential impacts of underwater noise emitted by the different anthropogenic activities in the marine environment. Among the most effective mitigation measures, however, are geographical and seasonal restrictions to avoid ensonification of sensitive species and habitats. Sound-producing activities can be designed to avoid areas and/or times where/when sensitive marine mammals and other species are usually engaged in susceptible activities such as mating, breeding, feeding, or migration.

Mitigation methods applied within the OSPAR area are:

- criteria and levels for noise exposure that should not be exceeded;
- areas of risk within which for example no marine mammal should be present during sound intensive activities, and the provision of practical measures to ensure that no sensitive species enters the area of risk, including for example:
    - acoustic harassment devices;
    - 'soft-start/ramp-up' procedures by slowly increasing the energy of the emitted sounds;
    - passive acoustic monitoring (PAM) and/or marine mammal observers (MMO); and
    - shutting-down of source(s) whenever marine mammals enter the area of risk.

Other mitigation methods, not yet applied, but under consideration / development are

- quieting ship propeller systems;
- installation of air-bubble curtains;
- vibration techniques for pile-driving;
- enclosing the ramming pile with acoustically-isolated material during pile-driving;
- chemical/thermal neutralization of dumped munitions instead of controlled explosions.

In any case, the appropriateness and effectiveness of these measures need to be monitored. Further details on mitigation measures for the various noise generating human activities are provided in Modules 3 – 8 of the background document.

Did it work?

It is currently difficult to provide a quantified evaluation of the effectiveness and adequacy of the measures taken and planned for the protection of the marine environment against effects from underwater noise. One has to bear in mind that - besides EIA and Habitats regulations – there is little regulation specifically addressing underwater noise yet, and it is therefore difficult to assess its effectiveness. One of the reasons for this is that there are still gaps in our understanding on the effects of underwater noise on marine life. There is evidence that some of the activities generate noise that is potentially harmful to marine mammals, fish and some marine invertebrates. The exact nature of the effects (TTS, masking, behavioural response) are not fully understood nor are the consequences at a population level from acoustic disturbance. The poor understanding of effects means that any regulation and mitigation measures are likely to be based on precaution. This makes it urgent to gather data on the effects of underwater noise in order to apply appropriate regulation / and or mitigation measures.

How does this field affect the overall quality status?

It is clear from this assessment and the background document that man made underwater noise has the potential to affect marine life in various ways, in some cases over relatively large areas and time scales. It is difficult to assess to what degree the introduction of man-made noise affects the overall quality status as there is very little data to allow us to quantify noise levels across the OSPAR area. However, most of the intensities of anthropogenic sounds listed in Table 1 exceed the ambient sounds in the marine environment by several order of magnitude that occur naturally, such as sounds that are induced by rain, wind and waves. Some episodically occurring events, such as sub-sea volcanic eruptions, earthquakes and lightning strikes, produce sounds that reach intensities comparable to those of the listed human activities. Biological sounds such as vocalisations of marine mammals, fish and certain crustaceans may reach high intensities too. However, in the case of biosonar, the emitted sound is highly directional and the chances of being 'hit' are less than when compared to man-made sonar (Møhl, 2003). Furthermore, many biological sounds are seasonal and the seas are therefore not *per se* a noisy environment. Finally, man made sound adds to the sound that is already out there and it can't be ruled out that even moderate levels are enough to increase ambient noise profiles considerably (Ross, 1993; NRC 2003; McDonald et al., 2006); see also background document).

As outlined in previous sections and also indicated in Table 4, underwater noise can have a range of impacts on marine life such as injury, permanent or temporary hearing loss, behavioural responses and masking of biological relevant signals. However, there are many uncertainties in assessing effects of noise due to the difficulties in observing individual or population level effects. Some negative effects might be countered by marine life (for cetaceans see Miller *et al*., 2000; Foote *et al*., 2004), yet, the costs of these counter-strategies are still unknown.

From a conservation perspective, it is important to assess whether anthropogenic sound has a significant effect on populations. It is also important in assessing the impacts of noise in relation, or addition to other stressors, either to assess cumulative impacts and / or to focus protection efforts. A number of anthropogenic activities exist which have proven to have a substantial effect on marine mammals. Among the most important is the by-catch of cetaceans in fisheries which cause the mortality of several hundreds of thousands of animals per year (Read *et al.,* 2006). Other factors include the depletion of fish stocks thus reducing prey availability or shift of prey species and chemical pollution (reviews for marine mammals in Perrin *et al.,* 2002). That doesn't mean that stressors have to be weighted against each other. The obvious conclusion is that all factors impacting on populations are cumulative and must be assessed together but there is currently no information available on the cumulative effects of the factors listed above. No agreed assessment framework for cumulative effects of diverse human activities exists to date.

