Agenda Item 3.2.2

Review of New Information on Threats to Small Cetaceans

Underwater Noise

Reports from Parties

Information Document 3.2.2.a

Concept for the Protection of Harbour Porpoises from Sound Exposures during the Construction of Offshore Wind Farms in the German North Sea

Action Requested

- Take note

Submitted by

Germany

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Secretariat's Note

The original, official and binding version of the Sound Protection Concept is in German. The English version has been prepared for international information.

Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

Concept for the Protection of Harbour Porpoises from Sound Exposures during the Construction of Offshore Wind Farms in the German North Sea (Sound Protection Concept)

Contents

1. Introduction

With the Energy Concept adopted in 2010 and its decisions on the transformation of Germany's energy system taken in June 2011, the German Federal Government has put forward for the first time a comprehensive strategy for the expansion of renewable energies in the decades to come. The intention is for the share of Germany's power supply provided by renewables to rise to at least 35% by 2020, and for them to become the main pillar of the country's energy supply by 2050, backed up with major progress in improving energy efficiency. Wind energy will be the cornerstone of the power system of the future. In particular, offshore wind energy holds out a great deal of potential for the future, given the high levels of capacity utilisation demonstrated at the turbines that have been installed to date.

However, the development of offshore wind energy is currently lagging markedly behind the original expectations. The German Federal Government has taken a large number of measures that will allow offshore wind energy to be expanded further. They include the decisions to give the transmission grid operators responsibility for grid connections, the KfW banking group's lending programme, the 'acceleration model', under which generators are paid a higher feed-in tariff for a shorter period of time, and the regulation of liability issues that had previously been unclear concerning delays in the expansion of the grid and interruptions to grid availability. At the moment, work is being done to expand the 2013 Offshore Grid Development Plan (O-NEP), which prioritises the measures for the connection of wind farms set out in the Spatial Offshore Grid Plan. The O-NEP is updated annually and forms an essential part of the framework put in place for the gradual expansion of offshore wind energy.

The Concept for the Protection of Harbour Porpoises from Sound Exposures during the Construction of Offshore Wind Farms in the North Sea (Sound Protection Concept) presented in this document is intended to foster greater clarity with regard to the requirements placed on the construction of offshore wind farms by nature conservation law. This is also being done with a view to the goal set by the German Federal Government that the construction and use of renewable energy facilities should not be pursued at the expense of biological diversity (cf. National Strategy on Biological Diversity, 2007). The Sound Protection Concept therefore takes account of the precautionary principle.

The basis for the Sound Protection Concept is the evidence that has been gathered about the impacts of the use of offshore wind energy on harbour porpoises. It is rooted, in particular, in the new and more detailed findings of the ecological research that has accompanied the construction and operation of the first offshore wind farms. In order to close the gaps that exist in our knowledge with regard to the possible impacts of offshore wind energy on the marine environment, extensive funding has been made available by the German Federal Environment Ministry (BMU) for parallel ecological research activities. In the years 2001 to 2012, more than 40 individual projects were carried out in this field with total funding worth more than €27m. In the course of these projects, it has become apparent, in particular, that the underwater noise generated by the driving of pile foundations for offshore wind farms can have significant impacts on marine mammals. Individuals can be damaged or whole populations suffer significant adverse impacts, the implication of which is that restrictions under nature conservation law need to be taken into consideration in this field.

The Sound Protection Concept takes account of the specific national conditions that pertain to the expansion of offshore wind energy. For reasons of nature conservation law, shipping law and concerns about tourism, offshore wind farms can only be constructed in the German North Sea at a large distance from the coastline and in accordingly deep water, which has direct effects on the scale of the sound immissions.

This Concept for the assessment of the ecological impacts of underwater sound during the construction of offshore wind farms is intended to create greater security for all parties in future with regard to the interpretation of the imprecise legal terms found in the relevant nature conservation standards ('injury' and 'significant disturbance' in the context of the prohibitions on taking under species protection law, 'significant adverse impact' in the context of site protection). It is intended to give the developers of offshore wind farms guidance concerning the application of these standards during the construction phase as early as possible in their very long planning processes. This will make it possible for the requisite organisational or technical measures for sound protection to be integrated into planning processes early on, so allowing costs to be minimised. The Concept does not replace or modify any requirements or procedural steps under nature conservation law, such as that of the Appropriate Assessment under the Habitat Directive, but is intended to offer assistance in the interpretation of the requirements of harbour porpoise protection.

The Concept will take effect as of 1 December 2013 as a basis for the assessment of projects that have not been approved up until this point. In view of the still limited impacts of the first construction phase of offshore wind energy to date and in the interests of a reliable basis for planning, the intention is that it should establish a fair balance between the protection of harbour porpoises and the development of offshore wind energy.

In the period between November 2012 and June 2013, consultations on the Concept were held twice with representatives of the offshore wind power industry and the nature conservation associations, and once with the coastal Länder. It has been further developed into its current form on the basis of the comments that were received.

2. Scope, delimitation and updating of the Sound Protection Concept

In this Sound Protection Concept, the harbour porpoise is treated as an indicator species for the assessment of the impacts of exposure to underwater sound on marine mammals because to date there has not been enough scientific evidence available concerning the problems of sound protection in relation to other marine mammals and, in particular, other species groups (e.g. fish) that would be sufficient to underpin the development of a sound protection concept for these other species.

The Concept only deals with the German Exclusive Economic Zone (EEZ) in the North Sea, for which the German Federation possesses immediate competence. The geographical limitation to the North Sea is necessary because no comparable data are available at the moment on the occurrence and distribution of harbour porpoises in the German Baltic Sea. Without this information, however, the requisite technical basis is lacking for the species to be incorporated conceptually in an appropriate manner into a sound protection concept that is intended, and able, to lay claim to validity for the Baltic Sea. It is therefore not possible for this Concept to be applied to the Baltic Sea.

Furthermore, only the generation of sound and exposure to noise during the construction of the foundations for offshore wind farms (wind turbines, transformer stations) and converter stations are dealt with within the framework set out in this Concept. The Concept addresses the cumulative effects caused by the multiple sound emissions from pile driving operations that usually involve more than a thousand strikes and the cumulative effects due to simultaneous activities at several construction sites. On account of the lack of data available, however, other sound sources that (may) lead to noise exposures, such as the noises emitted by offshore wind turbines during operation, noise from shipping activity, civilian and military sonar systems, and seismic explorations, are not examined in this Sound Protection Concept in terms of either their direct or their cumulative effects. Nevertheless, where they are known, the corresponding cumulative effects caused by these and other possible sound sources must be taken into consideration on a case-by-case basis as part of the Appropriate Assessment of projects' environmental impacts under the Habitats Directive provided for in Section 34(1) of the Federal Nature Conservation Act (BNatSchG), as is the case for all projects, including offshore wind turbines.

The complete coverage of the marine waters in Germany with their total spectrum of species, and the coverage of the entirety of sound sources and possible forms of noise pollution have been addressed in a European context (Marine Strategy Framework Directive).

The scientific evidence about the topics that are relevant here, such as the impacts of noise on harbour porpoises, the propagation of sound in the sea and foundation technologies, is based on recent advances in knowledge that are attributable, above all, to the experience gained from the construction of offshore wind farms in recent years and to the associated research projects funded by the Federal Environment Ministry. However, it may be assumed that even more will be learned over the next few years. In consequence, it will be indispensable for this Sound Protection Concept to be reviewed regularly and adjusted to take account of the latest findings.

Following an account of the ecology and conservation status of the harbour porpoises in the North Sea, this document discusses state-of-the-art foundation technologies and sound mitigation measures. Subsequently, the impacts of impulsive sound on harbour porpoises are set out. The last part of this document elaborates conventions for the assessment of the legal concepts found in nature conservation law that are to be formulated in concrete terms in this context.

