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Workshop Report

Methods and Models for the Assessment of Cumulative Effects of Offshore Wind Energy in the North Sea

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The content of this report is based on presentations and discussions among participants of the SEANSE project workshop "Methods and Models for the Assessment of Cumulative Effects of Offshore Wind Energy in the North Sea" on 22-23 October 2019 at the Bundesamt für Seeschifffahrt und Hydrographie Hamburg, Germany

Content

Abbreviations

BSH	Bundesamt für Seeschifffahrt und Hydrographie
CEAF	Common Environmental Assessment Framework
CRM	Collision Risk Model
EIA	Environmental Impact Assessment
ESAS	Comprehensive database for European Seabirds at Sea
MSP	Maritime (Marine) Spatial Plan(ning)
OWF	Offshore Wind Farm
RWS	Rijkswaterstaat
SNBC	Statutory Nature Conservation Body
SEA	Strategic Environmental Assessment
SEANSE	Strategic Environmental Assessment North Sea Energy

Background: Developing a framework for common environmental assessment of offshore wind energy in the North Sea (CEAF)

Renewable energy generated by offshore wind turbines in the North Sea is a critical building block of the European energy transition. Already today, the installed capacity of offshore wind turbines cumulates to some 15 GW in the North Sea. By 2030, this number will rise to around 50 GW, according to the accumulated numbers from offshore development plans by North Sea countries. The installed capacity is likely to grow even further in the future, combined with a steady cost decline and an increased awareness among political institutions about the importance of a clean and reliable energy supply in Europe. A sound and reliable assessment of the impacts on the ecologically sensitive habitats in the North Sea must be carried out in accordance with EU legislation to facilitate the decision-making process of the authorities.

Countries around the North Seas signed a Political Declaration on Energy Cooperation in 2016[1], in order to facilitate the further cost-effective deployment of offshore wind energy through voluntary cooperation, and ensure a sustainable, secure and affordable energy supply in the North Seas countries. One of the work areas defined by this declaration concerns maritime spatial planning. The ten signatory countries[2] therefore committed to coordinate planning and development of offshore wind beyond national borders, increase the exchange of marine data and best practices, and develop a common environmental assessment framework (CEAF).

The CEAF is developed by a working group consisting of seven North Sea countries, represented by their public authorities in charge. It is intended that the framework will provide tools for cumulative ecological effects assessments of wind farm developments in the North Sea for future Maritime Spatial Planning (MSP). The CEAF, in its current version, follows a population-based approach: Effects of offshore wind farms (OWF) are assessed for specific species, taking into account the abundance, distribution, and movements of the species' populations. The CEAF is set to be flexible, as it can be used for Strategic Environmental Assessments (SEA), Environmental Impact Assessments (EIA) and transboundary scenario research. Furthermore, it can incorporate new knowledge and new models, methods or approaches for the assessment of cumulative effects.

The CEAF is tested and refined within several case studies in the context of the EU Commission's DG MARE project SEANSE (Strategic Environmental Assessment on North Sea Energy). Furthermore, the SEANSE project aims to develop a coherent approach to SEA on offshore renewable energy to support the development and effective implementation of MSPs. The project, running from February 2018 to January 2020, is coordinated by the Dutch Rijkswaterstaat (RWS). Further partners include the German Bundesamt für Seeschifffahrt und Hydrographie (BSH), the French Service Hydrographique et Océanographique de la Marine (SHOM), the Danish Maritime Authority (DMA), Marine Scotland of the Scottish Government, and the Conference of Peripheral Maritime Regions of Europe (CPMR) that represents local and regional governments.

[1] More information and the full text of the political declaration can be downloaded at: msp-platform.eu/practices/political-declaration-energy-cooperation-between-north-seas-countries

[2] The signatory countries include Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the UK

Outline: Agenda, targets and proceeding of the workshop

Within the SEANSE project, the workshop on 'Methods and Models for the Assessment of Cumulative Effects of Offshore Wind Energy in the North Sea' took place in Hamburg, Germany, on the 22nd and 23rd of October 2019. The targets for the workshop were the following:

- Gaining a broader and deeper understanding of the variety of methods and models used for the assessment of impacts on marine wildlife and the environment
- Mapping out different experiences in working with these methods and models across countries
- Exploring complementarities, conflicts and common grounds between these methods and models and their application in different contexts
- Identifying concrete and immediate steps for improving and integrating these methods and models within the planning process.

