Intelligent Energy Europe

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SUPPORTING DECISIONS

SPatial Deployment of offshore WIND Energy in Europe (WINDSPEED)

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Horizontal Key Actions

"Calculation rules for the DSS"

WP3 Draft Report D3.3

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Calculation rules for the DSS

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- Wageningen ***IMARES*** conducts research providing knowledge necessary for the protection, harvest and usage of marine and coastal areas.
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Table of contents

Executive Summary

The WindSpeed project aims to develop a roadmap defining a realistic target and a development pathway up to 2030 for offshore wind energy in the Central and Southern North Sea (www.windspeed.eu). To achieve this roadmap spatial data on where these activities occur and if possible with what intensity is needed. This data can then be used as building material to feed into the DSS or Decision Support System that is also part of the project plan. This GIS-based tool will show a spatial representation of offshore wind energy potential in relation to non-wind sea functions and environmental aspects. The tool will also facilitate the quantification of trade-offs between electricity generation costs from offshore wind and constraints due to non-wind sea functions and nature conservation.

In order to assess the suitability of locations on the Central and Southern North Sea for offshore wind parks present sea use functions should be taken into account.
These sea use functions include

- shipping,
- oil and gas extraction,
- fisheries,
- cables and pipelines,
- military activities,
- sand extraction,
- radar interference and
- nature conservation.

This report is a printed version of deliverable ‘D3.3 A set of calculation rules for the interactions between offshore wind and other use functions‘ and is intended to promote discussion with stakeholders on the defined calculation rules. It builds on two previously published reports:

- D3.1. Overview report of non-wind sea functions currently at stake in the area, including scenarios for their development in the period up to 2030 (Van der Wal *et al.*, 2009a) and
- D3.2. Report with an analysis of positive and negative interactions between offshore wind and the other use functions of the North Sea (Van der Wal *et al.*, 2009b).

Based on the knowledge gathered from the present and expected future distribution and intensity of the sea use functions and the nature of the interactions between them, calculations rules for implementation in the DSS can be defined. A calculation rule for the DSS is a formula or an algorithm that defines how to calculate where a given sea use functions has a strong claim on an area and where it has a weaker claim or possibly no claim at all.
Four categories of calculation rules have been identified:
1 Exclusions
2 Economic values
3 Spatial suitability values
4 Refinements to reduce heterogeneity

The calculation rules are classified in four categories depending on the nature of the activity (or sub-category thereof) and the applicability of a certain rule to it.
For a given sea use function only one type of rule is used. Here a hierarchy exist: when an exclusion is used no use will be made of either an economic rule or a spatial suitability value.

The latter two types are mutually exclusive. Where ever possible an economic rule will be used, alternatively a spatial suitability rule will be used.

The analysis of positive and negative interactions of OWP and other sea use functions shows that similar to oil and gas extraction, OWP are more difficult to combine with other uses than those are with each other. Regarding priorities, as they are based mostly on economic considerations, the following sea use functions could be considered to have stronger claims on space at sea than OWP do:

- Shipping;
- Oil and Gas extraction;
- Cables and Pipelines.

Currently shipping claims a considerable part of the North Sea. Oil and gas extraction also lay to claim a large area. This strongly depends on the number of platforms that require helicopter access. Platforms with helicopter access need an exclusion range of ca. 5 nautical miles which lays claim to nearly 300 km^2 for a single platform.

In relation to military activities, the outcome is difficult to predict. Historically and politically, the requirements of the armed forces for areas to practice have been very highly regarded. Recently the threat of terrorism and the increased occurrence of acts of piracy help to strengthen such claims. It remains to be seen whether offshore wind energy is perceived by society and politicians as sufficiently attractive and rewarding as a source of renewable energy to be successful in laying claim to areas presently in use by the armed forces. Displacing military use to other locations will give rise to new conflicts with other sea use functions. On the other hand recent changes in the role of the military, such as peace-keeping and peace-enforcing operations or patrolling foreign sea areas to combat piracy, may mean that they have new requirements, that may mean a smaller need for space at sea or that this space should rather be somewhere else to better suite their purposes.

With respect to fisheries and sand extraction calculation rules based on economical value would be applicable and desirable, as this would provide a fair and straightforward method of weighting these activities against others. Sand extraction is an activity that has clear economical value to society. As availability of terrestrial sources of sand and gravel are on the decline, increased interest for exploitation of marine sources is to be expected. Unfortunately economical calculation rules could not be achieved for either of them as the available data was not sufficient for this purpose. For fisheries a coarse map showing the relative importance of ICES rectangles for fisheries based on effort expressed as spent days at sea has been build. By avoiding the most important fishing grounds, the interests of fishermen are at least partially safeguarded. A higher resolution in this dataset could not be achieved, mostly because privacy and confidentiality concerns prevents countries from granting access to better quality data.

Nature conservation is the last remaining sea use function to discuss that competes with OWP for space at sea. Most marine nature conservation areas have been designated as part of Natura2000 and as such this does not definitively exclude an OWP from the same area. However, the burden of proof showing that the wind turbines do not endanger the conservation goals for the area lies on the side of the OWP. Currently, it seems the preferred option is to develop OWP outside nature conservation areas. If the spatial requirements for offshore wind energy cannot be completely met outside nature conservation areas, prioritization rules can be devised that take the conservation goals and their compatibility with OWP into account.

All calculation rules that have been defined so far are category 4 where sub-categories are distinguished within a sea use function. For each sub-category the sub-rule can be either an exclusion, an economical value or a spatial suitability value.

Calculations with the WindSpeed DSS using the present datasets and calculation rules will tell whether these allow for sufficient space – and at an acceptable cost - to be allocated for OWP to reach the sustainable energy goals of the European Union and the partner countries while also taking all other interests into account. If this is not the case improvements to the spatial datasets or the calculation rules may help to find more space for offshore wind energy. These improvements can be targeted to address the issues that were found to be most restrictive to the development of offshore wind energy in the North Sea. The implementation of the calculation rules in the DSS is such that many options can be set and the calculation rules and values presented here form the core of the default calculations.

At first glance the calculation rule for each non-wind sea use functions leaves significant space available for the development of offshore wind energy. However the available area according to one rule is often not (fully) available according to another rule and the final area available to OWP without restrictions may be limited. Offshore wind may therefore not be able to develop to its full potential, unless decisions are made to enhance these possibilities at the cost of other uses of the North Sea.

It should be noted that hard exclusion of OWP from an area is only used for some human sea functions, where e.g. physical presence of installations or clear legal constraints apply. Mostly soft constraints are applied where a limited share of a given area is seen as potentially available for developing OWP. For the calculation rules no hard exclusion is used, although the default setting for Natura 2000 areas is to exclude these.

The DSS tool allows the user to modify settings, such as safety distances or sub-categories to include or exclude. In this way the DSS can reflect various spatial priorities as defined by individual stakeholders or policy makers.

1 Introduction

1.1 WindSpeed Work package 3 – Non-Wind Sea Uses

The WindSpeed project aims to develop a roadmap defining a realistic target and a development pathway up to 2030 for offshore wind energy in the Central and Southern North Sea (www.windspeed.eu). To achieve this roadmap spatial data is needed on where these activities occur and where possible with what intensity. This data can then be used as building material to feed into the DSS or Decision Support System that is also part of the project plan. This GIS-based tool will show a spatial representation of offshore wind energy potential in relation to non-wind sea functions and environmental aspects. The tool will also facilitate the quantification of trade-offs between electricity generation costs from offshore wind and constraints due to non-wind sea functions and nature conservation.

One of the main reasons to undertake this effort is a target of 20% share of renewable energy in the European energy supply by 2020 as set by the European Union in the new Renewable Energy Directive [1]. Wind energy including offshore is expected to contribute a major part to this objective.

The WindSpeed project will make the different claims of human activities on the North Sea spatially explicit. These activities include those related to offshore wind energy production, but also a number of non-wind or other sea use functions. To this end IMARES has collected data on these other sea use functions. We have gathered data from several national institutions, with a good deal of help from our project partners in identifying the best available sources. Next to datasets on human activities, data has been gathered on the location of different types of nature conservation areas and natural values in the marine area.

The deliverables of work package 3 are:

- D3.1. Overview report of non-wind sea functions currently at stake in the area, including scenarios for their development in the period up to 2030 (Van der Wal *et al.*, 2009a)
- D3.2. Report with an analysis of positive and negative interactions between offshore wind and the other use functions of the North Sea (Van der Wal *et al.*, 2009b)
- D3.3. A set of calculation rules for the interactions between offshore wind and other use functions, in a database or other digital format

This report is the printed version of D3.3 and is published mainly to aid in the next round of discussions with stakeholders about the definition of the calculation rules. Digitally the calculations rules have been implemented in the Decisions Support System at DLR, as part of work package 4.

1.2 Methodology

Within work package 3 of the WindSpeed project a systematic approach has been taken to arrive at the calculation rules that are specified in this report. Firstly an inventory was made of non-wind sea use function present in the WindSpeed area, including expected future

[1] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (published in OJ 140, 05.06.09, p. 16).

development of these sea use functions towards the target years 2020 and 2030. The following sea use functions were included:

- shipping,
- oil and gas extraction,
- fisheries,
- cables and pipelines,
- military activities,
- sand extraction,
- radar interference and
- nature conservation.

During the spring of 2009 a series of national stakeholder workshops was held. Here stakeholders were asked whether important sea uses were still missing. This action did not results in any additions to the list presented above. As part of the presentations given on the workshops the preliminary results of the data collection process were presented. This helped in identifying possible sources to fill the blanks that were at that time still present, with valuable suggestions from participating stakeholders.

An unexpected step was required to facilitate the use of the collected national datasets as the basis for building a DSS. All countries stored their geographical datasets in different ways and all these differences needed to be harmonised. This means that all different fields and languages used where adjusted to fit as much as possible into a single system and translated to the English language.