3. Ecology and conservation status of the harbour porpoise

The population of harbour porpoises in the German marine waters of the North Sea is subject to major variations from year to year and is stated to be 55,000 animals. Harbour porpoises occur throughout the year in the German North Sea, but exhibit seasonal 'hot spots' in their spatial distribution (GILLES *ET AL.* (2008), (2009a)). In the spring, such hot spots are found off the Lower Saxon coast on the Borkum Reef Ground, while there is another area of high density on the Sylt Outer Reef. The major surveys of 2002-2006 found that the total population at this time was 55,000 animals (n=55,048). In the summer months and the main breeding season, harbour porpoises continue to occur extensively with just one pronounced hot spot area on the Sylt Outer Reef. During these months, the population in the German North Sea is 50,000 individuals (n=49,687). The most recent area-wide survey in June/July 2009 found no significant deviations from these population levels, counting 54,227 animals (95% confidence interval 30,079 – 104,186, coefficient of variation (CV) =0.32) (GILLES *ET AL.* (2010)). In the autumn, the harbour porpoise population falls to 15,394 individuals (CV=0.33), and no recognisable population hot spots are evident. So far, the data published have been insufficient for an estimate of the population in the winter months to be attempted, but a large proportion of the animals evidently leave the German marine areas.

The harbour porpoises of the German North Sea belong to the subpopulation of the central and southern North Sea (EVANS, P. G. H. AND TEILMANN, J. (EDS.) (2009), INTERNATIONAL WHALING COMMISSION (2000)). For this reason and on account of the strong seasonal dynamics that have been described, the whole harbour porpoise population of the German North Sea is to be regarded as a local population that cannot be further subdivided.

According to recent findings, a female animal has approx. four to six calves during its lifetime (usually eight to ten years, rarely more than twelve years). In the North Sea, harbour porpoises give birth in the period from May to July (after an approx. ten to eleven month pregnancy). Renewed mating takes place immediately after the birth through to the beginning of August. The infants are nursed from the point of birth to the age of approx. eight to ten months. Harbour porpoises therefore find themselves in their reproduction and rearing period all year round.

Within the year-round breeding and rearing period, there is a particularly sensitive phase from May to August in the North Sea, during which disturbances have particularly high potential to worsen the conservation status of the local population because its reproductive success is immediately affected. This period includes the last few weeks before birth, the birth itself, the phase during which a stable mother-infant bond is formed and the parallel mating phase.

Harbour porpoises are classified as endangered on Germany's Red List (2009).

The harbour porpoise is a species of Community interest. It is included in both Annex II of the Habitats Directive (HD) (as a non-priority species for which Natura 2000 sites are to be designated) and Annex IV, which lists species for which a system of strict protection is to be established under Articles 12 ff. In German nature conservation law, it is covered by the provisions on site protection set out in Sections 32 ff. of the BNatSchG and the provisions on species protection set out in Sections 44 ff. of the BNatSchG (strictly protected species).

The conservation status of the harbour porpoise in the Atlantic Biogeographical Region (North Sea) is described as 'Unfavourable-Inadequate' in the German Federal Government's 2013 report under Article 17 of the Habitats Directive (cf. also GERMAN FEDERAL GOVERNMENT (2007)).

According to the Bern Convention and Annex II to the Convention, the harbour porpoise is one of the species that are to be strictly protected. Under the auspices of the Bonn Convention, a special Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) has been concluded in order to protect small cetaceans (which include harbour porpoises). In the Agreement, the Parties made comprehensive commitments to protect and preserve these species.

The harbour porpoise is included in the lists of threatened and declining species and biotopes administered by the commissions of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and the Convention on the Protection of the Marine Environment of the Baltic Sea (HELCOM).

4. Foundation technologies for offshore wind farms, sound emissions and sound mitigation technologies

4.1. Foundation technology

When it comes to the foundations for offshore wind turbines, three types of foundations can be distinguished: foundations that are anchored in the seabed with piles or other supporting structures, foundations positioned on the seabed and structures that are capable of floating. The suitability of a particular type of foundation depends crucially on the water depth, the conditions on the seabed, the concepts for the turbine and its construction, and the costs that are incurred for the manufacture of the substructure.

4.1.1. Driving of pile foundations

To date, offshore wind turbines in the North Sea and Baltic Sea have predominantly been constructed on pile foundations or supporting structures that are anchored in the seabed with piles. Depending on the specific structural design, it is possible to distinguish between ‘monopiles’ that consist of a single, large-diameter steel tube (pile), and multipile foundation structures erected on three or four piles (jackets, tripods, tripiles). All the different types of pile foundation possess a high degree of market maturity. As a rule, pile foundations are anchored in the seabed by means of hydraulic impact pile driving or – under certain preconditions – what is known as ‘vibration pile driving’, in which vertical vibrations are induced on the pile to drive it into the seabed.

a) Impact pile driving
The time taken to construct each foundation varies widely depending on the type of foundation and other factors. The driving process alone (net driving time) usually lasts between 30 and 100 minutes for monopiles. Approximately 30-60 minutes per pile are to be allowed for multipile foundation structures, i.e. between 90 and 240 minutes in total. The high impulsive sound emissions that arise during pile driving are believed to be problematic for harbour porpoises.

b) Vibration pile driving method
Subject to certain preconditions, foundation piles can be anchored into the seabed using vibration pile driving in soft and moderately firm sandy seabeds. Measurements show that the levels of noise generated by the vibration pile driving method are markedly lower than those from impact pile driving. By contrast to impact pile driving, continuous sound is emitted during vibration pile driving.
However, this installation method is subject to technical constraints. When tripod or jacket foundations are installed, vibration pile driving usually remains limited to the upper eight to twelve metres, since vibrating the pile any further would require costly action to provide proof of the foundations’ structural stability by conducting a dynamic pile load test. In order to ensure stability, foundation piles that have been vibrated for the upper metres of their length are driven to their final depth using impact pile driving. Subject to certain premises, as experiments at the Danish Anholt offshore wind farm have shown, monopiles can be driven to their final depth using the vibration pile driving method. In this case, the precondition is the provision of evidence that the bedding characteristics of the seabed are not altered disadvantageously and the structure is stable. Since no scientifically backed-up findings have been published on this topic to date, this method has not been applied for the installation of offshore wind farms in the German marine areas as yet.

4.1.2. Drilling methods

As a matter of principle, drilling methods also come into question for the installation of pile foundations. They represent a suitable alternative, in particular when seabed conditions are difficult and impact pile driving is not possible. Drilling methods are

appropriate for water depths of up to 80 metres. The centrepiece of the procedure is a vertical drilling machine, at the lower end of which a drilling head with a pivoted cutting cylinder is attached. Piles with diameters of up to ten metres and walls of any thickness can be installed with this method. Drilling technology has already been deployed in combination with the pile driving method for the construction of individual offshore wind turbines where substrate conditions are difficult (e.g. Barrow Offshore Wind Farm, UK). With a view to the possibility of its series application, however, this method does not yet have sufficient market maturity. Optimised concepts with more rapid advance rates and higher weather tolerance are currently the subject of research and development projects.
Apart from the method's technical practicality in the offshore sector, it is also still necessary to demonstrate its economic viability.
In contrast to impact pile driving, continuous sound emissions are generated when drilling methods are used. It is to be expected that the levels of sound emitted will be very markedly below those of pile driving methods. In consequence, this construction technology represents a low-noise option for the installation of foundations.

4.1.3. Suction bucket/suction can foundations

Foundations for offshore installations can be anchored in the seabed with low levels of noise using what are known as 'suction buckets' or 'suction cans', which are embedded in the seabed. This foundation concept is suited for the installation of supporting structures on sandy seabeds in water depths of up to 60 metres.
Although several transformer stations and service platforms for oil and gas extraction have already been installed on suction bucket foundations, they have played practically no role in the construction of offshore wind farms up until now.
Extensive further research and development efforts will be required if this method is to reach market maturity as a foundation technology for wind turbines.
The suction bucket represents a low-sound option for the construction of foundations with good prospects for the future.