In order to shed light on these issues and harvest diverse ideas and perspectives, around 40 experts from a variety of backgrounds convened in Hamburg for the two workshop days. Participants from seven countries (Belgium, Denmark, England and Scotland, France, Germany, and the Netherlands) shared their diverse experiences and expertise in fields such as marine biology (specialized in birds and/or marine mammals), physics and modelling, or maritime spatial planning. Participants mainly represented statutory nature conservation bodies and national authorities for marine governance, but also public and private research institutes. Conversations took place in a very open and constructive spirit. After an introduction of the different assessment approaches and following working groups about common grounds, conflicts or further research needs, experts discussed in detail different solutions in dealing with controversies between economic development, climate action and environmental protection ("engine room of the energy transition"). Three main thematic topics were covered in three distinct sessions during the two workshop days:

- Session I: Collision risks for seabirds
- Session II: Displacement effects on seabirds
- Session III: Underwater noise and marine mammals

Introductory remarks from RWS included four guiding recommendations to the participants:

- Be aware of selection criteria of methods/models made for (cumulative) assessment tools under discussion
- Be critical towards both, the methods/models used (maybe wrong choices made) and available basic databases (possibly insufficient)
- Assess the presented results of the model runs (with these methods/models) on their credibility/likelihood
- Focus on possibilities for improving methods/models, their (implicit) assumptions and underlying data, based on your specific expert knowledge and expertise

Workshop proceedings

The workshop was designed in the spirit of the overall goals and with the clear intention to explore common grounds as well as understanding potential controversies with regard to the use of different assessment methods and models. Figure 1 summarizes the schematic proceeding of the three sessions of the workshop: Each session started with presentations of case studies from the Netherlands, Germany and (in the case of seabirds) Scotland. The case studies were carried out within the SEANSE project. Results from the studies and the learnings from the case studies on deploying different methods, models and approaches for assessing cumulative environmental impacts, are sought to inform the future development of the CEAF, the decision-making authorities, research institutions and other involved institutions.

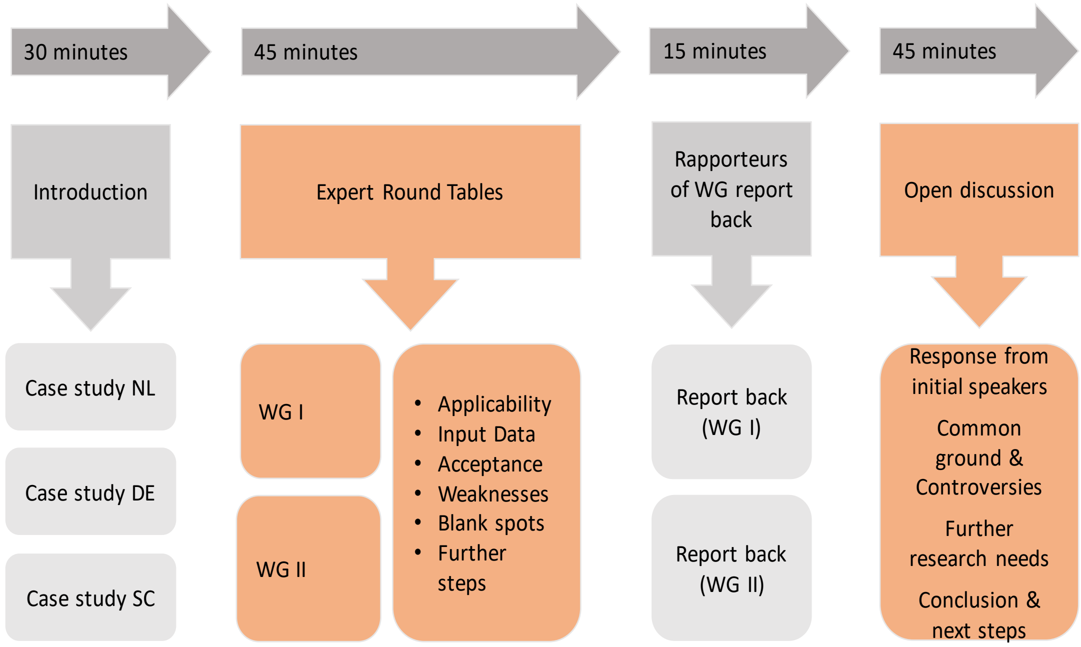

Figure 1: Structure of the workshop sessions

After the introduction of the case studies, participants split into two separate working groups. Both of these groups obtained the identical task to discuss and compare the experiences and results of the different case studies and evaluate the methods/models used. They were given six different topics to be used for structuring the discussion:

- **Applicability**: For which questions and contexts can methods/models be used? Is the approach suitable for SEA? Is it applicable across the entire North Sea area? How easy is it to use and refine?
- **Input data**: Is the required input data available and reliable? Can updated data be included?
- **Acceptance**: Is this a promising approach for effect assessment? Are the results reliable? What are the actual experiences in practical use and scientific evaluation?
- **Weaknesses**: What is missing? What are alternative models/approaches?
- **Blank spots**: Are any questions missing?
- **Further steps**: How can the used method/model be improved? What are the most pressing further research needs?