The results of the data collection, including expected future development for each of the non-wind sea use functions is reported in D3.1 Inventory of current and future presence of non-wind sea use functions (Van der Wal *et al.*, 2009a).

The next step in the process was an analysis of the interactions that OWP will have with the non-wind sea use functions. For the sake of being complete, the interactions between non-wind sea use functions were also included in the analysis. Interactions considered included exclusion, compatibility but also including the possibility of positive interaction. Positive interaction in this case signifying a situation where the presence of some sea use function improves the conditions for another sea use function, These interaction are analysed and presented in D3.2 Identification and analysis of interactions between sea use functions (Van der Wal *et al.*, 2009b).

The final step as part of Work Package 3 is the definition of calculation rules specifying the availability space for OWP in relation the the presence and/or intensity of a given non-wind sea use function for implementation in the DSS (this report). The DSS is developed as part of Work Package 4, its concept has been documented in Schillings, O'Sullivan and Wanderer (2009).

Work Package 2 also made major contributions towards the DSS by supplying geographical datasets and calculation rules on such topics as sea depth, wind speeds and distance from shore (Baldock and Jacquemin, 2009), location specifc cost for wind energy (Jacquemin *et al.*, 2009) and grid infrastructure (Korpås and Van Dyken, 2009). Together this part defines where OWP can be developed at what cost and how much electricity can potentially be generated at that location.

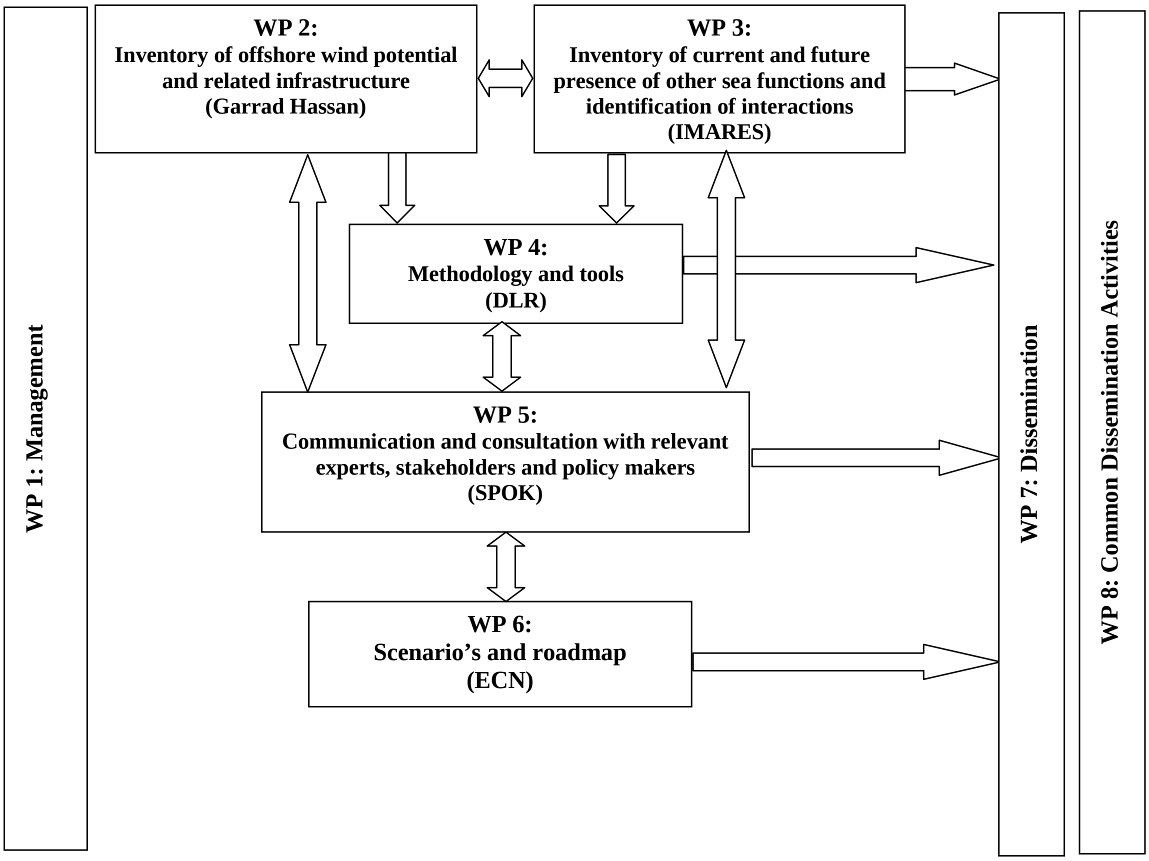


Figure 1 Flow chart of the Windspeed project

Figure 1 illustrates the flow of information through the WindSpeed project. The next phase in the project is to deploy the DSS and perform calculations with it. These results will be communicated with stakeholders in a second series of national workshops, scheduled for the autumn of 2010. These workshops are part of the activities from Work Package 5. The results from the DSS calculations are also used in an interactive process with the scenario analysis that are performed in Work Package 6. Here the final road map focusing on a growth path allowing maximum offshore wind and minimum negative impact on other sea use functions will be compiled.

2 Calculation rules for interactions between sea use functions

One of the main intended products of the WindSpeed project is a Decision Support System (DSS). This system will use the geographical datasets that have been described in Deliverable 3.1 ‘Inventory of current and future presence of non-wind sea functions’ (Van der Wal *et al.*, 2009a) as the inputs for the calculation rules implemented in the DSS. How these calculation rules need to be configured, is for a large part determined by interactions between the sea use functions as outlined in Deliverable 3.2 ‘Identification and analysis of interactions’ (Van der Wal *et al.*, 2009b), which includes both positive and negative interactions between offshore wind and the other sea use functions of the North Sea.

A calculation rule for the DSS is a formula or an algorithm that defines how to calculate where a given sea use functions has a strong claim on an area and where it has a weaker claim or possibly no claim at all. The different types of calculation rules that have been identified are outlined in the next section.

2.1 Types of calculation rules

The calculation rules are classified in four categories depending on the nature of the activity (or sub-category thereof) and the applicability of a certain rule to it.

For a given sea use function only one type of rule is used. Here there is a hierarchy, when an exclusion is used no use will be made of either an economic rule or a spatial suitability value. The latter two types are mutually exclusive; where possible an economic rule will be used or alternatively a spatial suitability rule will be used. In addition to these three basic rules we have defined a fourth category for those cases where a sea use function has sub-categories that need to be treated differently.

1 Exclusions

Exclusion is used where an activity present at a given location, cannot be combined with the presence of an OWP and cannot or is very unlikely to be moved. The incompatibility may be due to physical constraints, safety concerns, or to legal requirements.
Examples would be a munitions dumping location or a major IMO shipping route.

2 Economic values

Economy based calculation rules are used when a method is available for assigning some monetary value (loss or gain) to performing a given activity at a given location. This is the most desirable type of rule to achieve as most human activities are financially motivated. It provides a good method for direct comparison and weighting of activities. This type of calculation rule also combines well with cost functions for OWP which are developed as part of work package 2. This type of rule can be applied to fisheries and possibly to sand extraction, provided that the required data is available.

3 Spatial suitability values

Spatial suitability values define categories of suitability or some other measure of natural value. This type is used when no reliable method of expressing uses in monetary units (gains and losses) is available. In the case of natural values assigning a monetary value is not feasible due to lack of knowledge or difficulties in assigning such a value. However this can also be sufficient for spatial planning.

4 Refinements to reduce heterogeneity
All of the above rules can be made subject to refinement due to heterogeneity. This heterogeneity may arise from different sources. One example is differing policies applying to a certain sea use function in different countries. This also applies to use function where subcategories are identified that have strikingly different characteristics regarding their ability to be combined or not with OWP. The best example here are military activities, where hard constraints and soft constraints can be applied to different sub-activities.

Selective improvement
The calculation rules presented here are the first step in a process. It is expected that once implemented in the first version of the DSS, we learn which rules are most restrictive towards achieving the goals of generating electricity from OWP. Also this should show how large the need for finding additional space for OWP actually is. One possible scenario might be that the goals can easily be met even with fairly crude and restrictive calculation rules in place. In this case there would be little point in researching the possibilities of e.g. placing an OWP in or very close to an offshore marine protected area or near shipping routes servicing major ports. In the opposite case where there is a need for a substantial increase in the area available to OWP, the effort can be directed towards refining and further developing the most restrictive rules. The major point being that a given rule may appear to be very restrictive on its own merits, but because of other rules (stronger rules) excluding OWP from an area or the area excluded by the rule being relatively unattractive for OWP, the final effect of a rule may be much different from what the initial expectations are.
It must also be noted that the DSS also has geographical information and calculation rules on-board that deal with the potential energy gain and the costs of developing and maintaining an OWP. The combined result of all calculation rules (wind and non-wind) is to identify sufficient area for OWP at acceptable costs.

2.2 Defined calculation rules

In this section a calculation rule will be defined for each non-wind sea use function. The calculation rules are intended for implementation in the DSS. They are based on the information presented in the previous chapters, as well as on data from Deliverable 2.3 (Muñoz, 2009).

2.2.1 Shipping

The calculation rule for shipping consists of five sub-rules, with the following default settings:

1) Shipping routes and a 2 nm safety zone around form an exclusion zone for OWP
2) Anchorage areas and a 4 nm safety zone around form an exclusion zone for OWP
3) Shipping densities in the category ‘very high’ and ‘high’ are an exclusion zone for OWP. This adds to the area where OWP cannot go outside the shipping routes and anchorage areas.
4) OWP can go in areas on the shipping density map in the categories ‘very low’ or ‘low’
5) OWP can go in areas on the shipping density map in the three remaining categories: ‘low-med.’; ‘medium’; ‘med.-high’, provided they do not interfere with shipping outside defined routes i.e. do not cause ships to travel extra distance on what should be considered normal voyages.