4.1.4. Gravity foundations

Gravity foundations are concrete or steel structures that are positioned on the seabed and held in place by their own weight. The excavation that is required, gravity foundations' large footprint and their scour protection features take up comparatively large areas of the seabed.
To date, gravity foundations have been used for the construction of offshore wind farms in shallower areas of sea (e.g. Nysted Offshore Wind Farm, Lillegrund Offshore Wind Farm) and they possess a high degree of market maturity for these locations. In principle, this foundation concept is also regarded as suitable for the installation of offshore wind turbines in water depths of 30 to 40 metres, but further research and development will be needed in the immediate future. Apart from the method's technical suitability, it is also still necessary for the economic viability of this type of foundation to be proven.

High sound emissions are not generated when gravity foundations are installed, but problems are encountered in particular when work is undertaken in protected biotopes due to the large areas of the seabed that are occupied.

4.1.5. Floating foundations

Floating foundations are suited in particular for the construction of offshore wind farms in greater water depths (> 50 metres). However, there are various concepts that have hardly been trialled yet. A number of prototype floating foundation constructions have been tested, including Hywind since 2009 in Norway and Windfloat since 2011 in Portugal. However, it is apparent that major research and development efforts will still be required before floating foundations attain market maturity. Floating foundation concepts only come into question for the German marine areas to a limited extent due to the relatively gently sloping coastline and the prevailing water depths of up to 50 metres.
No large-scale sound emissions are generated when they are installed, making this a low-sound option for the construction of foundations.

Summary of foundation technologies

It is to be expected the offshore wind farms to be developed over the next few years will overwhelmingly be built on the tried-and-tested kinds of pile foundations and require the pile driving operations necessary for such structures. No alternative state-of-the-art foundation technologies for offshore wind turbines are yet available at present. Innovative concepts for the low-sound construction of foundations must be developed further in parallel research and development efforts, and continuously driven forward to become state-of-the-art technologies. Even if a procedure were to become the 'state of the art', other systems should continue to be researched and developed in the interests of diversifying the technological options that are available.

4.2. Sound emissions

In the quite overwhelming majority of cases, foundation piles are installed using hydraulic impact pile drivers. When these machines are in operation, the energy from the hammer is transmitted to the pile, with some of it being released as sound either directly from the pile or indirectly into the water via the seabed.

The indirect transmission of sound into the water column via the seabed has still not been researched comprehensively. The energy released from the pile into the marine environment in the form of impulsive sound represents the crucial variable for this Sound Protection Concept.

The fundamental principles of underwater sound propagation are well known. In practice, however, forecasting rapidly runs up against its limits because local parameters can heavily influence sound propagation. Among other things, the water depth, the marine substrate and the relief of the seabed are crucial. In addition to this, reflections, superimposition and interference cancellation may occur. There is currently no spatially resolved model of sound propagation for the German North Sea. The development and validation of such a model is the subject of a research project funded by the Federal Environment Ministry (BORA, http://www.bora.mub.tuhh.de/). At present, therefore, simplified calculations are carried out using standard values for sound propagation, although this means the forecasts are affected by corresponding uncertainties. In this respect, the uncertainty of the forecasts rises with increasing distance from the sound source.

4.3. Sound mitigation measures

The sound emissions caused by the driving of foundation piles can be reduced by technical measures, but not prevented as a rule. It is possible to distinguish between primary sound mitigation measures, which allow a reduction of the sound that is generated to be achieved, and secondary sound mitigation measures that are aimed at limiting or preventing the propagation of sound emissions. By contrast, the use of deterrence techniques (seal scarers, pingers) prior to piling operations, as prescribed in the licenses for wind farms, is not a sound mitigation measure but a protective measure.

4.3.1. Primary sound mitigation measures

Primary sound mitigation measures include the reduction of strike energy, and the extension of the contact time between the hydraulic hammer and the pile that is being driven, the 'prolongation of impact contact time' as it is termed. For the most part, pile driving operations begin with reduced strike energy, what is known as a 'soft start', which is intended to have a deterrent effect on marine mammals. As far as the prolongation of impact contact time is concerned, this approach to sound mitigation is based on the insertion of a 'soft' intermediate layer (e.g. a steel cable) between the hammer and pile to prolong the contact time and so reduce the 'energy peaks' of the strike impact. Its effectiveness has been proven, but there is still considerable need for research.

4.3.2. Secondary sound mitigation measures

Secondary sound mitigation measures are considerably more significant and effective. The Federal Environment Ministry's research projects are therefore concentrated on this field. At present, the following sound mitigation measures are being deployed or are in development and trial operation:

- Bubble curtains
  - 'Little' or 'small' bubble curtains
  - 'Big' or 'large' bubble curtains
- Pile sleeves
- Hydro sound dampers
- Coffer dams

a) Bubble curtains

The most common sound mitigation measures in Germany at the moment are bubble curtains of various designs. Bubble curtains involve compressed air being fed into perforated pipe or hose systems that are laid on the seabed or arranged in the water body. Ideally, the bubbles that rise from the openings form an unbroken barrier that extends the whole height of the water column. The reduction in sound depends, among other things, on the volume of compressed air that is used, the density of the bubble curtain and the size of the bubbles.

The following bubble curtain designs are being deployed or trialled at present in Germany:

- 'big' or 'large' bubble curtain: rising bubbles are generated using a system of pipes or hoses laid on the seabed at a relatively large distance around the location where the noise is generated,
- 'little' or 'small' bubble curtain: rising bubbles are generated using a number of small-diameter rings arranged one above the other directly around the pile to be driven or the foundation structure,
- guided bubble curtain: the air bubbles rise up along a membrane or a wall, which detaches them from the potential influences of flowing water.

Bubble curtains have been deployed in the last few years for various purposes, including sound mitigation during port and bridge construction works. Engineers have started to gain experience of their use during the construction of offshore wind turbines. It has been possible for important evidence to be gathered about these systems in the course of BMU-funded research projects.

The effectiveness of a big bubble curtain during pile driving work on foundations in the offshore sector was evaluated for the first time in 2008 while the FINO 3 research platform was being constructed. On this occasion, it was possible for an attenuation effect of 7 to 12 dB re 1µPa (SEL) or up to 14 dB re 1 µPa (SPL) to be achieved (GRIEßMANN *ET AL.* (2010)).

A technically optimised big bubble curtain suitable for series deployment was trialled and evaluated for the first time under real construction conditions during the construction of the Borkum West II offshore wind farm in 2012 (PEHLKE ET AL. (2013)). The centrepiece of the sound protection system was a perforated hose laid by automated machinery, which was used successfully on 31 of 40 tripod foundations. The results of the measurements taken show that an attenuation effect of 9 to 13 dB re 1 µPa (SEL) or 10 to 17 dB re 1 µPa (SPL) can be achieved at water depths of around 30 m with a single-row 'big bubble curtain'. The mean attenuation effect was 11 dB re 1 µPa (SEL) or 14 dB re 1 µPa (SPL). Tests conducted with a two-row configuration indicate there is the potential for greater reductions. The sound protection system that was used allowed the sound protection threshold set by the authorities to be complied with at 12 out of 40 foundations on the Borkum West II site. The reduction of underwater sound in these cases made it possible for a clear lessening in the disturbance effect on harbour porpoise by up to 90% to be achieved (PEHLKE ET. AL. 2013).

However, compliance with sound protection thresholds cannot currently be guaranteed because the degree of sound mitigation attained to date is sometimes not sufficient in other circumstances at particular locations with greater water depths, unfavourable weather conditions and larger piles.