The above-mentioned structure was deliberately classified as voluntary. Participants of the working groups were asked to disregard the above listed order of questions if needed and to focus on those aspects most relevant to the group.

Each group was also asked to select one or two rapporteurs to take notes during the round tables. Rapporteurs were also tasked with reporting back key points of the working group's discussion to all workshop participants. An open discussion among all participants followed: Speakers who initially presented case studies were asked to respond, and participants discussed common ground and controversies between the different approaches and methods/models, as well as further research needs and potential next steps on the way towards a CEAF and a more coherent approach for SEA.

The authors of this report took minutes of the working group meetings as well as in the open plenary discussions. These minutes, together with the insights from the case study presentations and notes taken by the rapporteurs, informed this workshop report.

Overview: Issues, methods and models discussed at the workshop

Experiences from and results of three different case studies were presented during the workshop. The Dutch (commissioned by RWS) and German (commissioned by BSH) case studies looked into environmental effects of main pressures of offshore wind energy (collision and displacement for seabirds, pile driving noise for marine mammals) on representative receptor species. The cumulative effects were assessed for three scenarios of wind farm development across the entire North Sea: Until 2023, until 2030, and beyond 2030 (as far as information on planned numbers and locations of offshore wind energy farms were available). Furthermore, a regional case study by Marine Scotland covered the impacts of OWF on seabirds within a geographically enclosed region in the south eastern Scottish waters. This case study also calculated cumulative effects for three scenarios: The first with no offshore wind, the second with around 2.2 GW of offshore wind, the third with a total of 5 GW and large-scale offshore developments far away from the shores. In addition, the German habitat approach to deal with cumulative effects was presented by BSH.

A variety of different approaches, methods and models were applied in the case studies and discussed within the workshop. These include:

- Collision risk: SOSS Band model (Band 2012) and Stochastic CRM (2018)
- Displacement risk: BSH/RWS calculation approaches and SeabORD/Matrix method
- Underwater noise: AQUARIUS model for calculating sound production and propagation from piling activities
iPCoD and DEPONS models for population impact assessment

Based on an extensive literature review, an initial inventory and assessment of these methods and models (as well as some others) was carried out by Royal HaskoningDHV[3]. The study was commissioned by RWS and published in May 2018. Its results were presented at the workshop and served, together with the presented case studies, as a foundation for the expert's discussions on the specific approaches that are summarized in the next chapters for each thematic session.

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[3] Royal HaskoningDHV (2018): Inventory and assessment of models and methods used for describing, quantifying and assessing cumulative effects of offshore wind farms. Report commissioned by RWS.

Session I: Collision risk for seabirds

The CEAF working group identified two representative seabird species as receptor species for collision risks: black-legged kittiwake (*Rissa tridactyla*) and lesser black-backed gull (*Larus fuscus*).

Different collision risk models (CRM) are used to calculate the number of collision victims for these species. While the Dutch case study applies the SOSS Band model, an updated stochastic Band model (Stochastic CRM) is used in the German case. Marine Scotland also uses the stochastic CRM, but follows a more integrative approach and combines collision and displacement risk assessments.

Comparison of different methods and models

The Band model of the Dutch case study requires location-specific data on wind turbines and bird presence, and can theoretically be used for all bird species. Bird distribution data consists of interpolated survey data from the European Seabirds at Sea (ESAS) database for the period 1991-2014 and aerial survey data from the Dutch MWTL monitoring programme for the period 1991-2017. In order to calculate collision victims, the Band model is fed with input parameters relating to characteristics of the wind turbines and the bird species, such as their average body length, degree of nocturnal activity and flight speed. It is assumed that only rotating offshore turbines kill birds, and that birds die immediately once they hit a rotating turbine. Changing parameters such as flight height of birds, or especially their avoidance rate (even small variations between 99.5 % and 99.8 %) might result in substantial differences in the calculated number of collision victims. Fatalities are calculated for six bimonthly periods of the year. Because birds could theoretically die more than once in the model, the bimonthly numbers of collision victims are not totalled to a year's count, as this would lead to overestimations.

The stochastic CRM used in the German and Scottish case studies is similar to the Band model in a number of aspects and rests on comparable basic assumptions. However, it takes into account empirical data about individual variations within the species, for instance in terms of the birds´ size and their flight height distributions. As the model is stochastic in nature, it does not predict an absolute number of collision victims, but rather a probability distribution for different outcomes.

Working group discussions focused not so much on differences between the two CRMs, but rather on their common challenges, that especially concern the accessibility and quality of input data, the assumptions made about birds' behaviours and the general use of the models in MSP. Furthermore, uncertainties were discussed on a changing marine environment but also with regards to future development of wind turbines (possibly fewer but higher turbines within an OWF) and what this means for the collision risk of seabirds.