Please note that the calculation rule as presented here is based on a reprocessed version of the shipping density map from Van der Wal *et al.* (2009a). More categories have been added in the medium range, so that more relevant choices can be made available for calculations with the DSS. The present map has redefined categories 'low-med.' (> 1 ship / week); 'medium' (>1 ship per 4 days) and 'med.-high' (>1 ship per 2 days). The categories 'very low' and 'low' as well as 'high' and 'very high' are unchanged.

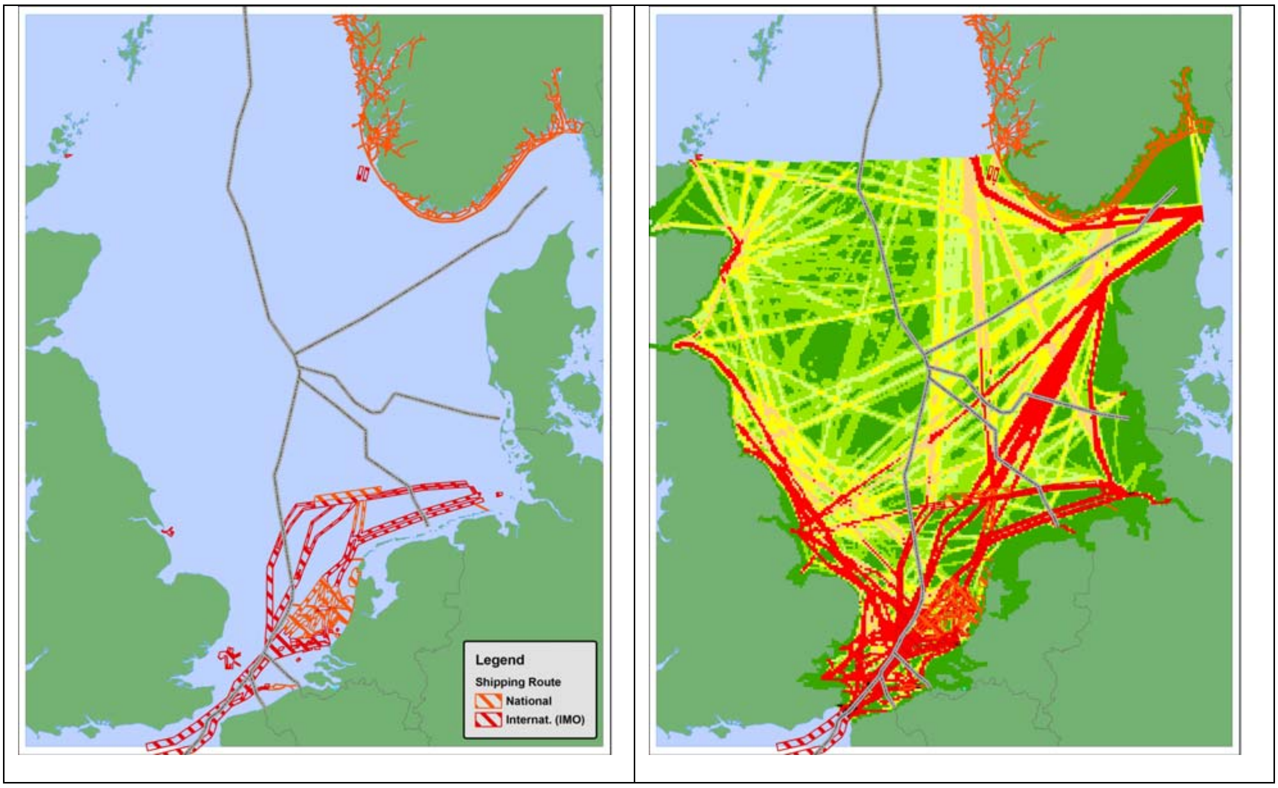


Figure 2 Shipping routes including anchorage areas (left), same including shipping density map (very high=black, high=red, high-med.=tan, medium=yellow, med.-low=sand, low=light green, very low=green).

As outlined in section 2.1.2 of D3.1 (Van der Wal *et al.*, 2009a) a yearly increase of shipping movements of 1% is the default value. The category values of the shipping density map can be adjusted to 110% for 2020 and 122% for 2030 of their current values for these future target years. This will not change the spatial configuration of shipping including present shipping routes and anchorage areas.. No major changes to any of these are foreseen at this time.

Based on the above-mentioned calculation rules the area available to OWP is mainly the area from the categories 'very low' and 'low' in Figure 2. Together these categories cover over 240000 km^2, which is over 50% of the area (Table 1, Van der Wal *et al.*, 2009a). Additional area could be made available by carefully selecting parts classed as 'low-med.'; 'medium'; and 'med.-high' intensity shipping.

2.2.2 Oil and gas extraction

The calculation rule for oil and gas extraction consists of three sub-rules,

1) Around sub-surface installations a 500 m safety zone is defined, mainly relevant for shipping
2) Around surface installations a 500 m safety zone is defined, for all those installations known not to be accessible by helicopter
3) Around surface installation that are (or might be) accessible by helicopter a 5 nm safety zone is defined to ensure safe access

The currently available dataset does not have reliable information on the absence or presence of a helicopter landing platform for surface installations. This in effect makes sub-rule 2 superfluous for now. However, by already implementing this sub-rule an updated dataset will instantly yield more accurate results in this respect and could result in additional area becoming available to OWP. The area covered by the yellow dots representing surface installations in Figure 3 is more or less representative of the area not available to OWP as a result of sub-rule 3. This is a spatial claim of 62 000 km^2 or 10% of the North Sea, based on the worst-case assumption that every surface installation does have a helicopter landing platform. This estimate is corrected for overlapping safety zones, which occurs wherever oil or gas platforms are closer together than 10 nm.

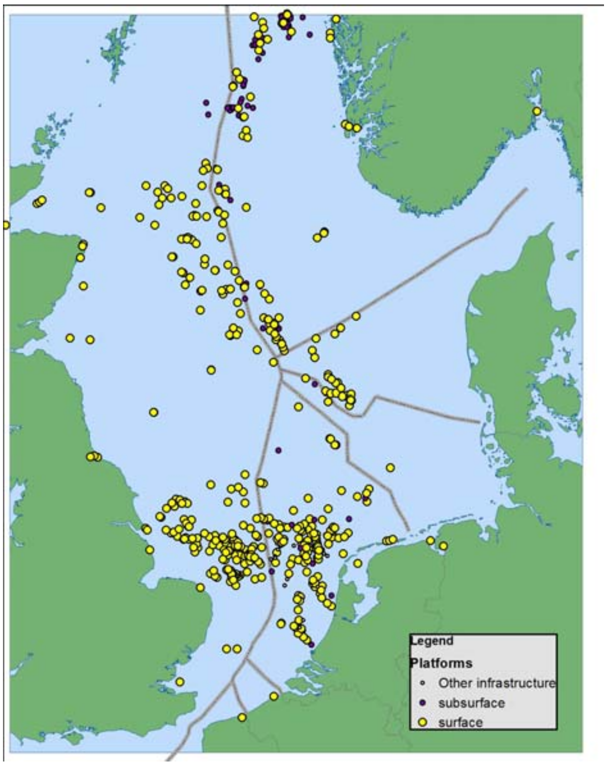


Figure 3 Offshore Oil and Gas installations

Table 1 Estimated Number of Oil and Gas installations present in the North Sea area for 2010 (initial), 2020 and 2030

Year	Number of installations
2010	750
2020	303
2030	100

For 2020 and 2030 the expected number of installation still present is given in Table 1. Information on which installation is to be decommissioned at what time is currently not included in the dataset. This information does exist and could be made available to the WindSpeed project from external sources. Alternatively an algorithm could be implemented to randomly select a set number of installations for a given target year.

2.2.3 Fisheries

For fisheries the calculation rule is based on a distribution of fishing effort per ICESblock, which is available for the WindSpeed partner countries and Sweden. The presented calculation rule or map for fisheries is a surrogate for an economic value map. The intention was to award an economical value in Euro's to each ICESblock, based on the gross revenue generated by each national fleet within the area combined with the known distribution of effort. However the revenue generated within the area cannot be calculated or estimated to a satisfactory degree to be relied upon for an economical calculation rule. The WindSpeed study area overlaps with 218 ICESblocks, an even distribution of fishery effort would results in each block receiving just under 0.5% of the effort or less than 563 fishing days of effort (Figure 4).

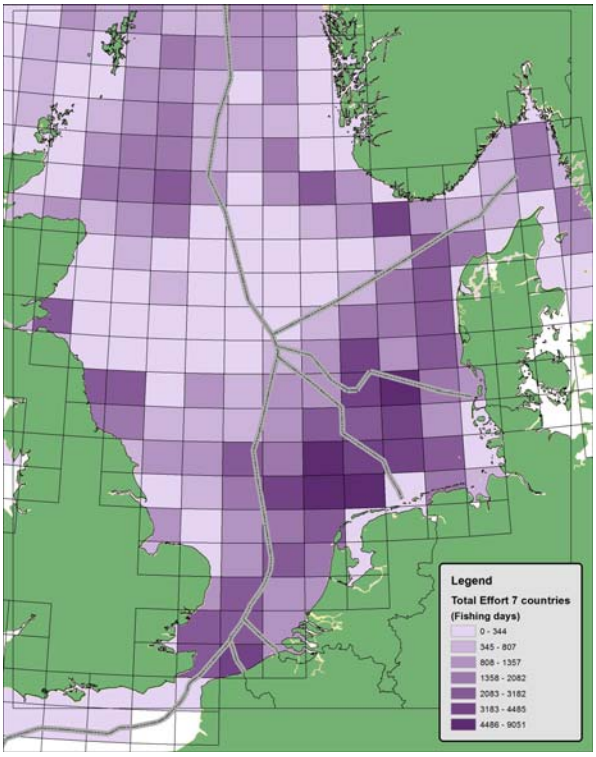


Figure 4 Fishery effort per ICES-block, Total for 7 countries (UK, BE, NL, DE, DK, SE, NO)

The calculation rule for fisheries consists of six sub-rules, with the following default settings:

1) ICESblocks that receive less than 0.25% of the effort are fully available to OWP
2) ICESblocks that receive between 0.25 and 0.5% of the effort can be used for upto 60% for OWP
3) ICESblocks that receive between 0.5 and 1.0% of the effort can be used for upto 45% for OWP
4) ICESblocks that receive between 1.0 and 2.0% of the effort can be 30%
5) ICESblocks that receive 2 % or more of the effort can be used for upto 15% for OWP
6) ICESblocks that are nationally important (receiving over 5% of effort from a national fleet) are treated the same as those from sub-rule 5.