What do we do next?

Research including behavioural and auditory studies, monitoring of the distribution, both of the noise sources and of relevant species, and investigation of anthropogenic sound budgets will be needed to improve our understanding of the effects of underwater sound on marine life.. Furthermore there is an urgent need for standardisation of methodologies to study the impact of sound on marine species over larger spatial scales. OSPAR can assist in the sharing of knowledge and understanding between Contracting Parties and other international organisations (for example International Maritime Organisation), the coordination of data and measures specific to the OSPAR regions (appropriate to future Quality Status Reports and the Marine Strategy Framework Directive (2008/56/EC)), standardisation of measurements (for example guidelines on data collection methodologies). One of the first priorities should be to update the information provided here in further assessments, including data on important contributors to underwater noise such as military sonar and shipping.

Looking at the issue of effects of underwater sound in more general terms, (Southall *et al.,* 2007 and IACMST, 2006) provide a detailed list of recommendations for future research. There are several areas where research on the effects of underwater noise on marine mammals could be considered. Some of them are:

- Standardisation of measurement units;
- Further development and use of mathematical models for underwater sound transmission;
- Acoustic measurements of relevant sound sources: detailed measurements of source levels, frequency content, and radiated sound field around intense and / or chronic noise sources;
- Ambient noise measurements: systematic measurements of underwater ambient noise to quantify how human activities are affecting the acoustic environment. Exploration of ambient noise maps;
- Hearing measurements: much more autographic data (sensitivity of individuals vs. frequency of sound) is needed both for marine fish and marine mammals to assess impacts;
- Behavioural responses to sound exposure: measurements of behavioural reactions to various underwater sound types are urgently needed to establish more robust cause-effect relationships;
- Effects of sound exposure on hearing: masking, PTS and TTS. It is necessary to further investigate the physiological effects of underwater noise;
- Establishment of standardised protocols for testing the extent to which sources radiate sound in the marine environment. This needs to include a system for collecting data in appropriate formats, to be used in future models predicting ambient noise in the seas;
- The applicability of existing regulations and treaties for the protection of the marine environment should be investigated specifically to cover underwater sound. Where necessary, amendments should be proposed;
- Building of a modern regulatory, risk based framework relating to noise in the marine environment. This should be based on existing legislation and the application of the precautionary principle. Its purpose should be to provide agreed impact / harm criteria, eliminate confusion over terminology, and enable more consistent mitigation measures;
- Testing the efficiency of mitigation methods (for example soft start).

In the meantime increased efforts should be made to develop and apply effective mitigation measures to reduce the impacts of underwater noise (of any source) on marine life. The most effective mitigation measures are geographical and seasonal restrictions to avoid ensonification of sensitive species and habitats. Sound-producing activities may be planned in a way to avoid areas and/or times where/when sensitive marine mammals and other species are usually engaged in susceptible activities such as mating, breeding, feeding or migration. Mitigation measures have to be selected and designed on a case-by-case basis. It should be realized that no single mitigation method alone might be sufficient. In particular for all those activities for which scientific information are not sufficiently available yet, the measures should be precautionary, and a suitable combination of options may be chosen. For further information and details, please refer to the section “What has been done” and Background Document (Module 3, Chapter 4 – 8).

OSPAR guidance on measures to mitigate emissions and the environmental impacts of underwater noise on the marine environment should be developed. This guidance should include the description of appropriate mitigation methods (best available technologies, best environmental practices) that could/should be deployed concerning the different noise generating human activities. The purpose of the guidance should be to assist OSPAR Contracting Parties and any other interested party in their efforts to reduce potentially negative effects of anthropogenic noise on the marine environment. Relevant related work of other frameworks and fora (for example ASCOBANS; ACCOBAMS) should be taken into account when developing this OSPAR guidance.