Outlook: Common issues, challenges and next steps forward

Overall, the experts viewed the development of the stochastic CRM as a step in the right direction towards more realistic estimations, and it was seen as a foundation for future improvements of CRM.

Increase of data quality and accessibility

To make better use of the data that already exist on bird distribution (and in fact also on future OWF developments and their exact location), it was recommended that data should be compiled and made available in one central platform. A lot of data has been collected and would be valuable to analyse further; however, wind farm developers and national governments are often reluctant to share all available information. It was suggested that the EU commission might overcome this knowledge-sharing barrier by establishing a programme designed to compile all existing data on seabirds into one publicly accessible platform. Furthermore, the ESAS database contains some rather outdated and narrow information and should be revitalized.

The collection of additional data is also needed for improving CRM models. The lack of empirical observations on flight height, flight speed and avoidance rate has been identified as a core challenge. These input parameters strongly influence the modelled estimates of collision victims, and there are large gaps between the generic data often used for input and the few empirical studies. It was noted that some data is especially difficult to collect, for instance the actual number of collision victims. Additional data should be collected via tagging of individual seabirds around the year, through GPS and altitude tracking. These individual observations can also help to gain more insight into the birds' behaviour (and the factors that influence it) and thus inform the development of more individual-based models.

Development of individual-based models

The development of an individual-based CRM was identified by many participants as a desirable mid-term goal. Such an individual-based model would take into account variations within the behaviour of individual birds and their behavioural changes over time. For instance, birds might adapt to changes in their habitat, learn from experiences, and modify their actions around wind turbines. While results from individual-based simulations are expected to be more accurate, it was noted that these models take much time and resources to be developed, and require a lot more information on the behaviour of individuals from specific species than is currently known. The development of an individual-based model would therefore need to take place in a gradual manner, incorporating new information step-by-step as it becomes available.

Clarifying the scope of application: European guideline on 'how to use the results of modelling'

The question on 'when and how to use results of the model' was controversially discussed – and captured the potential dilemma authorities may face when in charge for authorization of new offshore wind farms. Participants agreed that currently existing CRMs still have limitations in their application for licensing procedures. As of today, different countries use CRM at different stages of the planning process; some apply them for SEA, others for EIA. Some participants argued that CRM should only be used for strategic spatial planning and scenario comparison, but not for concrete licensing, as vague assumptions could lead to unreliable results. Therefore, it was suggested that a European guideline on how to deal with CRM results in maritime spatial planning might be useful. Besides, the CEAF working group could develop a roadmap with specific suggestions on the next steps for improving CRM for environmental assessments in MSP, give recommendations at which stage of the planning process models might be used, and how results should be interpreted. Such advice could eventually facilitate case-by-case decision-making of the respective authorities and help to mature more harmonized standards of environmental impact assessment, that still take into account the respective conditions and ecological values of different areas and habitats.

Session II: Displacement effects on seabirds

Once OWF are in operation, seabirds might avoid these areas and retreat to other places for foraging. This loss of habitat is referred to as displacement. Red-throated diver (*Gavia stellata*) and common guillemot (*Uria aalge*) are common receptor species for displacement effects.

Both the Dutch and German case studies follow similar approaches to calculate the number of seabirds displaced by OWF. The cumulative number of displaced birds is estimated for bimonthly periods by removing the displaced proportion of birds (up to 100 %) from the area covered by wind farms, and a buffer zone around them. Marine Scotland uses an integrative approach, combining collision and displacement risk assessments for seabirds, in order to estimate annual impacts on productivity and survival, and therefore carry out a population viability assessment for the species. Specifically, for the calculation of displacement effects, the Scottish approach combines an individual based simulation (SeabORD, for the breeding season) and a matrix method.

Comparison of different methods and models

Similar to collision risk calculations, the Dutch and German case studies use ESAS and Dutch MWTL data of bird density and distribution across the North Sea to inform the initial assessment of varying density and distribution of red-throated divers and common guillemots over the year. The number of displaced individuals is calculated for bimonthly periods. The Dutch case studies calculate cumulated displacement numbers for all annual six bimonthly periods and for the three scenarios (2023, 2030, beyond 2030). The German case study calculates displacement numbers only for the second scenario (displacement by OWF in 2030) and for those selected bimonthly periods of the year, in which densities of the respective species are highest (March-April for divers, January-February for common guillemots).

In both the RWS and BSH approaches, the actual number of displaced individuals is calculated by multiplying the area of the footprint of the wind farms with the local density of the species in this area. The footprint consists of the OWF layout and an additional buffer zone related to the assumed disturbance sensitivity of the respective species (5.5 km for red-throated divers, 2 km for common guillemots). While the Dutch approach assumes a 100 % displacement rate inside the footprint areas for all species, the German case study analyses three scenarios. First, a 100 % displacement of divers within the total footprint area; second, a 99 % displacement of divers insight the wind farm layout and 50 % displacement inside the buffer zone; third, a 75 % displacement of guillemots insight the wind farm layout and 50 % displacement inside the buffer zone.