The 5% effort threshold set for a block being nationally important has been decided based on the assumption that each national fleet should have at least one ICESblock that is nationally important. The British fishing fleet has the most even distribution and with 5% has one nationally important ICESblock. Some nationally important ICESblocks already have at least one OWP; therefore the assumption seems valid that one OWP is still acceptable.
Based on an estimated minimum space requirement of an OWP of ca. 400 km^2, this equals 13% (rounded up to 15%) of an ICESblock. This minimum space requirement is for a relatively small wind park of 100MW installed power, matching with an array density of 4 MW/km^2 such as used in Baldock and Jacquemin (2009) as a low end estimate.

The resulting map for this calculation rule is presented in Figure 5 and some associated statistics are given in Table 2. A large part (40%) of the North Sea is fully available for OWP falling under sub-rule 1. Based on the estimated size of an OWP there would be room for upto 760 OWP on the North Sea, when taking into account the relative availability of each area as specified.

Table 2 Statistics for the fisheries calculation rule showing number of ICESblocks and square kilometres per sub-rule and the number of 400 km^2 OWP that could fit

Sub-rule	%Effort	n ICESblocks	km^2	n OWP
1	<0.25	102	196900	490
2	0.25-0.5	47	81100	120
3	0.5-1	36	88500	100
4	1-2	19	32100	20
5+6	>2 + NI	14	47500	20
Total				760

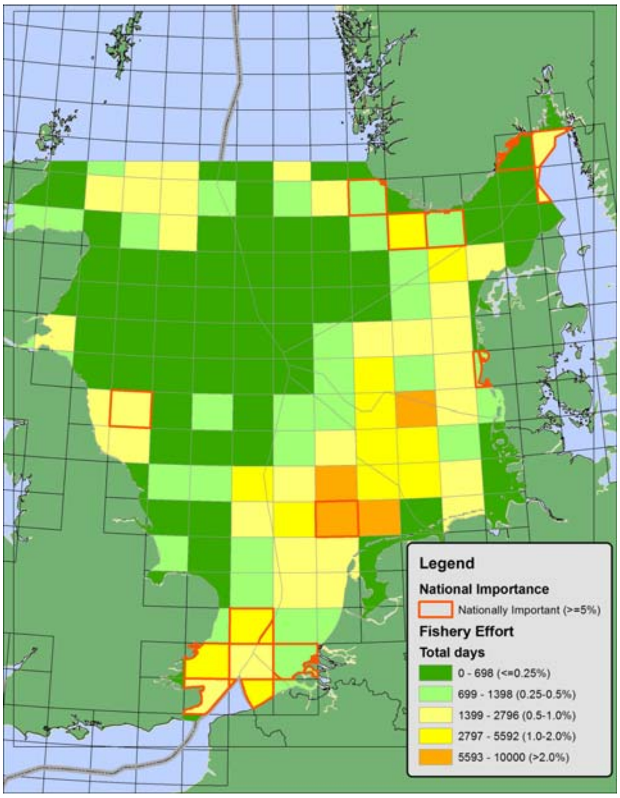


Figure 5 Fisheries calculation rule

2.2.4 Cables and pipelines

For both cables and pipelines the same basic calculation rule can be applied:

1) Define a 500 m safety zone (to either side) as an exclusion zone for OWP.

This safety zone is based on UNCLOS and also has the intention of ensuring the possibility of access by ship to both cables and pipelines for maintenance or inspection.

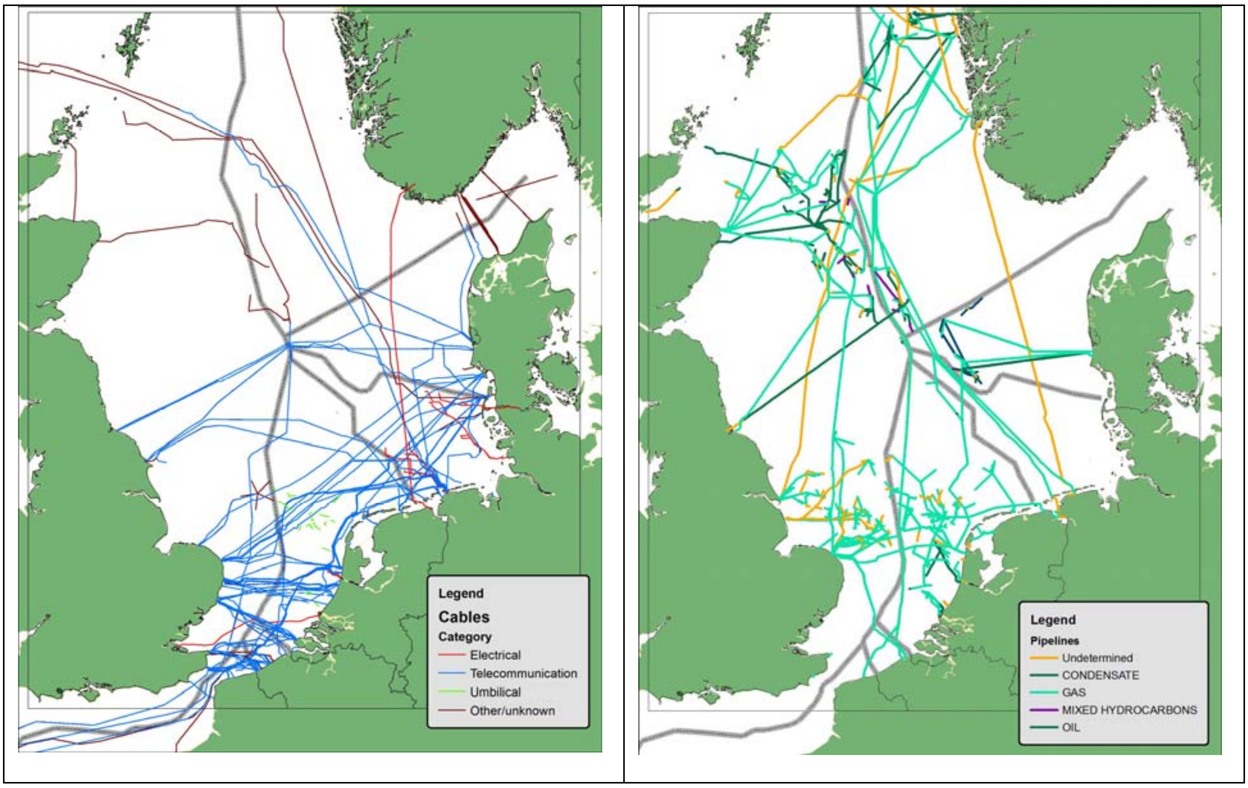


Figure 6 Cables and Pipelines within the WindSpeed study area.

The total area not available to OWP based on the presence of cables is 36000 km^2 or 6% of the North Sea (Table 7, Van der Wal *et al.*, 2009a). For pipelines these numbers are 30000 km^2 or 5% (Table 8, Van der Wal *et al.*, 2009a).

2.2.5 Military activities

The calculation rule for military activities consists of four sub-rules, as no different categories have been identified that should not be treated the same with respect to their compatibility with OWP.

1) Munitions dumping areas are not available for OWP
2) Areas with unknown or unspecified use are not available for OWP
3) Zones designated for aircraft manoeuvres are possibly accessible for OWP. OWP should not take away or use more than 20% of the area.
4) All remaining[2] military use categories are possibly accessible for OWP. OWP should not take away more than 5% of the area and be contiguous with OWP outside the area.

[2] Remaining categories include amongst others: mine-laying and hunting; ship firing, mortar firing gun firing,, bombing, torpedo, ship exercises, submarine exercises.

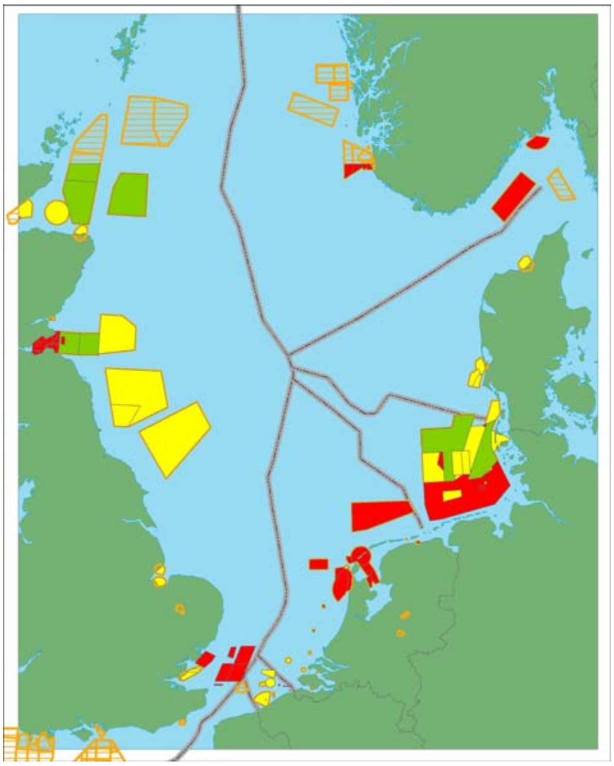


Figure 7 Military use areas within the WindSpeed study area

As can be determined from Figure 7 and Table 3 the first sub-rule is not of much influence on the area available to OWP. The second rule is more restrictive and points out that having more accurate data on the military use in an area could improve our options of finding locations where OWP could go. With the cut-offs as defined for sub-rules 3 and 4 a considerable area is potentially available for OWP. Please note that the numbers presented in Table 3 have not been corrected for the overlap present between categories of military use. As a result the numbers presented here cannot be compared directly with those in Table 9 from D3.1 (Van der Wal *et al.*, 2009a).