The BMU's ongoing research and development projects are focussed on improving the effectiveness of these technologies, minimising the time required to lay out and gather in the hose or pipe system, and developing durable materials and robust technical components.

b) Pile sleeves
Pile sleeves decouple the pile acoustically from the water body as far as possible. Pile sleeves are suitable for the construction of monopiles. Some concepts also permit their application for multipile foundation structures. As far as their design is concerned, they can be configured as double-wall or single-wall designs with some form of insulation in place along the whole length of the pile (air, foams, bubble curtains).

It is possible to distinguish several concepts for the operational deployment of pile sleeves in the construction process:
- A crane is used to place the pile sleeve over the pile to be driven, which has already been positioned on the seabed, and raise it back to the offshore installation vessel after the conclusion of the pile driving.
- The pile to be driven is inserted into the pile sleeve on the installation vessel and positioned together with it on the seabed, then the sleeve is lifted back up once the pile driving has been completed.
- The installation vessel lowers a pile sleeve mechanically onto the seabed, into which the pile to be driven is inserted. After the pile driving, the sleeve is raised again and the installation vessel moved to the next driving location.
- A pile sleeve consisting of two halves is attached to the pile on the installation vessel. The sleeve is mechanically closed once the pile to be driven has been positioned, then opened again after the conclusion of the driving.
- The foundation piles consist of an inner tube and an outer tube. After the pile driving of the inner tube ('tube-in-tube piling'), which serves to anchor the outer tube in the seabed, the turbine is constructed on the outer tube.

The practicality of pile sleeve technology was demonstrated during the construction of the Riffgat offshore wind farm. The 30 monopile foundations were driven using a 30-m-long, 10-m-wide, double-walled steel tube with an internal bubble curtain.

The deployment of pile sleeves as a sound minimisation measure is dependent on particular preconditions being satisfied as far as logistics are concerned because sufficient capacities for the storage of the pile sleeve and an appropriately configured crane must be kept available.

Further need for development is seen with regard to the deployment of these systems in greater water depths and experimental work to optimise them.

c) Hydro sound dampers

Hydro sound dampers (HSDs) are air-filled balloons with a thin, highly elastic skin that are fastened together in a net-like structure. The cylindrical net is placed over the pile to be driven and lowered to the seabed. This is intended to shield the noise source from the environment to a large extent. By contrast to bubble curtains, the hydro sound damper concept allows the shape, size, number and arrangement of the 'artificial air bubbles' to be precisely predetermined. This means the attenuation effect can be tailored so as to target it at the frequency range relevant for the sound from the pile driving operations.

After it was possible for its suitability to be confirmed in the course of the ESRa project (WILKE *ET AL.* (2012)), an HSD prototype was trialled at the London Array offshore wind farm in August 2012. It was found the system offered an attenuation effect of 8 to 12 dB re 1 µPa (SEL) or 8 to 14 dB re 1 µPa (SPL). As far as its level of development is concerned, the hydro sound damper is to be characterised as a highly promising sound mitigation method, but one that has undergone little trialling. The development of a concept suitable for series deployment is currently the focus of ongoing research activities.

d) Coffer dams

A 'coffer dam' is generally a structure that can be used to create a dry, accessible area at the bottom of a water. For example, a coffer dam can be designed as a steel tube, which is placed on the bed of the water and drained using pumps. Construction works – such as the driving of a pile – can then be carried out in the drained area. When this approach is taken, a considerable reduction in sound can be achieved by decoupling the pile from the body of water. In an experiment with a test pile that was conducted in December 2011 in the Danish Belt Sea at a water depth of approx. 20 m, it was found the coffer dam principle had an attenuation potential of 22 dB (SEL) or 18 dB (SPL). One conceptual study has suggested the development of a telescopically extendable coffer dam that would also be suitable for the construction of wind turbine foundations in greater water depths. At present, however, no empirical data have yet been published on this topic.

4.4 Research and development

In order to overcome the problems caused by the impacts of construction-induced sound emissions on harbour porpoises, the BMU has funded diverse projects with the following priorities under its Future Investment Programme, the 5th and 6th Energy Research Programmes and the Environmental Research Plan (UFOPLAN):

- surveying the impacts of sound emissions on harbour porpoises,
- developing and trialling (new) low-noise options for the construction of foundations,
- developing and trialling efficient, practical, economic (new) noise minimisation measures.

Apart from this, wide-ranging projects designed to augment scientists' knowledge of the fundamental principles of acoustic engineering, model sound propagation and evaluate deterrence methods have been, and are being, funded.

Most of the projects on low-sound options for the construction of foundations and sound minimisation technologies, in particular, have been conducted with participation from the private sector and industry. If the diverse foundation technologies and sound minimisation measures that are being researched and trialled are to be converted into state-of-the-art methods in the near future, it will also be necessary for the offshore industry to continue its committed involvement in both development work, and the application and optimisation of technologies during concrete offshore projects. The Federal Environment Ministry would like to support these activities. According to the current funding regulations for research and development in the renewable energies sector promulgated on 13 December 2011 (http://www.erneuerbare-energien.de/die-themen/forschung/foerderbekanntmachung/), the research funding disbursed by the Federal Environment Ministry will continue to be focussed on the funding priorities discussed above.

Conclusions

In view of the current state of the art, it is not possible to dispense with pile driving technology when installing the foundations for offshore wind farms, even though innovative low-sound or sound-reducing technologies are in development and some of them are already well advanced. At present, however, no state-of-the-art technology has become established that guarantees compliance with the sound exposure level (L_E) threshold of 160 dB re 1µPa² s or the peak sound pressure level ($L_{peak-peak}$) threshold of 190 dB re 1µPa (at a distance of 750 m), irrespective of the diameter of the pile. The improvement of sound protection technologies is being driven further ahead, thanks in part to the research funding provided by the BMU. However, given the technological advances that have been made, it is indispensable at present for the consequences of the impacts of impulsive sound events due to pile driving activities during the construction of offshore wind farms to be dealt with in this Sound Protection Concept.

5. Impacts of impulsive sound events on harbour porpoises

Harbour porpoises can suffer temporary or permanent damage to their hearing as a result of impulsive sound. On the one hand, it may trigger a raising of their hearing threshold for a limited period, i.e. a temporary lowering of hearing sensitivity (temporary threshold shift, TTS). On the other hand, there may be a permanent raising of their hearing threshold (permanent threshold shift, PTS) that can go as far as complete deafness. When this happens, the rise in the hearing threshold may be limited to certain frequency ranges or occur over the whole hearing curve. Damage to hearing is to be regarded as an injury within the meaning of Section 44(1) of the BNatSchG. An injury within the meaning of the prohibition on taking under species protection law is an impairment of an animal's physical welfare or damage to its health. This encompasses any impairment of its physical integrity.

According to the latest academic findings, a threshold shift is triggered among harbour porpoises by impulsive sound events with a broadband single event sound pressure level (L_E) above 164 dB re 1µPa² s combined with a peak level ($L_{peak-peak}$) of 199 dB re 1µPa (LUCKE *ET AL.* (2009)). The single event sound pressure level (L_E) is identical with the sound exposure level (SEL). The peak level ($L_{peak-peak}$) is identical with the peak sound pressure level ($SPL_{peak-peak}$).

Recent progress in the research and the thresholds set on the basis of these findings, a sound exposure level (L_E) of 160 dB re 1µPa² s and a peak sound pressure level ($L_{peak-peak}$) of 190 dB re 1µPa (at a distance of 750 m), are based on the effects of a single acoustic event. When a driven foundation structure is installed, several thousand hammer strikes are required for each pile (multiple sound emissions from pile driving). Models of the corresponding cumulative sound exposure caused by multiple sound emissions of this kind suggest that the thresholds may not be sufficient (e.g. AUSTRALIAN GOVERNMENT (2008), FINNERAN AND SCHLUNDT (2004), FINNERAN *ET AL.* (2002)).