The Scottish study combines stochastic collision risk assessment and different approaches for calculating displacement (individual-based SeabORD for breeding season, matrix approach for non-breeding season) to estimate annual impacts on productivity and survival for five different seabird species (including common guillemot, but not red-throated diver). Hence, the case study is able to carry out a population viability assessment with longer-term projections of population size.

Opposed to the German and Dutch calculation approaches, the Scottish case study does not only take into account at-sea survey data, but combines it with GPS tracking data obtained from individual birds from different colonies during the breeding season. The SeabORD approach is then used to calculate displacement effects for GPS tracked species during the breeding season. Where the SeabORD approach was not applicable, the Scottish case study used a matrix approach similar to the RWS and BSH calculations to assess the number of displaced individuals. The Scottish calculations assumed displacement rates between 30 and 80 % for different species (60 % for the guillemot) and a mortality rate of the displaced birds between 0.25 and 2 %.

Overall, the Scottish approach is more comprehensive than the similar Dutch and German methods, but only on a regional scale. It combines CRM, displacement assessment and links these insights to determine effects on the overall population. By using the SeabORD model, individual behaviour and the resulting mortality rates can be compared between a baseline scenario (with no wind farms) and scenarios with offshore wind development. Furthermore, the model is able to distinguish between effects on adult and juvenile birds, and it also takes into account the changes in energetics and energetic costs of displacement and barrier effects (meaning birds have to fly or swim around the wind farm) to breeding seabirds.

Outlook: Common issues, challenges and next steps forward

Generally speaking, experts agreed that there is currently far less knowledge on displacement than on collision risks. Knowledge gaps concern the question of how many birds are displaced due to wind farms, as well as the question of what displacement means in terms of the individual bird’s survival rate and the long-term viability of the species´ populations. Furthermore, and similar to collision risk assessment, there is a lack of reliable and useful data and knowledge to inform the models.

Expanding knowledge about displacement rates

There is no clear understanding of how many birds are actually displaced by a wind farm. The Dutch and German case studies follow (in one scenario) a “precautionary, but not necessarily most realistic approach” and assume a 100 % displacement rate within the total footprint area of the wind farm. Based on bird monitoring at specific OWFs, the Scottish and German calculations (in a second scenario) assume that some seabirds continue foraging within the extent of a wind farm layout, and especially the buffer zones around it. This uncertainty regarding displacement effects was also reflected in the working groups: while some experts emphasized that the cumulative consequences of displacement might in the long run be more impactful than those of collisions, others argued that general hydrographic factors and trends, as well as the availability of prey, have great influence on the density of seabirds within an OWF. For instance, seabirds could get used to the turbines and even increase their foraging in these areas due to restricted fishing activities within OWF. A key question is what actually causes the displacement of the birds and how e.g. ongoing maintenance activities contribute to the displacement effect in addition to the rotating turbines. Participants agreed that the monitoring of seabirds and actual displacement effects needs to be increased, in order to fact-check the assumptions on displacement rates in all the calculation approaches.

Develop an understanding of displacement and its effect on population level

Another core challenge is to understand what happens to individual birds once they are displaced, and how displacement affects their individual and populations’ chance of survival. In the RWS and BSH calculations, birds simply disappear, as the density of birds in wind farm footprints is set (close to) zero. As the Scottish approach takes into account individual behaviour and barrier effects, the density of seabirds around the OWF actually increases. The Dutch and German case studies make no statements yet on the mortality rate of displaced birds. While the Scottish case study assumes mortality rates between 0.25 and 2 %, earlier calculations for the Dutch KEC study assumed mortality rates of 10 % of the population. All of these assumptions were regarded as rather arbitrary and weak, and experts called for more empirical studies on mortality rates.

Acceptable population impact models would also need to take into account the demographics of the affected population. Furthermore, a comprehensive definition of "population" in terms of its geographical spread (local, regional, whole North Sea region, etc.) and its trajectory would need to be defined. The Scottish approach is rather advanced in terms of taking into account the specific demographics of a specific population.

It was also suggested to monitor where seabirds displace to and to explore maximum density levels or carrying capacity of the areas around wind farms, where displaced seabirds share their hunting grounds with others. This assessment would also need to consider individual behaviour: some birds might suffer in new areas because their hunting strategies do not work anymore, even though there is enough prey available.