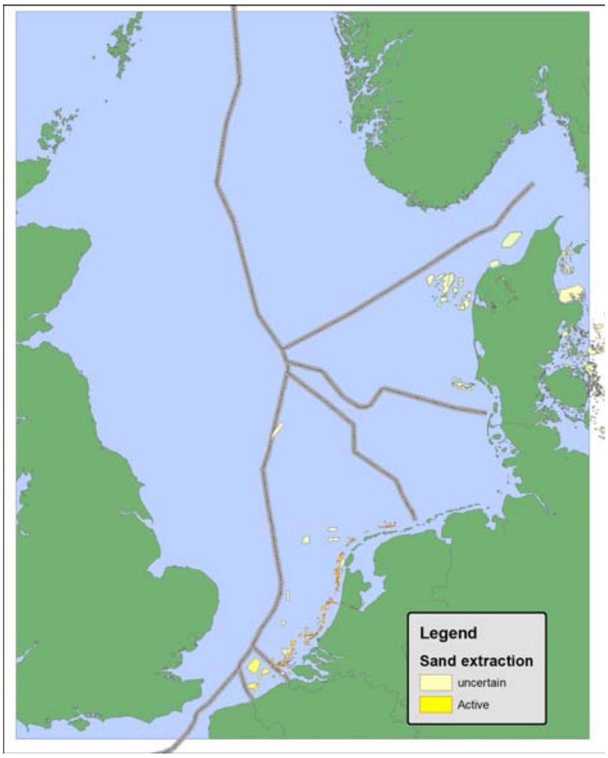
Table 3 Area in use per category of military use and area potentially available for OWP according to the specified calculation rule

Military use category	Area (km2)	Potentially available for OWP (km2)
Munitions dumping	79.9	
Unknown/unspecified	32186.5	
Aircraft maneuvers	15755.9	3151.2
Remaining uses	141984.0	7099.2

2.2.6 Sand extraction

The calculation rule for sand extraction is a single rule:

1) Areas designated as in use or potentially in use for sand extraction (or other aggregates) are exclusion zones for OWP.



The best way forward would be to know (or estimate) the amount of sand (x million m^3) that can be extracted from a given area. This combined with a price per unit would give a total value for a given extraction area. However there are problems associated with this. Even for areas now actively in use the amount of sand that can be extracted is not well known. Many extraction areas are located in deposition areas and the resource will regenerate naturally. Therefore the extractable amount also depends on the time period being considered, but also on societal limitations like the allowed extraction depth in the license. For potential sand extraction areas these number are not yet known, they still have to be determined by surveying the spatial extent and depth of the deposits that are of interest.

Table 4 Sand extraction activities and dredging (for navigational purposes) area in use (km2) and percentage of WindSpeed area

Category	Area (km2)	%% of WindSpeed area
Sand extraction	8350	2%
Dredging	12169	3%

As sand extraction areas only take up around 2% of the WindSpeed study area (Table 4) it seems that excluding all of this area should not pose too much of a problem. Dredging (for navigational purposes) is per definition located in shipping lanes and as such not of any further interest. The area where this activity occurs is already unavailable to OWP as a result of shipping activities.

2.2.7 Radar interference

Figure 8, also presented in section 2.7.1 of D3.1 (Van der Wal *et al.*, 2009a), demonstrated the possibility of wind turbines of a size expected to be used offshore to interfere with radar observation over a large area. As radar is used to monitor civil aviation, as well as shipping and onboard both aircrafts and ships, there is good reason to be aware of this. However with improvements to the positioning of radar systems or the addition of extra radar observation positions and technological improvements to make radar systems less susceptible to this type of interference, the urgency of the problem is decreasing. The available geospatial data on radar interference is limited to the United Kingdom. Therefore for WindSpeed a choice is made not to have a calculation rule defined for inclusion in the DSS.

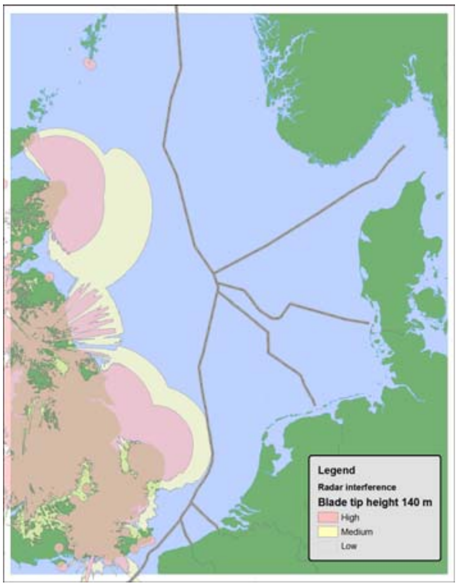


Figure 8 Map showing the areal extent of radar interference from wind turbines with a blade tip height of 140 m. for the United Kingdom.

Issues regarding radar interference could be included in the DSS provided a dataset is made available that covers the whole North Sea or is assembled from national datasets. Otherwise the issue will have to be addressed at a later stage when an actual OWP is in the planning process. Here options to combat or mitigate the negative effects of radar interference should be studied and a choice should be made on what measures to implement and how to finance them.

2.2.8 Nature conservation

Regarding nature conservation areas the calculation rule for the DSS consists of a number of sub-rules. Figure 11 shows the nature conservation areas colour coded by the nature of the conservation goals.

The suggested calculation rule is primarily based on the location of marine nature conservation areas. The default setting for the rule will be not to allow OWP to be constructed inside designated nature conservation areas. However as the national policies are not the same across all countries users will be allowed to set a percentage of nature conservation area that can be made available to OWP. The setting may even be such that it can be varied separately for each country. In order to take natural values into account that are present outside nature conservation areas, separate sub-rules and associated maps are included for four major fauna groups: sea mammals, birds, fish and benthos. Unfortunately a map or dataset that is fit for use has not been identified for sea mammals. The sub-rule for sea mammals will have to remain symbolic for the present time. For birds IMARES has been able to construct a bird value map for the North Sea. For details on this WSI-index map please read Appendix 1 to this report.
For the fish community a sub-rule will be defined based on the Species Richness map (Van der Wal *et al.*, 2009a). It should be noted that the number of fish species and their exact

distribution will vary from year to year. The calculation rule allows only for a limited percentage of those areas that have a high species richness to be used for OWP. The reasoning behind this is that although OWP are thought to possibly have a positive effect on fish biodiversity, this is still a topic of scientific investigation. By preferring other areas the risk of a possible negative impact is limited and the benefits of a positive influence are increased. Benthos includes all organisms living on or in the sea floor, such as shells, worms, sea stars, crabs and lobsters etc. For this group of organism a benthic value map has been constructed (Van der Wal *et al.*, 2009a) and a sub-rule for benthos is based on this map.

The calculation rule has the following five sub-rules:

1) Designated conservation areas are available to OWP to a limited degree. As in some countries (a.o. DE, NL) the national policy is not to have OWP inside nature conservation areas, the default setting for the percentage area that is available to OWP is 0% (zero). Available choices could be percentage points upto 10% of the area being available to OWP.
2) Areas with high densities of sea mammals (also if only for part of the year) should be avoided as much as possible. Please note that no map is presently available for implementing this sub-rule.
3) Areas with a high score on the bird sensitivity map, indicating presence of susceptible bird (populations) either resident, breeding or migratory should be avoided as much as possible. Details on the this map (Figure 9) are given in Appendix 1 to this report (Leopold and Dijkman, 2010).
    a. Area identified as ‘less concern’ will be mostly available (75%) to OWP
    b. Area identified as ‘concern’ will have upto 50% available to OWP
    c. Area identified as ‘high concern’ will have only 25% available to OWP
4) Based on the species richness map for the fish community the following categories are defined (Figure 10):
    a. 17.0 – 35.8 species (lowest three categories, 60% of the area) will be mostly available (75%) for placing OWP
    b. 35.9 – 39.5 species (20% of the area) 50% of this area is available to OWP
    c. 39.6 – 62.2 species (20% of the area) here only 25% will be available for OWP.
5) Based on the benthic value map each category is decreasingly available for OWP within increasing benthic value as follows:
    a. Low is mostly available for OWP, 70%
    b. Medium is 50% available for OWP
    c. High is 40% available for OWP
    d. Very high is 30% available for OWP

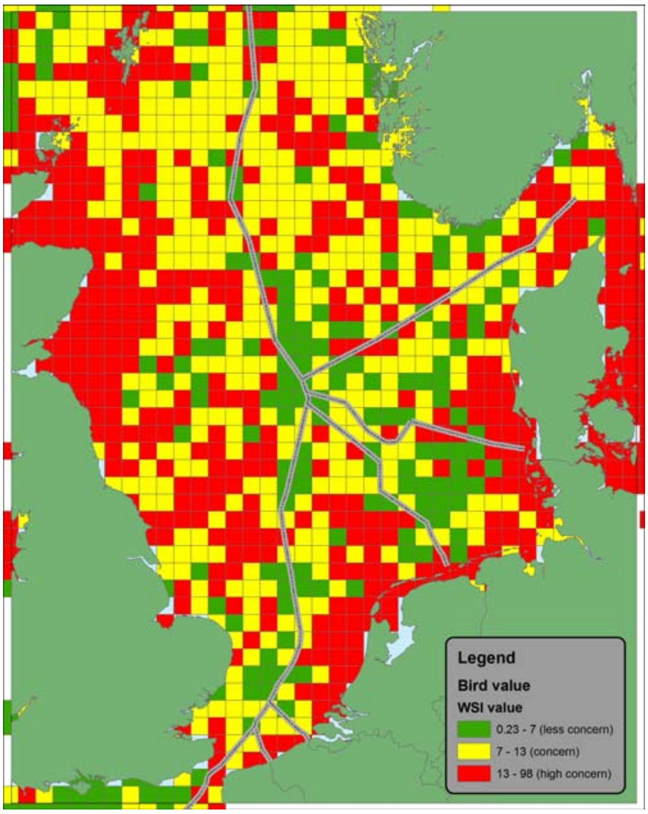


Figure 9 Windturbine Sensitiviy Index map of the Windspeed study area for Birds. Details on this map can be found in Appendix 1 (Leopold and Dijkman, 2010) to this report