Even at an impulsive sound exposure of markedly less than an SEL of 164 dB re 1µPa² s, harbour porpoises respond with pronounced avoidance behaviour and behavioural changes, which are visible in particular in the form of flight responses away from the sound source that can result in them leaving the space affected by strong sound emissions (habitat loss). Other behavioural changes such as the interruption of feeding or resting phases, and the prevention of or interference with communication are currently not recorded. Since the space gradually comes into use again once the sound exposure has ceased, this disturbance lasts for a limited period (BRANDT *ET AL.* (2011)).

Flight responses and avoidance behaviour at distances up to over 20 km from pile driving have been demonstrated among harbour porpoises in the North Sea where no sound mitigation technologies are deployed (LUCKE *ET AL.* (2010); TOUGAARD *ET AL.* (2006)).

If an impulsive sound exposure causes a flight response on the part of a mother-calf pair, the mother may lose contact with the calf, while mating may be significantly disrupted or fail on account of the relatively short conception period (just a few days for each individual). Scientifically backed-up findings on the level of sound pressure that leads to these responses have not been published to date.

Behavioural effects can result in harbour porpoises being driven away temporarily or permanently from ecologically important areas. Harbour porpoises have a high digestion rate and need to consume food frequently in the course of the day. If a harbour porpoise consumes no food for just a few days, it may suffer hypothermia and die. There are no scientifically backed-up findings about the level of sound pressure that leads to behavioural responses of this kind either.

Looked at in isolation, the impulsive sound inputs attributable to the driving of piles into the seabed for the foundations of offshore wind turbines are temporary events that are limited to the construction phase of an offshore wind farm. In view of the large number of turbines at each wind farm (up to 80 turbines in the current pilot phases), combined with the number of planned offshore wind farms that have already been licensed or are going through the approval process, it is to be expected that temporary sound exposures of this kind could well be occurring in the German North Sea for a period of about 30 years. This is far longer than the approx. 8-10 years a harbour porpoise generation lasts.

6. Disturbances

The concept of disturbance is of central significance if the impacts of sound generated by pile driving activities during the construction of offshore wind farms are to be assessed properly because the Federal Nature Conservation Act takes the term as its starting point. It is for this reason that this section sets out in detail the basis on which the concept of disturbance has been developed for the Sound Protection Concept presented in this document.

Sound as disturbance: What behavioural changes may be triggered by sound among harbour porpoises?
Harbour porpoises are essentially reliant on their hearing. Sound events provoke various responses among harbour porpoises. Above a certain threshold, the sound becomes noise and has a disturbance effect. Noise is a recognised stress factor and provokes stress responses among harbour porpoises. At present, the threshold as of which sound becomes noise cannot be determined exactly for harbour porpoises and, furthermore, varies depending on the condition of the individual animal, the stage it has reached in its biological cycle (infant, rearing, mating) and the activity it is engaged in at a particular time. Apart from the strength of the noise, the frequency range also plays a crucial role because harbour porpoises' hearing ability

and noise sensitivity differ depending on the frequency of the sound to which they are exposed.

There have been no scientific studies aimed at conducting a complete survey of disturbances among marine mammals. Hitherto, findings on individual aspects of the issue have merely been recorded for certain individual species. Nevertheless, it has been possible to synthesise these data to arrive at a sufficiently robust overview. The following behavioural patterns among harbour porpoises are evidence of the presence of an acoustic disturbance:

- directed swimming away from the sound source (evasion, flight),
- interruption of feeding,
- interruption of communication,
- interruption of resting behaviour.

Apart from this, their location and communication signals may be 'masked' (reduced perception of acoustic signals as a result of the superimposition of other loud acoustic signals) (NRC (2005)). This prevents or interferes with

- feeding (location of food),
- communication between harbour porpoises,
- orientation.

What can be detected?

In order to be able to detect disturbances to harbour porpoises with some degree of precision, the specified impacts would have to be recorded for each individual animal. However, such individual observations or measurements can only be carried out with a justifiable amount of effort in a few cases. The comprehensive determination of the impacts of sound on harbour porpoises therefore comes up against its limits, and such impacts can only be determined approximately at present.

Attempts are currently being made to survey the impacts of sound generated by pile driving activities on harbour porpoises using porpoise detectors (PODs). PODs permit changes in the acoustic activity of harbour porpoises and their precise timing to be recorded continuously and correlated with the times of sound-intensive pile driving operations. These alterations are either to be attributed to behavioural changes in the animals that are present (e.g. 'falling silent'), a change in the number of animals present (immigration or emigration) or a combination of both effects. None of the other impacts of disturbances discussed above can be determined with this method. This methodological limitation is important for the classification of the results from these investigations.

The consequences of sound-induced disturbances, both for individual animals and also at the population level, can only be traced with difficulty among harbour porpoises, not only on account of the inaccessibility of wild harbour porpoises for investigations in their real surroundings, but above all in view of the complexity and large number of the factors to be analysed.

In 2005, the US National Research Council (NRC) developed what is known as the Population Consequences of Acoustic Disturbance (PCAD) model as a tool for the analysis of population-relevant effects that occur due to acoustic disturbances. The model, which is organised in a series of manageable stages, shows a causal chain from the original source of the (sound) exposure to the impacts on mammals' individual behaviour, the vital functions affected, the exposure's impacts on the vitality rate and the population effect in which they result (see Figure 1). There is insufficient knowledge of, in particular, the interactions and linkages between the different individual stages.

[Abbildung 1:
Schall = Sound
Quelle = Source
Pegel = Level
Frequenz = Frequency
Dauer = Duration
Zyklus = Cycle
Stunde – Saison = Hour – Season
Verhaltensänderung = Behavioural change
Orientierung = Orientation
Atemfrequenz = Breathing frequency
Vokalisation = Vocalisation
Tauchen = Diving
Ruhen = Resting
Mutter-Jungtier-Beziehung (räuml.) = Mother-infant spatial relationships
Meidung = Avoidance
Saison – Jahr = Season – Year
Betroffene Lebensfunktionen = Life functions affected
Überleben = Survival
Wanderung = Migration
Fressen = Feeding
Aufzucht = Rearing
Reaktion auf Fraßfeinde = Response to predators
Jahr – Generation = Year – Generation
Vitalitätsrate = Vitality rate
Abh. v. Altersklasse = Stage-specific
Überlebensrate = Survival rate
Geburtenrate = Birth rate
Fortpflanzungsrate = Reproduction rate
eine – mehrere Generationen = One – Several Generations
Populationseffekt = Population effect

Wachstumsrate d. Pop. = Population growth rate
Populationsstruktur = Population structure
Austauschdynamik = Transient dynamics
Empfindlichkeit = Sensitivity
Elastizität (Resilienz) = Elasticity (resilience)
NRC 2005 (abgewandelt) = NRC 2005 (adapted)]

Figure 1
Key: Indicator scale

+++	Well known
++	Comparatively well known
+	Some knowledge
o	Unknown

The use of PODs to survey the impacts of sound from pile driving activities on harbour porpoise currently represents a practical, well established method for the observation of disturbance effects, provided it is taken into consideration when this is done that only some of the actual disturbances can be recorded.

What is the spatial range of disturbances?
If the distances around a sound source at which disturbances can still be expected are to be determined, it becomes necessary, among other things, to appraise sound propagation characteristics. According to measurements taken by the German Wind Energy Institute (ISD, DEWI, ITAP (2004)), the decrease in the sound level as the distance from the sound source increases can be calculated with what is known as the 'Thiele formula' (THIELE (2002) AND THIELE, R. AND SCHELLSTEDE, G. (1980)), which was developed for application in the sandy coastal areas of the North Sea and the Baltic Sea. However, the frequency of the sound is factored into the calculation and the attenuation values calculated are accordingly frequency-dependent as well. As far as broadband sound from pile driving operations in the North Sea is concerned, DEWI (ISD, DEWI, ITAP 2004) determined a decrease in the sound level by 4.5 dB for every doubling of the distance from the sound source (does not apply for the near-field).