Obtain data on individual behaviour through tracking

The SeabORD model was regarded as a good model and valuable step forward by the expert groups. However, the model is 'data-hungry' and can for now only be applied to a small geographical range and a certain number of species. Comprehensive GPS tracked data is needed as input for the SeabORD model, ideally combined with additional data on the birds´ diving depth or speed. Tracking birds and obtaining the data is, however, difficult: after foraging, birds need to return to the same place from which they started (which they do only in the breeding season, hence SeabORD can only be applied to these periods of the year) and small seabirds cannot carry many different tracking devices. But some additional tracking studies are underway and might increase data availability in the future. It was also suggested to focus empirical studies and data collection on specific regions (especially valuable habitats for divers, instead of the whole North Sea) and then develop and apply individual-based models only to these smaller regions.

Processing studies as a means to better evaluate model based decision-making

Some workshop participants argued to not focus entirely on the collection of new data. Instead, they suggested that more studies on data processing were needed in order to evaluate the existing data and their use in the models. These studies would need to evaluate the calculated results by relating them to actually observed and monitored impacts, and feed learnings back into the models. By reading and interpreting existing data, a better understanding of the consequences of displacement effects could be reached.

Merging collision and displacement models

Experts agreed that, in the long-term, more comprehensive models are needed. These approaches should take into account factors such as the general state and properties of the birds' habitats, changes in climate, or in the availability of the birds' prey. They should also take into account the combined effects of collision and displacement. This is especially relevant for species that are not 100% displaced by wind farms, and that reach flight heights at which they might collide with turbines.

Precautionary planning through mapping of sensitive habitats

As displacement is yet little understood, governing bodies need to ensure that wind farm operators and researchers collect sufficient and comparable data on bird displacement after turbine construction. Furthermore, planners need to recognize these uncertainties and develop and approve new offshore projects with caution. Updated distribution data can be the start for mapping sensitive habitats of seabirds or to conduct habitat suitability modelling as a basis for decisions on potential wind energy sites. As far as sensitive habitats are excluded from offshore wind development, this planning approach might be more promising than assessing mortality rates of displaced populations due to offshore projects close to sensitive habitats. The current approaches (for the non-breeding season) are not validated models yet and deliver rather obvious results, which might not always give advice on where to place OWF from an ecological perspective.

Session III: Underwater noise and marine mammals

Underwater noise from anthropogenic activities disturbs marine mammals, especially impulsive sounds from pile driving activities during the installation of turbines. The harbour porpoise (*Phocoena phocoena*) is the representative receptor species for assessing effects of cumulative noise disturbance. If porpoises are exposed to noise above a certain threshold (in terms of volume, frequency, and time of exposure), increased mortality rates of the calves and decreased fertility of the adults can be observed.

The Dutch case study uses a combination of the AQUARIUS 4.0 (for calculating sound production and propagation from piling activities) and iPCoD model (for calculating impacts on harbour porpoise populations in a top-down, statistical manner). The German case study applies the bottom-up agent-based DEPONS model (Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea).

Comparison of different methods and models

Assessing the impact of noise on a species' population requires at least two modelling steps: First, it is necessary to quantify the sound level of the piling activity and model the propagation of the sound under water. Second, the impact of the noise on the porpoises needs to be calculated, based on the (modelled) distribution of the population in the North Sea and the time that individuals are exposed to noise levels above harmful threshold levels.

In the Dutch case study, the AQUARIUS 4.0 model was used to model noise production and propagation. This model takes in a lot of parameters regarding the source of the noise (for instance pile location, size, material, hammer energy, bathymetry, sediment properties…) and allows for a detailed calculation of sound distribution.

To determine the cumulative impact of turbine construction on the porpoise population, the Dutch study applies the iPCoD (interim Population Consequence of Disturbance) model. This rather simple stage-based matrix model runs simulations quickly and requires little input data. It can be used to assess disturbance of other species (grey seal, harbour seal, bottlenose dolphin and mink whale) across the entire North Sea. The model relies on a set of fixed assumptions: Individuals share identical properties (but they are classified into different groups regarding age and disturbance levels) and they do not remember noise disturbances from previous years (disturbance effects are statistically cumulated over each calendar year). Key input parameters of the iPCoD model are based on expert assessments: For instance, the relationship between the number of days disturbed and the survival or birth rate, or the inter-annual variation in birth rate and survival of juveniles and adults as a result of environmental variation. In the Dutch case study, porpoises are defined to be disturbed more than six hours of the day if exposed to noise exceeding a certain noise threshold.

The DEPONS model studied in the German case study is a more complex model. It is a bottom-up and agent-based tool, as it models the behaviour and disturbance of individual porpoises and aggregates results to the population level. In 30-minute time steps, DEPONS models the choices individual porpoises take on direction and speed of movement (determined in the model by a set of 22 parameters for movements in (un)disturbed waters, calibrated for North Sea harbour porpoise), based on the type of habitat occupied and the level of noise exposure. The current version of the DEPONS model includes a simplified model for noise production and propagation, corresponding with a fixed response distance for all piling activities. The model then considers the energetic status of the individual and determines its change of survival. DEPONS also assumes that a high population density is linked to increasing mortality. The habitat quality is modelled to real North Sea conditions; however, food supply is constant and static and there is no environmental stochastic in the model.