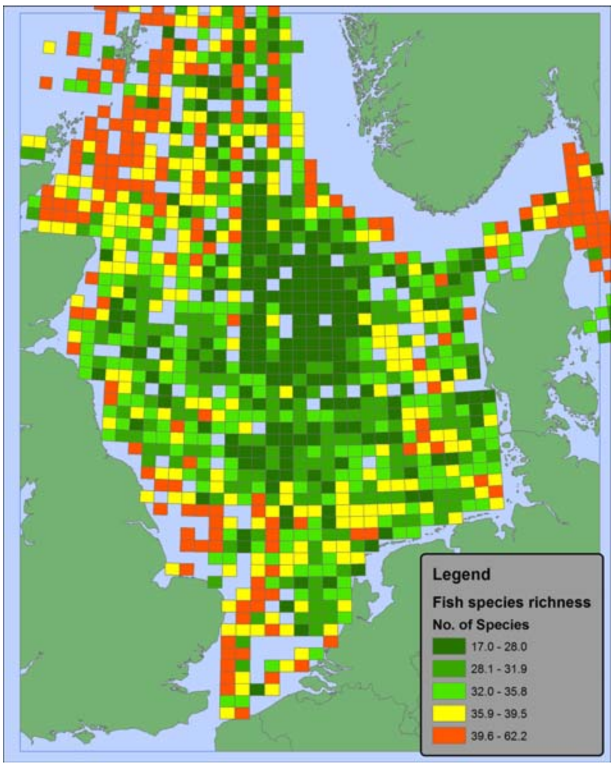


Figure 10 Spatial pattern of fish species richness in relation to percentage area available to OWP: greens = 75%, yellow = 50%, orange = 25%

To anticipate on improved scientific knowledge regarding the degree to which OWP are incompatible with nature conservation goals, the WindSpeed dataset on nature conservation areas has been updated to include information on what specific habitats and/or species from groups such as fish, birds or sea mammals are part of the conservation goals for a given area. Such data was available from the EEA in the form of a GIS-dataset and an associated database covering Denmark, Germany, Belgium and the Netherlands. For Norway this was attempted based on associated data in the existing dataset, e.g. where reference is made to sea birds or birdlife as reason to designate an area. For the United Kingdom, data was retrieved from the JNCC website for this purpose. From the point of view of the WindSpeed project it was envisaged that with this data Natura 2000 areas could be identified that could become available to OWP in the future. Considering the characteristics of the species groups continued conflict with OWPis likely for sea mammals and birds, even with improved knowledge. As can be seen from Figure 11 either birds or sea mammals or both are most often included in the conservation goals and the question on how much additional space can be found in future by combining N2000 and OWP in the same area remains open.

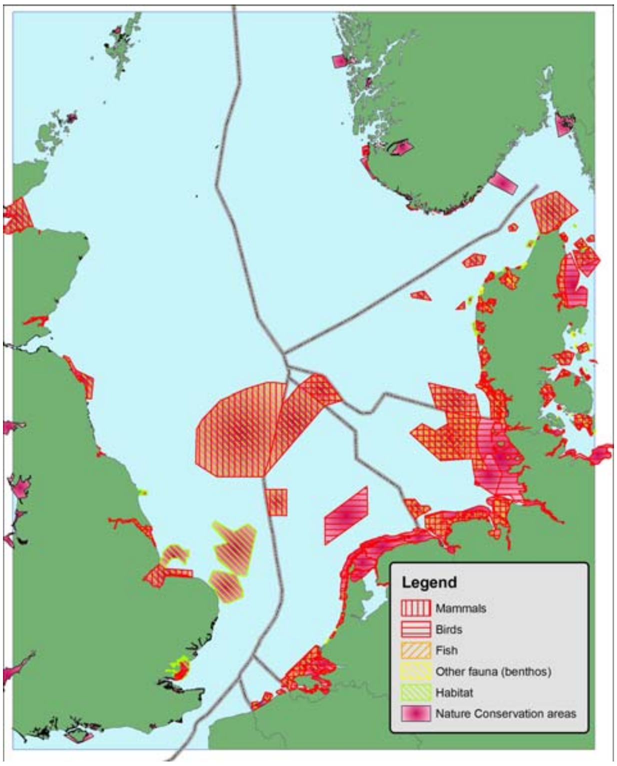


Figure 11 Nature conservations goals for Natura 2000 areas (including draft areas) within the WindSpeed study area.

3 Conclusions

Three deliverables have been defined for work package 3 in the Windspeed project:
1) an overview of non-wind sea use functions and their future development upto 2030 (D3.1, Van der Wal *et al.*, 2009a) ;
2) an analysis of positive and negative interactions between offshore wind and other use functions (D3.2, Van der Wal *et al.*, 2009b) and
3) a set of calculation rules specified in such a way that they can be implemented in the Decision Support System (DSS) (this report). This DSS is a deliverable of another work package (WP4) of the WindSpeed project, led by DLR.

After collecting and analysing the data on all the non-wind sea use functions, their expected future development and the interactions, calculation rules have been defined for implementation in the DSS. From this we should learn whether the present datasets and calculation rules allow for sufficient space to be allocated for OWP to reach the sustainable energy goals of the European Union and the partner countries while also taking all other interests into account. If this is not the case improvements to the spatial datasets or the calculation rules may help to find more space for offshore wind energy. These improvements can be targeted to address the issues that were found to be most restrictive to the development of offshore wind energy in the North Sea. The implementation of the calculation rules in the DSS is such that many options can be set and the calculation rules and values presented here form the core of the default calculations.

At first glance the calculation rule for each non-wind sea use function leaves significant space available for the development of offshore wind energy. However the available area according to one rule is often not (fully) available according to the another rule and the final area available to OWP without restrictions may be limited. Offshore wind may therefore not be able to develop to its full potential, unless decisions are made to enhance these possibilities at the cost of other uses of the North Sea.

It should be noted that hard exclusion of OWP from an area is only used for some human sea functions, where e.g. physical presence of installations or clear legal constraints apply. Mostly soft constraints apply where a limited share of a given area is seen as potentially available for developing OWP. For the calculation rules, dealing with nature conservation areas or natural values, no hard exclusion are used. Although the default setting for Natura 2000 areas is to exclude these.

The DSS tool allows the user to modify settings such as safety distances or sub-categories to include or exclude. In this way the DSS can reflect various spatial priorities as defined by individual stakeholders or policy makers.

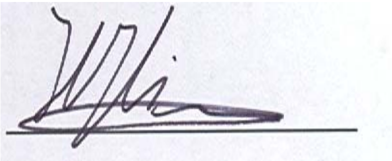
4 Quality Assurance & Justification

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 December 2009. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2009 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation, with the last inspection being held on the 5th of October 2007.

Rapport C058/10

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of Wageningen IMARES.

Approved: Dr. H. Lindeboom
Marine Ecologist

Signature: 

Date: 16 June 2010

Approved: J.H.M. Schobben MSc.
Head of the Department of Environment

Signature: 

Date: 16 June 2010

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Appendix 1: Windspeed – a North Sea map of seabird vulnerability for offshore wind farms

Mardik F. Leopold & Elze M. Dijkman
IMARES, Ecology Department
April 2010

Windspeed – a North Sea map of seabird vulnerability for offshore wind farms

Mardik F. Leopold & Elze M. Dijkman
IMARES, Ecology Department

Introduction

Governments of countries around the North Sea are developing plans for extensive use of offshore wind power. The first offshore wind parks are now operational, and many more are planned. "Green" energy has become a high priority in a world that faces ever-increasing atmospherical CO_2 levels and rising global temperatures. Wind power is one of the major techniques currently used for generating CO_2-neutral energy, but space on land, where this energy is to be used, is limited. Attention is thus diverted to the vast open space of the sea, that seems to have ample space for large-scale development of wind power.

There are certain concerns with developing offshore wind farms, however. First, safety at sea is an issue and collisions between passing ships and static wind turbines need to be avoided. Major and minor shipping lanes, including harbour approaches are therefore no-go areas for offshore wind farms. A second concern is of technical/financial nature. Building wind parks far offshore or in very deep waters involve very high costs and such areas are, at present, not feasible for development. This may change in years to come, as our technical abilities are further developed and as the price of alternative energy sources rise. A third concern is, that the sea is not devoid of life, and that certain natural values, that are protected under national and international law (most importantly the EU's Birds and Habitats Directives) may suffer from offshore wind power development. This would be at odds with the idea that wind power is "green".

Under the Birds Directive certain (Annex 1) species of seabirds are specifically protected, but in addition, all migratory birds are protected. Migratory birds are birds that breed in one country, and cross national borders to moult or winter in other countries. With very few exceptions, most North Sea seabirds meet this criterion. Moreover, many seabirds are protected in their breeding colonies and developments that interfere with these birds outside the colonies, also have an impact on the protected colonies themselves. There is thus every reason to consider the possible impacts of offshore wind power development, on the North Sea's seabirds.