Using measurements of sound exposure levels taken during the pile driving for the met mast at the Amrumbank West offshore wind farm, ELMER *ET AL.* (2007) were able to show that the decrease in the sound level became greater as the distance from the sound source increased and, in particular, clearly diverged from the forecast values at greater distances from the location of the pile driving operations. The investigations by PEHLKE *ET AL.* (2013) also demonstrate sound immissions from pile driving activities at greater distances are overestimated when geometrical propagation loss is calculated in accordance with the BSH's *Measuring Instruction* and the semi-empirical approximation of propagation loss put forward by THIELE AND SCHELLSTEDE (1980) is applied. In consequence, use is not made of the Thiele formula below, but a formula derived from ELMER *ET AL.* that depicts a faster rate of propagation loss at greater distances. These authors used measurements of peak sound pressure level taken at various distances from the met mast to determine the distance-dependent transmission loss (TL) for broadband sound from pile driving operations (sound pressure level):

(1) $TL = (14 + r \cdot 0.0002) \cdot LOG(r)$.

Here, TL states how many dB the sound level has fallen by in comparison to the level at a distance of one metre from the location of the pile driving operations, in which respect it is merely the distance r (in metres) that is factored into the calculation.

After the pile driving for the Amrumbank West met mast, sound measurements were taken at different distances during the pile driving for the FINO 3 research platform and the installation of the foundations for the Horns Rev II, alpha ventus and BARD Offshore I wind farms, which were conducted by the same group of authors (BETKE (2008), GRIEßMANN *ET AL.* (2010), BETKE AND MATUSCHEK (2009)). In order to examine whether the distance-dependent falls in the sound exposure level (SEL) measured at the specified installations can also be depicted with sufficient precision by Formula (1), the values measured were standardised. The first step was to calculate a sound curve (T 1) that followed Formula (1) and showed exactly 160 dB re 1 μPa^2 s (SEL) at a distance of 750 m from the sound source. Furthermore, the measured sound levels for each individual project were standardised so that the value measured closest to 750 m in each case came to lie on the sound curve (T 1) calculated in the first step. The only measurements that diverged from this had been taken at alpha ventus 2 because a sound exposure level (SEL) of 166 dB re 1 μPa^2 s had been measured at distances of both 500 m and 1,500 m. Here, the individual values were reduced by 6 dB in each case. The approach taken allowed the use of Formula (1) to arrive at a sufficiently good approximation of the distance-dependent sound exposure level caused by pile driving events that comply precisely with the thresholds set for a distance of 750 m. This method means forecasting is possible, in particular for the area of interest here up to a distance of approx. 20 km from the pile driving site.

However, as already explained in section 4.2, exact forecasting is not possible because the propagation of sound in the sea is dependent on, among other things, the water depth, the water temperature, the morphology of the seabed and swell conditions. Nevertheless, the Elmer formula (1) is used below for reasons of practicality and in the absence of more exact bases for the calculations.

In contrast to visual investigations, POD-supported measurements allow very much more detailed evidence to be gathered about flight and avoidance responses. Various parameters (encounters, porpoise positive 10 minutes/day (PP10min/d), porpoise positive minutes/hour (PPM/h), waiting time between detections) can be ana-

lysed to illuminate harbour porpoises' acoustic activity and so supply evidence about the behaviour and/or occurrence of animals in the vicinity of the PODs. The POD investigations at Horns Rev II mentioned above found reduced PPM/h values, which suggested disturbance effects were occurring at distances of up to 17.8 km (meaned) from the pile driving site. The authors state that the increased values recorded at a distance of 21.2 km (meaned) actually point to an aggregation of animals caused by the dispersal effect (BRANDT *ET AL.* (2011)). If Equation 1 is used (see above), it can be calculated from the sound levels quoted by BETKE (2008) that the sound exposure level (SEL) values at this distance were 138 dB re 1µPa² s or 134 dB re 1µPa² s. At alpha ventus, DIEDERICHS *ET AL.* (2010) used waiting times to demonstrate significant effects up to 16.4 km, while no more significant impacts were to be found at a distance of 21 km. BETKE AND MATUSCHEK (2011) measured a sound exposure level of 140 dB re 1µPa² s (SEL) at 16.4 km, while a value of 134 dB was calculated for 21 km. The above-mentioned POD data indicate that disturbances are demonstrable even at sound exposure levels of 138-140 dB re 1µPa² s (SEL) while at 134 dB re 1µPa² s it is not possible to identify any further dispersal effects, at least. These figures are clearly lower than the results found in the investigations by LUCKE *ET AL.* (2009), in which the harbour porpoise that was studied displayed a startle response and corresponding behavioural avoidance in the direction of the location of the sound source when exposed to a single sound event at 145 dB re 1µPa² s (SEL). However, LUCKE *ET AL.* (2009) point out the animal that was studied lived in an environment in which it experienced intense exposures to sound and may have displayed an unnaturally high level of tolerance to underwater sound, so the actual level at which behavioural responses start to occur could be markedly lower. PEHLKE *ET AL.* (2013) found a significant detection threshold for disturbance at 144 dB re 1µPa² s (SEL) for the hours during which pile driving was taking place (p. 162) and highly to extremely highly significant disturbance during the following 24 hours at up to 140 dB re 1µPa² s (SEL) (PEHLKE ET. AL. (2013), p. 165). Highly significant disturbances occurred only temporarily at levels between 135 and 140 dB re 1µPa² s (SEL) (PEHLKE ET. AL. (2013), p. 165).
At present, it is not possible to set an exact sound threshold for disturbances on the basis of the observations discussed above. Rather, in the interests of simplicity, it is therefore assumed below that if the 160 dB (SEL) threshold is complied with, measured at a distance of 750 m, disturbances will occur within a radius of eight kilometres around the sound source, in particular avoidance and flight behaviour. Back-calculation using Equation 1 shows that at this distance the sound exposure level would be 140 dB re 1µPa² s (S_E), a figure that is to be described as plausible in the light of the studies that have been published. This value is also confirmed by the new results and still incomplete evaluations of NEHLS and DIEDERICHS (2013), who also assume a disturbance radius of eight kilometres.

Provided the sound exposure level (SEL) is lower than the threshold of 160 dB re 1µPa² s at a distance of 750 m, it may be posited that the radius around the sound source within which a disturbance of the kind described above is to be assumed is also reduced accordingly. This means it is possible to derive immediately from the measured sound exposure the corresponding disturbance radiuses up to the point at which acoustic attenuation has reduced the sound level to approx. 140 dB. In order to anchor this effect within the framework put in place by the Sound Protection Concept, disturbance radiuses have been determined in conformity with the method for their derivation using Equation 1. By way of illustration, Table 1 shows the corresponding disturbance radiuses for two other values (155 dB re 1µPa² s and 150 dB re 1µPa² s at a distance of 750 m).

Table 1:
Disturbance radiuses dependent on sound exposure

dB SEL at a distance of 750 m	Disturbance radiuses
160	8 km
155	5 km
150	3 km

The disturbance radiuses derived in this way form the basis for the interpretation of the relevant provisions of nature conservation law within the framework of the Sound Protection Concept presented in this document. Areas where different disturbance radiuses overlap are only counted once (and not cumulated), because the disturbance is triggered by the first increase in noise levels.

7. Sound Protection Concept Guidelines

7.1. Best available technology

The principle applies that the best available technology in each case is to be used in order to implement the most ecologically appropriate option, and therefore minimise sound exposures and other negative impacts on the marine environment as far as possible overall. An explicit decision has been taken not to stipulate a specific foundation technology. Rather, the Sound Protection Concept and the research activities funded by the BMU are intended to incentivise and support the development and rapid deployment of innovative, low-noise technologies.