***Table 4.** Overview of human activities generating noise with a rough estimate on relative levels of activities and type and scale of potential effects on marine life (+: low level of activity; ++: medium level of activity; +++: high level of activity: scale of effects: short range: in close vicinity of the activity or area activity is carried out; long range: beyond the activity area (depending on species and activity; details see paragraph 10; *Insufficient data for a firm assessment).*

Region	Activity	Noisy source	BD	Parameter	Activity Level	Potential effects on marine life (range)
I	Sand and gravel extraction	Dredger, ship engine	4,5	Number of sites, amount of material dredged	-	Masking, behavioural response (long)
I	Dredging for navigational purposes	Dredger, ship engine	4,5	Number of sites, amount of material dredged	n.i.	Masking, behavioural response (long)
I	Dumping of wastes	Ship engine	5	Number of dumpsites	++*	Masking, behavioural response (long)
I	Dumped munitions	Ship engine, explosion	4,5	Number and location of sites	+	Ship: Masking, behavioural response (long); Explosion: Death (short), PTS, TTS (short), behavioural response (long)
I	E&P industry: exploration	Ship engine, airgun array	5, 7	km surveyed / year	n.i.	Ship: Masking, behavioural response (long), Airgun: PTS (short), TTS (short), behavioural response (long)
I	E&P industry: production	Drilling, drillship engine	4,5	Number of platforms	++	Masking, behavioural response (long)
I	Offshore wind farm construction	Pile driving	4	Number of sites/ turbines authorised	-	Death (fish, short); PTS (short), TTS (short) behavioural response (long)
I	Offshore wind farm operation	Operational noise, maintenance ships	4,5	Number of wind farms and turbines	-	Masking , behavioural response (short)
I	Placement of structures	Pile driving, ship engines, hammering *etc.*	4,5	Number of installations	++*	Death (fish, short); PTS (short), TTS (short), behavioural response (long)
I	Cables and pipelines	Ship engine, cable trenching	5	Number of cables	+	Ship: Masking, behavioural response (long); Trenching: masking behavioural response (short)
I	Artificial reefs	Ship engine, placement of reef	5	Number of areas	+	Ship: Masking, behavioural response (long).
I	Coastal defence structures	Construction activities	-	Length of coast protected	-	Undefined
I	Tourism	Whale watching ship engine,	5	Number of arrivals / bedplaces	+	Masking, behavioural response; (long).

Region	Activity	Noisy source	BD	Parameter	Activity Level	Potential effects on marine life (range)
		recreational boat engine, cruise ship engine				
I	Mariculture	Deterrent and harassment devices	8	Production values	+++	Behavioural response (short-long)
I	Sonar (military, private, research)	Ship engine, sonar ping	5,6		n.i.	Ship: Masking, behavioural response (long); sonar: PTS (short), TTS (short), behavioural response (long)
I	Shipping	Ship engines	5		n.i.	Ship: Masking, behavioural response (long)
I	Other activities (research, data transmission.)	Boat / ship engines, acoustic devices *etc.*	5,8		n.i.	Masking, behavioural response, range unknown
II	Sand and gravel extraction	Dredger, ship engine	4,5	Number of sites, amount of material dredged	+++	Masking, behavioural response (long)
II	Dredging for navigational purposes	Dredger, ship engine	4,5	Number of sites, amount of material dredged	+++	Masking, behavioural response (long)
II	Dumping of wastes	Ship engine	5	Number of dumpsites	+++	Masking, behavioural response (long)
II	Dumped munitions	Ship engine, explosion	4,5	Number and location of sites	++	Ship: Masking, behavioural response (long); Explosion: Death (short), PTS, TTS (short), behavioural response (long)
II	E&P industry: exploration	Ship engine Airgun array	5, 7	km surveyed / year	+++*	Ship: Masking, behavioural response (long), Airgun: PTS (short), TTS (short), behavioural response (long)
II	E&P industry: production	Drilling, drillship engine	4,5	Number of platforms	+++	Masking, behavioural response (long)
II	Offshore wind farm construction	Pile driving	4	Number of sites/ turbines authorised	+++	Death (fish, short); PTS (short), TTS (short) behavioural response (long)
II	Offshore wind farm operation	Operational noise, maintenance ships	4,5	Number of wind farms and turbines	+++	Masking , behavioural response (short)
II	Placement of structures	Pile driving, ship engines, hammering *etc.*	4,5	Number of installations	+++*	Death (fish, short); PTS (short), TTS (short), behavioural response (long)
II	Cables and pipelines	Ship engine, cable trenching	5	Number of cables	+++	Ship: Masking, behavioural response (long); Trenching: masking behavioural response (short)