Seabird densities and species assemblies vary widely across the North Sea, both in space and between seasons (Skov et al. 1995; Stone et al. 1995). It follows, that different areas at sea have different values for birds, both on the species level and on the level of communities (Skov et al. 2007). This value also varies over time, as seabirds migrate in massive numbers across the North Sea, exploiting different areas at different times of year. However, an offshore wind farm, once in place, occupies a site year round. This means, that year-round surveys of bird values are needed to assess the importance of sites and that (across-year) average or even maximum values are the most appropriate parameters for assessing the values of sites in relation to offshore wind parks.

Because different bird species respond differently to offshore wind turbines and because the "value" of different birds species may be appreciated differently, depending for instance on their global population size, birds need to be weighted before a general assessment of the risk of interference between offshore wind parks and seabirds can be made. Garthe & Hüppop (2004) have developed a wind farm sensitivity index (WSI) for seabirds that occur in the

German part of the North Sea. The index takes into account nine factors, that influence a species' vulnerability to wind turbines: flight manoeuvrability (can they easily avoid collisions?); flight altitude (do they fly at rotor height?); percentage of time flying (birds cannot collide with rotors while swimming); nocturnal flight activity (birds are more vulnerable at night, when rotors are not visible or when the threat (noise) cannot easily be assessed); sensitivity towards disturbance by ship and helicopter traffic (birds flushed from the water may fly into rotors); flexibility in habitat use (more flexible birds may easier avoid impacted areas); biogeographical population size (fatalities have less impact if population size is large); adult survival rate (demography is impacted more through addition mortality in birds with high natural survival rates); and European
threat and conservation status (birds already severely threatened may be extra vulnerable to additional stress factors). Each factor was scored on a 5-point scale from 1 (low vulnerability of seabirds) to 5 (high vulnerability of seabirds) and summed values were used to make comparisons between species.

Material and Methods

Multiplying each species's WSI with local densities, provides a means to add up figures for all birds that occur in a given area. We repeated the exercise of Garthe & Hüppop (2004) for the entire North Sea, using the European Seabirds At Sea Database (**ESAS**) that holds densities of all seabirds, across the entire North Sea, for all seasons. We used the WSI developed by Garthe & Hüppop (2004) with some modifications. These involved adding several species that were not treated by Garthe & Hüppop (2004) and slight modifications to the species-specific vulnerability factors (Table 1). We used six bimonthly seasons: Feb/Mar, Apr/May, Jun/Jul, Aug/Sep, Oct/Nov and Dec/Jan, that were finally used to estimate maximum values for the entire area, across the year.

Bimonthly maps were made by multiplying seabird densities on the level of 5 or 10 minute counts (all ship-based survey data, see for methods Tasker et al. 1984; Komdeur et al. 1992) with the appropriate WSI. Cumulative values for all birds per count were calculated and Ordinary Kriging was used to predict total seabird wind farm sensitivities across the North Sea, using a 25x25 km^2 grid. Explorative analyses had shown, that 25 km was the appropriate lag size for these data, i.e. data points within 25 km of each other still were correlated. A 25x25 km^2 grid also resulted in almost total coverage of the entire North Sea, for all bimonthly periods (cumulative data for 1979-2009). Yearly maximum values for each square, based on these six bimonthly maps are shown the final map.

Three categories are used in the maps: areas of less concern, areas of concern and areas of high concern. The cut-off points between categories are based on the frequency distribution of the WSI values (cf. Garthe & Hüppop 2004) across the 25x25 km^2 blocks in the North Sea, over all six bimonthly periods. The 60% blocks with the lowest values are considered less concern (green in the maps); the 20% blocks with the highest values are or high concern (red) and the blocks with intermediate values are of concern (orange).

Bird species	A	B	C	D	E	F	G	H	I	SSI
Red-throated diver	5	2	2	1	5	4	5	3	5	48.75
Black-throated diver	5	2	3	1	5	4	4	3	5	49.5
Great crested grebe	4	2	3	2	3	4	4	1	1	19.25
Red-necked grebe	4	2	1	1	4	5	5	1	1	21
Nothern fulmar	3	1	2	4	1	1	1	5	1	5.83
Nothern gannet	3	3	3	2	1	1	4	5	3	11
Great cormorant	4	1	4	1	3	3	4	3	1	20
Common eider	4	1	2	3	4	4	2	4	1	23.33
Common scoter	3	1	2	3	5	4	2	2	1	16.88
Velvet scoter	3	1	2	3	5	4	3	2	3	27
Arctic skua	1	3	5	1	2	2	4	3	1	13.33
Great skua	1	3	4	1	2	2	5	4	2	16.5
Little gull	1	1	3	2	2	3	5	2	4	16.04
Black-headed gull	1	5	1	2	1	2	1	3	1	5.63
Common gull	1	3	2	3	1	2	2	2	4	9
Lesser black-backed gull	1	4	2	3	1	1	4	5	2	9.17
Herring gull	2	4	2	3	1	1	2	5	1	7.33
Great black-backed gull	2	3	2	3	1	2	4	5	2	13.75
Black-legged kittiwake	1	2	3	3	1	2	1	3	1	5.625
Sandwich tern	1	3	5	1	1	3	4	4	4	20
Common tern	1	2	5	1	1	3	3	4	1	12
Arctic tern	1	1	5	1	1	3	3	4	1	10.67
Black tern	1	1	4	1	1	3	4	4	4	14
Common guillemot	4	1	1	2	2	3	1	4	1	10
Razorbill	4	1	1	1	2	3	2	5	2	13.13
Atlantic puffin	3	1	1	1	3	3	2	5	5	18

Table 1. Summed wind farm sensitivities (last column) for the main North Sea seabirds (first column), based on underlying factors 1-9. The factors 1-9 are: A: flight maneuverability, B: flight altitude, C: percentage flying, D: nocturnal flight activity, E: disturbance by ship traffic; F: habitat use flexibility, G: biogeographical population size, H: adult survival rate, I: European Threat and Conservation Status (see text). The summed sensitivity is calculated by weighting the nine factors as follows:
SSI = ((A3+B3+C3+D3)/4)*((E3+F3)/2)*((G3+H3+I3)/3), and the wind turbine sensitivity index (WSI) is calculated as:
WSI = Σspecies (ln (density + 1) × SWGI).

Results and Discussion

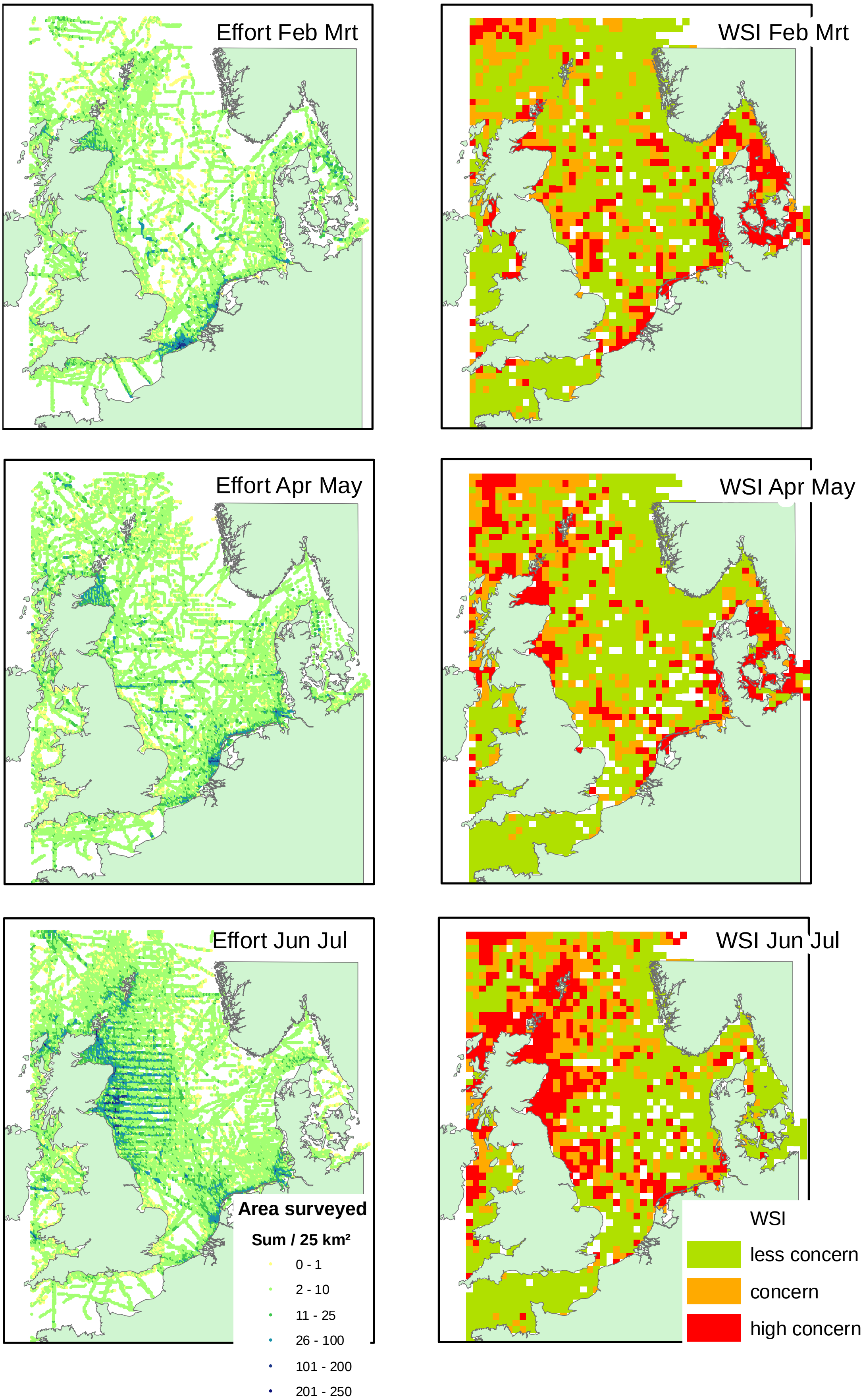
Figure 1 shows the bimonthly maps (right-hand panel) and the available effort (number of individual counts in the database). Effort in most seasons is concentrated in waters that are relatively close to shore, while the Central North Sea is underrepresented. For the current discussion, on where best to plan future wind farms, this probably is not a significant problem, as the next generation of windparks will not be built in the Central North Sea. However, with the shallow Dogger Bank in the Central North Sea, this may change in the near future and extra survey data are required for this area.