Most experts agreed that both the iPCoD and DEPONS models have their value and draw on complementary strengths. Whether their application is ultimately suitable depends on the questions that policy makers and planners want to be answered. The DEPONS model is very detailed and more realistic, as it takes into account individual behaviour. However, complicated models are not necessarily always better. While DEPONS is 'data-hungry', takes a long time and much expertise to run, and applies only to one species, iPCoD is better suited to create a general overview on possible population impacts (e.g. on the number of impact days).

Generally speaking, it was also noted that the population approach is still far from being exhaustive and a number of uncertainties remain. For example, assessing the impact of underwater noise on marine mammals is currently at the centre of different EIA models and methods, while dynamics of population can be also hugely influenced by changes in predator-prey behaviour, bycatch, and other factors. Furthermore, in terms of forecasting uncertainties in measuring the impact of noise emissions, parameters should be as inclusive as possible and cover the broad range of behavioural disturbances[4].

Outlook: Common issues and challenges and the next steps forward

The AQUARIUS model was generally regarded as a good tool for acoustic modelling by the experts in the workshop. But participants called for further validation of the model, as its results were only validated once with real data from a piling site. Furthermore, AQUARIUS is owned by the Dutch TNO and not publically available. This might change in the future, but until then, national authorities use other, more basic methods and models, that were also regarded acceptable, provided that they are somehow validated. It is also possible to work with fixed parameters for noise propagation around wind farm construction sites.

Better differentiation of underwater sound

There was some concern whether the noise exposure metrics measured at piling sites and informing the models were actually appropriate. There are indications that exposure metrics that include a frequency weighting corresponding with the hearing sensitivity might provide a better prediction of how harbour porpoise might react to noises than the currently assumed unweighted metrics. As a precautionary measure, it was suggested that more comprehensive information on different noise levels at different frequencies should be measured during turbine piling. Models could introduce a frequency weighting based on the real hearing ability of harbour porpoises, but more research is needed to establish the appropriate weighting functions for behavioural response. It was also put forward to assess the effects of noise reduction measures in a comprehensive study to gain understandings e.g. on how the affected area changes, when noise is reduced by 5 dB, 10 dB etc.

[4] Müller-BBM note, Nr: M146361/08

Impact of noise levels on the recipient

The issue of noise frequencies links to one of the most crucial challenges identified by workshop participants: The understanding of how exactly which noise metrics link to which reactions and ultimately the effects on the porpoise population. More empirical studies are needed on this subject and permanent threshold shifts might need to be reconsidered. A better understanding would improve the models, especially iPCoD that relies heavily on the general assessment by experts (whose knowledge is, up to this point, limited). It was noted, however, that porpoises are generally difficult to study and observe in their natural habitat, and that there are few GPS tracked individuals.

Comparing iPCoD and DEPONS is needed

Experts also suggested to conduct a comparative parameter study on the variances of the iPCoD and DEPONS models for different scenarios. Such a systematic study would enhance the understanding of the models' limits and how altered assumption variables and input factors affect the actual differences between model outputs. To properly compare the modelling approaches, DEPONS modelling should be carried out for the same North Sea piling scenario(s) for which iPCoD modelling was carried out in the Dutch case study.

Thresholds - useful or not useful?

Two controversial discussion points concerned the general applicability of iPCoD and DEPONS models to MSP and whether there is a need for clearly defined threshold levels for the population's overall disturbance. As these controversies tie into larger and general themes of the workshop discussions, they will be discussed in the following chapter.

Overriding challenges for cumulative environmental assessment

Over the course of the two workshop days, some overriding challenges were raised repeatedly. As they do not only concern a specific method or model, discussions on these issues are summarized here.

Generally speaking, experts agreed that the current understanding of the complex and constantly changing ecosystem of the North Sea remains vague. However, many authorities are faced with an increased demand for efficient renewable energy generation such as offshore wind, which eventually cumulates in additional burdens for that very ecosystem ('in-combination impact effects').

'Complexity of the ecosystem' vs 'Need to measure environmental impacts'

Existing knowledge about the North Sea environment does not provide certainty on the absolute population numbers of a species nor their extinction thresholds: how many seabirds and marine mammals actually live in the North Sea and how can these populations be defined? The modelled scenarios also lack much information that might influence the behaviour and overall population numbers of the investigated species in the future: for instance, how do impacts of climate change on the flora and fauna of coastal regions change the picture? How do changes of population distribution and levels affect the abundance and distribution of prey, and how do changes for these species in turn influence the receptor species? Modellers and planners need to be aware that their models and their results are not responding to these questions, or only work with rough estimates and educated guesses on these issues. Model outputs should depict the range and probability of outcomes, to further facilitate a transparent discussion between modellers and planners.