Region	Activity	Noisy source	BD	Parameter	Activity Level	Potential effects on marine life (range)
II	Artificial reefs	Ship engine, placement of reef	5	Number of areas	++	Ship: Masking, behavioural response (long).
II	Coastal defence structures	Construction activities	-	Length of coast protected	+++	Undefined
II	Tourism	Whale watching ship engine, recreational boat engine, cruise ship engine	5	Number of arrivals / bedplaces	+++	Masking, behavioural response; (long).
II	Mariculture	Deterrent and harassment devices	8	Production values	+++	Behavioural response (short-long)
II	Sonar (military, private, research)	Ship engine, sonar ping	5,6		n.i.	Ship: Masking, behavioural response (long); sonar: PTS (short), TTS (short), behavioural response (long)
II	Shipping	Ship engines	5		+++*	Ship: Masking, behavioural response (long)
II	Other activities (research data transmission)	Boat / ship engines, acoustic devices *etc.*	5,8		++*	Masking, behavioural response, range unknown
III	Sand and gravel extraction	Dredger, ship engine	4,5	Number of sites, amount of material dredged	++	Masking, behavioural response (long)
III	Dredging for navigational purposes	Dredger, ship engine	4,5	Number of sites, amount of material dredged	+++	Masking, behavioural response (long)
III	Dumping of wastes	Ship engine	5	Number of dumpsites	+++*	Masking, behavioural response (long)
III	Dumped munitions	Ship engine, explosion	4,5	Number and location of sites	+++	Ship: Masking, behavioural response (long); Explosion: Death (short), PTS, TTS (short), behavioural response (long)
III	E&P industry: exploration	Ship engine, airgun array	5, 7	km surveyed / year	++	Ship: Masking, behavioural response (long), Airgun: PTS (short), TTS (short), behavioural response (long)
III	E&P industry: production	Drilling, drillship engine	4,5	Number of platforms	++	Masking, behavioural response (long)
III	Offshore wind farm construction	Pile driving	4	Number of sites/ turbines authorised	++	Death (fish, short); PTS (short), TTS (short) behavioural response (long)
III	Offshore wind farm operation	Operational noise, maintenance ships	4,5	Number of wind farms and turbines	++	Masking, behavioural response (short)

Region	Activity	Noisy source	BD	Parameter	Activity Level	Potential effects on marine life (range)
III	Placement of structures	Pile driving, ship engines, hammering *etc.*	4,5	Number of installations	+++*	Death (fish, short); PTS (short), TTS (short), behavioural response (long)
III	Cables and pipelines	Ship engine, cable trenching	5	Number of cables	++	Ship: Masking, behavioural response (long); Trenching: masking behavioural response (short)
III	Artificial reefs	Ship engine, placement of reef	5	Number of areas	+	Ship: Masking, behavioural response (long).
III	Coastal defence structures	Construction activities	-	Length of coast protected	+++	Undefined
III	Tourism	Whale watching ship engine, recreational boat engine, cruise ship engine	5	Number of arrivals / bedplaces	++	Masking, behavioural response; (long).
III	Mariculture	Deterrent and harassment devices	8	Production values	+++	Behavioural response (short-long)
III	Sonar (military, private, research)	Ship engine, sonar ping	5,6		n.i.	Ship: Masking, behavioural response (long); sonar: PTS (short), TTS (short), behavioural response (long)
III	Shipping	Ship engines	5		++*.	Ship: Masking, behavioural response (long)
III	Other activities (research data transmission.)	Boat / Ship engines, acoustic devices *etc.*	5,8		n.i.	Masking, behavioural response, range unknown
IV	Sand and gravel extraction	Dredger, ship engine	4,5	Number of sites, amount of material dredged	+-++*	Masking, behavioural response (long)
IV	Dredging for navigational purposes	Dredger, ship engine	4,5	Number of sites, amount of material dredged	+-++*	Masking, behavioural response (long)
IV	Dumping of wastes	Ship engine	5	Number of dumpsites	++*	Masking, behavioural response (long)
IV	Dumped munitions	Ship engine Explosion	4,5	Number and location of sites	+++	Ship: Masking, behavioural response (long); Explosion: Death (short), PTS, TTS (short), behavioural response (long)
IV	E&P industry: exploration	Ship engine, airgun array	5, 7	km surveyed / year	n.i.	Ship: Masking, behavioural response (long), Airgun: PTS (short), TTS (short), behavioural response (long)