The WSI maps confirm what was known from generalized seabird density maps (Skov et al. 1995). The highest values, indicating the most vulnerable areas are found along the UK seaboard (particularly in the northwestern North Sea), due to very high densities of auks, gannets, kittiwakes and other breeders, during the moulting seasons of auks and during winter, in the Skagerrak/Kattegat. High values are also found along the mainland shores, due to high numbers of breeding birds (gulls, terns), wintering birds (divers, seaduck) and migrating birds. Values in The Channel are generally lower, excepting in mid-winter when many North Sea birds have moved south. A diagonal band of high values, connecting UK waters with mainland shore waters can be seen in the summer and autumn months, signifying the exodus of auks and other migrant UK seabirds.

Both the bimonthly maps and the overall map show that there are potential conflicts between further offshore wind farm development, and seabirds. Nearshore waters almost anywhere have very high bird values, at certain times of year. Most promising for future developments, seem waters that are slightly further offshore (Denmark, Germany, Netherlands, Belgium and SE England). Particular care should be taken in Scottish waters, and in nearshore waters along the entire mainland coast. Areas in the Central North Sea, that are considered of little concern based on the available data, should receive more survey effort.

Windturbine sensitivity all birds included

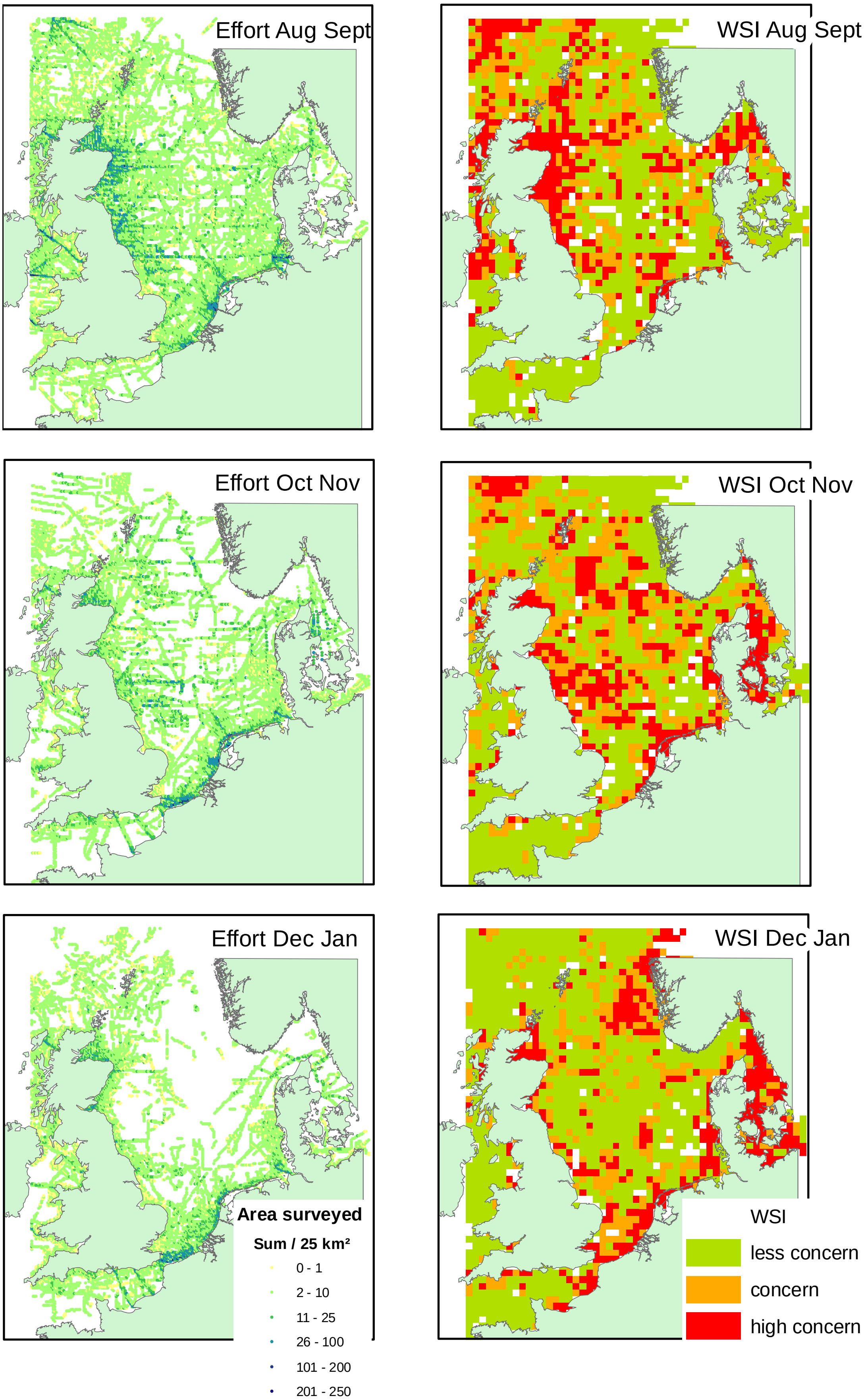
ESAS ship countings 1979-2009



Appendix 1: Windspeed – a North Sea map of seabird vulnerability for offshore wind farms

Windturbine sensitivity all birds included

ESAS ship surveys 1979-2009

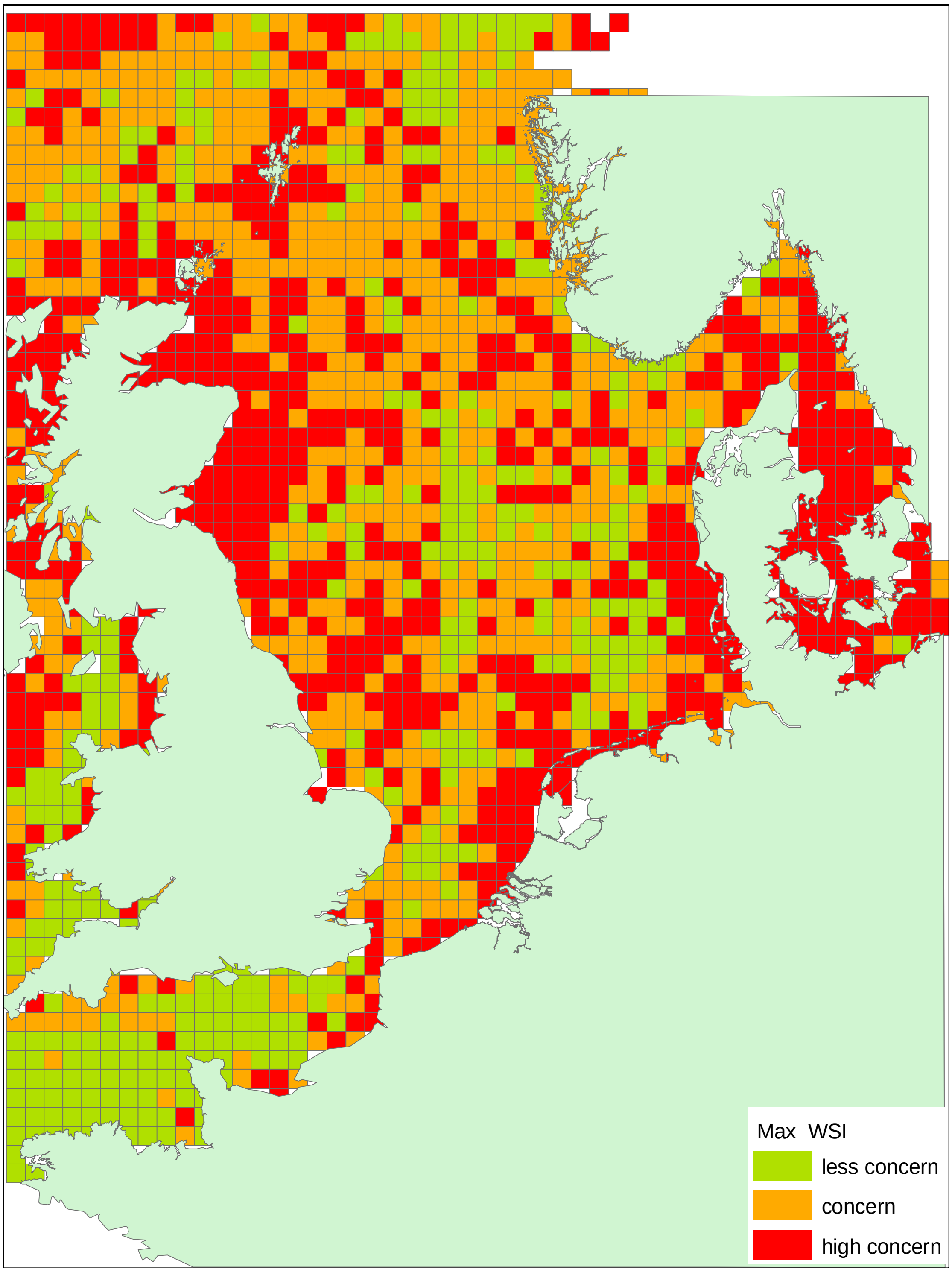


Appendix 1: Windspeed – a North Sea map of seabird vulnerability for offshore wind farms

Windturbine sensitivity all birds included

ESAS ship surveys 1979-2009

Overall consideration for all seasons



Appendix 1: Windspeed – a North Sea map of seabird vulnerability for offshore wind farms

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