'Models can help to assess environmental impacts' vs 'Models can be misleading if results are used for SEA'

There was some fundamental discussion on whether models are actually needed for cumulative impact assessments on specific species and where they should be used in the decision-making processes (in strategic planning or only past construction). If the input data of the models are incomplete can and should the models be used as a tool for SEA? For instance, the German BSH expressed scepticism on the reliability of the population-based iPCoD and DEPONS models and does not prioritize advancing them further. Instead, they shifted to a habitat-based approach: specific areas/habitats with a greater ecological value are defined, and cumulative impacts are assessed for these habitats, as they serve for specific species. The BSH argues that this is a more precautionary approach, and that it is easier for planners to manage and assess the disturbance of certain areas, instead of the behaviour of individual animals. The BSH continues working with underwater sound propagation models, in order to assess overall noise impacts on the habitats.

Many experts believed that population-based models, even though not perfect, are useful for answering some questions and provide valuable starting points from which to enhance the quality of data and the understanding of the ecosystems. This, however, requires a decent consideration of the questions and an appropriate choice of models based on these questions. With mid-term visions for more ideal models on the horizon, the current methods and models can be enhanced step-by-step.

For seabirds, a mid-term target would be the development of an individual-based model integrating collision risk and displacement effects. For marine mammals, advanced models should draw on more validated observations of the relationship between noise disturbance and population impacts. For both applications, it would be desirable to take into account more information and parameters on changes in the ecosystem which are unrelated to offshore wind energy development.

‘Red lines for the decline of population size are needed’ vs ‘Thresholds only apply for a certain location and are not transferable’

A controversial discussion evolved around the topic of thresholds. Should there be clearly defined levels of a minimal population size, at which further offshore development would need to stop in order to avoid reaching crucial tipping points and, ultimately, the extinction of a species in the North Sea? Some experts expressed scepticism: they pointed out that thresholds would need to be very place- and population-specific and generalized numbers for the entire North Sea would not be reputable from a scientific standpoint. They also argued that set thresholds would require extensive monitoring and much more harmonization in terms of data collection by different countries. Moreover, setting thresholds or defining acceptable levels of potential impacts would require a societal debate. On the other hand, participants emphasized that threshold levels (e.g. fishing quotas) and intensive monitoring have proven to be a successful approach for managing fish populations. The Marine Strategy Framework Directive already requires the member states to define threshold levels on noise for the Good Environmental Status in European Seas. Therefore, defining threshold levels or so-called acceptable levels of impact should be considered a useful step forward from the policy and planning perspective.

‘Precautionary approach on ecosystems’ vs ‘Rapid upscaling of offshore wind energy as a contribution to combat the global climate crisis’

Even though the further rollout of offshore turbines is an important contribution to mitigating the climate crisis, its consequences on marine wildlife and habitats are not yet fully understood. Participants agreed to deploy a precautionary approach in all matters regarding future OWF. Population-based models should be built on very precautionary assumptions and constantly validate input parameters and monitor results. Planners should be aware of the uncertainty within population-based models, when they use them in MSP. It was also stated that protecting especially important and sensible habitats from offshore wind developments would be the best precautionary measure. Furthermore, potentially harmful environmental impacts should be mitigated (e.g. by using technology to reduce noise from piling activities).

Closing remark

Planners from different countries should not lose track of the common European target of reducing cumulative environmental impacts from human activities in the North Sea. However, finding a ‘one size fits all’ solution for environmental impact assessment remains far from being realistic, as the complexity of an ecosystem and its relationship with its immediate environment does not match with entirely harmonized standards and tools.

Furthermore, a number of rather concrete proposals were raised at the workshop:

- Comparing the actual impact of existing sites with the assumptions on which these sites were authorized (‘monitoring studies’)
- Improving data accuracy by acknowledging existing gaps and generating further input where available (‘data collection’)
- Comparing outcomes of different models (e.g. DEPONS and iPCoD) and potentially integrating them (e.g. CRM and displacement approaches)
- Taking individual behaviour into account can be complex, but could increase the understanding of environmental impacts over time (individual-based models)
- Providing guidance for authorities on how to use the model results in their day-to-day business (‘data processing’ and advice by environmental working group)

- Facilitating the process of developing new and adjusting existing models by enabling regular exchange of experts, model builders and authorities ('institutionalizing and improved dialogue among authorities')

Participants acknowledge that identifying common grounds among European North Sea countries and among different approaches to measure environmental impacts remains a reasonable pathway towards the overall goal of the European energy transition. The workshop contributed to this goal, as it broadened the understanding of the expert community about the variety of different approaches taken by countries, and thus marked a step into the direction of a more harmonized and coordinated environmental assessment.

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Annex: List of participants

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