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IV	E&P industry: production	Drilling, drillship engine	4,5	Number of platforms	+*	Masking, behavioural response (long)
IV	Offshore wind farm construction	Pile driving	4	Number of sites/ turbines authorised	-	Death (fish, short); PTS (short), TTS (short) behavioural response (long)
IV	Offshore wind farm operation	Operational noise, maintenance ships	4,5	Number of wind farms and turbines	-	Maskin , behavioural response (short)
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IV	Cables and pipelines	Ship engine, cable trenching	5	Number of cables	+*	Ship: Masking, behavioural response (long); Trenching: masking behavioural response (short)
IV	Artificial reefs	Ship engine, placement of reef	5	Number of areas	+++	Ship: Masking, behavioural response (long).
IV	Coastal defence structures	Construction activities	-	Length of coast protected	n.i.	Undefined
IV	Tourism	Whale watching ship engine, recreational boat engine, cruise ship engine	5	Number of arrivals / bedplaces	+++	Masking, behavioural response; (long).
IV	Mariculture	Deterrent and harassment devices	8	Production values	+++*	Behavioural response (short-long)
IV	Sonar (military, private, research)	Ship engine, sonar ping	5,6		n.i.	Ship: Masking, behavioural response (long); sonar: PTS (short), TTS (short), behavioural response (long)
IV	Shipping	Ship engines	5		n.i.	Ship: Masking, behavioural response (long)
IV	Other activities (research data transmission.)	Boat / ship engines, acoustic devices *etc.*	5,8		n.i.	Masking, behavioural response, range unknown
V	Sand and gravel extraction	Dredger, ship engine	4,5	Number of sites, amount of material dredged	-	Masking, behavioural response (long)
V	Dredging for navigational purposes	Dredger, ship engine	4,5	Number of sites, amount of material dredged	-	Masking, behavioural response (long)
V	Dumping of wastes	Ship engine	5	Number of dumpsites	+*	Masking, behavioural response (long)

Region	Activity	Noisy source	BD	Parameter	Activity Level	Potential effects on marine life (range)
V	Dumped munitions	Ship engine, explosion	4,5	Number and location of sites	+	Ship: Masking, behavioural response (long); Explosion: Death (short), PTS, TTS (short), behavioural response (long)
V	E&P industry: exploration	Ship engine, airgun array	5, 7	km surveyed / year	n.i.	Ship: Masking, behavioural response (long), Airgun: PTS (short), TTS (short), behavioural response (long)
V	E&P industry: production	Drilling, drillship engine	4,5	Number of platforms	n.i.	Masking, behavioural response (long)
V	Offshore wind farm construction	Pile driving	4	Number of sites/ turbines authorised	-	Death (fish, short); PTS (short), TTS (short) behavioural response (long)
V	Offshore wind farm operation	Operational noise, maintenance ships	4,5	Number of wind farms and turbines	-	Masking, behavioural response (short)
V	Placement of structures	Pile driving, ship engines, hammering *etc.*	4,5	Number of installations	+ (Azores)	Death (fish, short); PTS (short), TTS (short), behavioural response (long)
V	Cables and pipelines	Ship engine, cable trenching	5	Number of cables	+-++	Ship: Masking, behavioural response (long); Trenching: masking behavioural response (short)
V	Artificial reefs	Ship engine, placement of reef	5	Number of areas	-	Ship: Masking, behavioural response (long).
V	Coastal defence structures	Construction activities	-	Length of coast protected	-	Undefined
V	Tourism	Whale watching ship engine, recreational boat engine, cruise ship engine	5	Number of arrivals / bedplaces	+	Masking, behavioural response; (long).
V	Mariculture	Deterrent and harassment devices	8	Production values	-	Behavioural response (short-long)
V	Sonar (military, private, research)	Ship engine, sonar ping	5,6		n.i.	Ship: Masking, behavioural response (long); sonar: PTS (short), TTS (short), behavioural response (long)
V	Shipping	Ship engines	5		n.i.	Ship: Masking, behavioural response (long)
V	Other activities (research data transmission.)	Boat / ship engines, acoustic devices *etc.*	5,8		n.i.	Masking, behavioural response, range unknown

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ISBN : 978-1-906840-76-1
Publication Number: 436/2009