Since it is currently not yet possible to dispense with pile driving technology, at least for the construction of offshore wind farms, the individual requirements of nature conservation law concerning species protection under Section 44(1) of the BNatSchG and site protection under Sections 32 ff. of the BNatSchG are formulated in concrete terms below in the form of appropriate conventions for the assessment of impulsive sound inputs attributable to pile driving activities during the construction of offshore wind farms.

7.2. Species protection: prohibitions on injury and killing

According to point 1 of Section 44(1) of the BNatSchG, it is prohibited to kill or injure harbour porpoises. Damage to an animal's hearing is to be regarded as injury within the meaning of Section 44(1) of the BNatSchG. The noise prevention values recommended by the UBA and established with binding force by the BSH, consisting of the twin criteria of a sound exposure level (SEL) of 160 dB re 1µPa² s (unweighted) and a peak sound pressure level ($SPL_{peak-peak}$) of 190 dB re 1µPa at a distance of 750 m, are to be complied with in this regard. In areas where higher levels of sound pressure occur, suitable measures are to be taken to ensure that no animals are present there at the time of the sound event (deterrence). This is to be proven by the monitoring of noise emissions and harbour porpoises using methods that are to be formulated in concrete terms during the licensing process.

7. 3. Species protection: prohibition of disturbance

Not all disturbances to the harbour porpoise population are prohibited during their all-year-round breeding and rearing periods by point 2 of Section 44(1) of the BNatSchG: this is only the case for significant disturbances (see section 3 above). A significant disturbance occurs if the conservation status of the local population is worsened. In the North Sea, the reference variable 'local population' is equivalent to the whole population of harbour porpoises in the German part of the North Sea.

Conservation status of species under the Habitats Directive

Conservation status is characterised by the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within the territory referred to. The conservation status is taken as 'favourable' when population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

The following criteria are drawn on to assess the conservation status of species covered by the Habitats Directive for the national reports provided for in Article 17 of the Habitats Directive:

1. current natural range (extent, trend),
2. population (population size, reproduction, age structure, mortality, health status),

3. habitat for the species (area and quality, incl. structures and functions),
4. future prospects (as regards to population, range and habitat availability, incl. pressures and threats, and long-term viability).

Sources: GERMAN FEDERAL GOVERNMENT (2007); EUROPEAN UNION, DG ENVIRONMENT B2 (2005): DocHab 04-03/03-rev.3; SACHTELEBEN, J. AND BEHRENS, M. (2010)

It is therefore not the disturbance of an individual animal that is relevant under species protection law. Rather, the proposed conventions elaborated below imply that, as a rule, it is only the presence of several pile driving sites with the associated disturbance radiuses at the same time that results in disturbances that are population-relevant and therefore significant. Only then are they relevant under species protection law. Among other things, of course, the significance of a disturbance to a local population is also connected conceptually with the question of the proportion of the population of harbour porpoises that may be disturbed in a particular temporal context. However, the proposed conventions set out below relate to spatial factors (number of disturbance radiuses, distance from protected site, etc.) in order to ensure the conventions are manageable, allow licensing authorities and developers to plan efficiently, and can therefore be implemented in practice. This is possible because the spatial and temporal distribution patterns and densities in the German North Sea are essentially well known and can be taken into consideration appropriately in modelling. The harbour porpoise densities in question are therefore factored into the evaluation criteria accordingly.

In order to simplify the process of determining the impacts attributable to a whole project (construction of an offshore wind farm), the project’s individual wind turbines are not looked at separately, but the geographical centrepoint of the area to be occupied by the offshore wind farm is taken as the basis for the calculation of the disturbance radius in each individual case.

The circannual rhythm of harbour porpoise breeding and rearing phases discussed in section 3 means that during the particularly sensitive part of the breeding period (North Sea: May-August) the significance threshold set in point 2 of Section 44(1) of the BNatSchG is reached by disturbances of lower intensity than outside this period because the population’s reproductive success is immediately affected. The prohibition on disturbance is therefore to be interpreted in a differentiated fashion, depending on the season.

7.3.1. Assessment convention for the prohibition on disturbance outside the particularly sensitive period

In order to rule out significant, population-relevant disturbances in the German North Sea now and in future, sufficient areas unaffected by sound from pile driving must be available for harbour porpoises, in particular. It is assumed that sufficient areas of this kind are certainly always available if no more than ten per cent of the area of the EEZ in the German North Sea falls within the disturbance radiuses of the offshore wind farms that are under construction, and there is compliance with the impulsive sound thresholds set for compliance with the prohibitions on killing and injuring (broadband sound exposure level (SEL) of 160 dB re 1 µPa² s or peak sound pressure level ($SPL_{peak-peak}$) of 190 dB re 1 µPa at a distance of 750 m from the location where the sound is generated). As far as this is concerned, the location of the individual sound sources remains disregarded. If the thresholds are complied with, it is possible to rule out significant disturbance to the local harbour porpoise population.

7.3.2. Assessment convention for the prohibition of disturbance during the particularly sensitive period

In the German North Sea, the harbour porpoise goes through its most sensitive reproduction phase during the period from May to August. At the same time, the population displays a clear aggregation in an area north west of Sylt (main area of concentration). Furthermore, when consideration is given to the sometimes significant year-on-year fluctuations in density among the harbour porpoises in the German North Sea, the outstanding significance of this area within the German EEZ in the North Sea is apparent across all the years when studies were conducted (Fig. 2). In areas with high harbour porpoise densities, exposures have greater potential to cause population-relevant disturbance than in areas with lower densities.

[Abbildung 2:

Flugzählungen zur Erfassung von Schweinswalen = Aerial counts to survey harbour porpoises

Datenquelle: Mai bis August (gepoolt über die Jahre 2005-2010) = Data source: May to August (pooled over the years 2005-2010)

effektive Flugstrecke = 27.100 km (an 43 Flugtagen) = Effective distance flown: 27,100 km (on 43 flight days)

Anzahl gesichteter Schweinswalgruppen 2.960 mit 3.583 Individ. = Number of harbour porpoise groups sighted: 2,960 with 3,583 individuals

mittlere Schweinswaldichte (Ind./km^2) = Mean harbour porpoise density (ind./km^2)

Zellen: 10x10 km = Cells: 10x10 km

Mutter-Kalb Paar = Mother-calf pair]

Figure 2: Raster grid of the distribution of harbour porpoises in the German North Sea and sightings of mother-calf pairs (Gilles, unpublished), Habitats Directive special protection ar-

eas in the EEZ and boundaries of the main area of concentration on the Sylt Outer Reef (black, dotted line)

In addition to this, in order to ensure harbour porpoises permanently have sufficient opportunities to evade exposures and in order limit the disturbances to the population to technically justifiable and legally permissible levels, in the particularly sensitive phase it is necessary to keep the main area of concentration free of sound-intensive construction activities during which a cumulative area of more than one per cent of the site is located within the disturbance radius. The areas of the disturbance radiuses for all projects in which the foundation construction phase has already begun and has not yet been concluded are cumulated.

All projects licensed as of 1 December 2013 are to be subject to this Concept. The developers of these projects can therefore organise their construction schedules accordingly at the point in time when the license is granted and allow for a period when pile driving will potentially be ruled out during the particularly sensitive phase. The principles laid down in section 7.5., 'Old licences', apply for projects that have been licensed in the past.

The main area of concentration is shown with its coordinates in Annex 1.

7.4. Site protection

The harbour porpoise is a conservation target for all Habitats Directive special protection areas in the German EEZ in the North Sea (Table 2). However, it is only in the Sylt Outer Reef and Dogger Bank Habitats Directive special protection areas that the reproduction of harbour porpoises is also an explicit conservation target.

Table 2: Conservation targets

Special protection area	Harbour porpoise is conservation target	Harbour porpoise reproduction is conservation target
Sylt Outer Reef	X	X
Borkum Reef Ground	X	-
Dogger Bank	X	X

The criteria for the assessment of an adverse impact on a site are the constitutive elements of the protective purpose or conservation target. The functions of a site for the population of harbour porpoises found at that site are to be protected.

Under the premise that the driving of piles for the foundations of offshore wind turbines constructed at distances greater than eight kilometres from a Habitats Directive special protection area complies with the thresholds specified in section 7.2 and could not result in any other significant adverse effects within the meaning of

Section 34(2) of the BNatSchG, there is no necessity for an Appropriate Assessment under the Habitats Directive to be conducted for these projects.

The constitutive elements of the protective purposes or conservation targets for Habitats Directive special protection areas must not suffer significant adverse impacts due to underwater sound. A significant adverse impact on a Habitats Directive special protection area is usually presumed if there is a permanent loss of one per cent of a habitat found within the site (LAMBRECHT *ET AL.* (2004)). Since the sound exposure caused by pile driving activities occurs for limited periods of time, it is justifiable here from a technical, nature conservation perspective for ten times this figure, i.e. ten per cent, to be defined as the significance threshold for a temporary, reversible loss of function in the area described by the disturbance radiuses.

A significant adverse impact on a site is therefore to be presumed if at least ten per cent of the area of the site is located within the disturbance radius (provided there is compliance with the sound exposure level (SEL) threshold of 160 dB re 1 μPa² s or the peak sound pressure level (SPL) threshold of 190 dB re 1 μPa at a distance of 750 m). Sound events caused by various sound sources are to be cumulated for analysis as follows. The areas of the disturbance radiuses for all projects whose foundation construction phase has already begun and has not yet been concluded are cumulated.

Habitats Directive special protection areas in which harbour porpoise reproduction is a conservation target (Table 2) require an enhanced level of protection, and no more than one per cent of the area of the site may be impinged upon by disturbance radiuses in the particularly sensitive phase from May to August discussed above (provided there is compliance with the sound exposure level (SEL) threshold of 160 dB re 1 μPa² s or the peak sound pressure level (SPL) threshold of 190 dB re 1 μPa at a distance of 750 m). The same cumulation rule as above applies.

7. 5. Old licences

The aim of the Sound Protection Concept is to manage the future expansion of offshore wind energy in order to protect harbour porpoises on the basis of assessment criteria that are well known in good time. This can only be implemented appropriately and successfully if it is possible for these assessment criteria to be integrated into the planning process at an early stage, which means there is no expectation this concept will be applied for previously licensed projects. Licenses granted in the past are final and absolute, and remain unaffected by the evaluation criteria laid down in the Sound Protection Concept. The same applies for projects whose licenses are extended unchanged.

The legal options open to the BSH to take recent scientific findings into consideration under the Ordinance on Offshore Installations Seaward of the Limit of the German Territorial Sea remain unaffected by this arrangement. Old licences are to be factored into the cumulative analysis of sound events caused by various sound sources that occur simultaneously.

7. 6. Requests for variation

On account of the long lead times involved in the planning of offshore wind farms, it is still common, and frequently necessary, to make modifications to a project after the license for the construction of an offshore wind farm has been obtained. This is done by submitting requests for variation. In some cases, depending on the modifications planned, requests for variation require the project's environmental impacts to be assessed once again.

However, only modifications that could cause additional, previously unconsidered adverse impacts as a result of a change in the scale of the sound emitted are relevant to the application of the Sound Protection Concept. This is to be examined in the concrete individual case.

Sources and further reading:

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Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

Abbreviations

ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BNatSchG	German Federal Nature Conservation Act
BSH	German Federal Maritime and Hydrographic Agency
CV	coefficient of variation
dB	decibel
DEWI	German Wind Energy Institute
EEZ	Exclusive Economic Zone
HD	European Habitats Directive
Helcom	Commission of the Convention on the Protection of the Marine Environment of the Baltic Sea
HSD	hydro sound damper
ISD	Institute of Structural Analysis
ITAP	Institute for Technical and Applied Physics GmbH
IWC	International Whaling Commission
L_E	sound exposure level
$L_{peak-peak}$	peak sound pressure level
NERI	Danish National Environmental Research Institute
NRC	US National Research Council
O-NEP	German Offshore Grid Development Plan
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
Pa	pascal
PCAD	Population Consequences of Acoustic Disturbance model
POD	porpoise detector
PP10min/d	porpoise positive 10 minutes/day
PPM/h	porpoise positive minutes/hour
PTS	permanent threshold shift
SEL	sound exposure level
SPL	sound pressure level
TL	transmission loss
TTS	temporary threshold shift

Annex 1

ENTWURF = DRAFT
Hauptkonzentrationsgebiet der Schweinswale in der deutschen AWZ von Mai bis August = Main concentration area for harbour porpoises in the German EEZ from May to August
Bundesamt für Naturschutz (BfN), Fachgebiet II 5.2 Meeres- und Küstennaturschutz = Federal Agency for Nature Conservation Section II 5.2 Marine and Coastal Nature Conservation
Stand: Juni 2013 = June 2013
Punkt 1 = Point 1
geographische Länge (WGS84): 6.324038 = Geographical longitude (WGS84): 6.324038
geographische Breite (WGS84): 55.400854 = Geographical latitude (WGS84): 55.400854
Punkt 2 = Point 2
geographische Länge (WGS84): 7.551322 = Geographical longitude (WGS84): 7.551322
geographische Breite (WGS84): 55.166951 = Geographical latitude (WGS84): 55.166951
Punkt 3 = Point 3
geographische Länge (WGS84): 8.044337 = Geographical longitude (WGS84): 8.044337
geographische Breite (WGS84): 55.099176 = Geographical latitude (WGS84): 55.099176
Punkt 6 = Point 6
geographische Länge (WGS84): 6.324038 = Geographical longitude (WGS84): 6.324038
geographische Breite (WGS84): 54.947240 = Geographical latitude (WGS84): 54.947240
Punkt 5 = Point 5
geographische Länge (WGS84): 7.020467 = Geographical longitude (WGS84): 7.020467
geographische Breite (WGS84): 54.538849 = Geographical latitude (WGS84): 54.538849
Punkt 4 = Point 4
geographische Länge (WGS84): 7.530935 = Geographical longitude (WGS84): 7.530935
geographische Breite (WGS84): 54.241864 = Geographical latitude (WGS84): 54.241864
Punkt = Point
geog. Länge (WGS84) = Geog. Longitude (WGS84)
geogr. Breite (WGS84) = Geog. Latitude (WGS84)
ACHTUNG: = WARNING:

Für die Grenzpunkte sowie die Grenzverläufe des Hauptkonzentrationsgebiets, die zwischen den Punkten 1 bis 4 den Seegrenzen entsprechen, ist der proklamierte Grenzverlauf mit den entsprechenden Koordinaten in ED 50 maßgeblich. = The proclaimed course of the border with the corresponding coordinates in ED 50 is authoritative with regard to the boundary points and the course of the boundaries of the main concentration area where they coincide with maritime borders between Points 1 and 4.
Die hier genannten Koordinaten in WGS 84 können den Grenzverlauf nur näherungsweise wiedergeben. = The coordinates in WGS 84 quoted here can only represent the course of the border approximately.
Legende = Key
Hauptkonzentrationsgebiet Schweinswale = Main concentration area for harbour porpoises
Vogelschutzgebiet = Bird protection area
FFH-Gebiete = HD special protection areas
Deutsche AWZ = German EEZ
Deutsches Küstenmeer = German neritic zone
Seemeilen = Sea miles
Bezugssystem: WGS 84 = Datum: WGS 84
Projektion: Mercator (54º) = Projection: Mercator (54º)