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Sensitivity of offshore seabird concentrations to oil pollution around the United Kingdom: Report to Oil & Gas UK

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Contents

Executive summary

Seabirds are particularly vulnerable to the effects of oil pollution, and in the UK, seabird survey data have been used to predict the location of the most sensitive concentrations in the UK Continental Shelf ("UKCS") during different analyses. The methods for combining these data for contingency planning for oil pollution and in the event of a live incident have evolved and improved over a number of years. However, the quantity of data available for such analyses has declined during the last two decades and seabird distribution and abundance at sea has changed, leading to recommendations for a new analysis of the sensitive seabird concentrations to oil pollution using only data collected during the last 20 years.

This report describes the results of a project to "… *update the Seabird Oil Sensitivity Index ("OSI") for the United Kingdom Continental Shelf* ("*UKCS*")*, using the best available data to support the OSI factors and density data. The completed OSI will be made publically available through a GIS tool*". The report and its GIS companion are designed to be used by a wide range of scientific, nature conservation, government and industry professionals for contingency planning for oil pollution and for use in live oil pollution incidents.

The authors calculated a single measure of the sensitivity of seabird concentrations to oil pollution using the methods of Certain *et al.* (2015). Data collected since the beginning of 1995 were selected from a wide study area beyond the UKCS using boat-based, visual aerial and digital video aerial survey techniques. Seabird tracking data were not used, for reasons outlined in the report. Scaling factors were applied to all three types of survey data to control for known biases in the data, where possible, such as to control for distance effects on detection rates from boat-based and visual aerial survey methods, responsive movement towards the boats and for availability bias in digital video aerial survey methods. It was not possible to control for all biases, and would undoubtedly have led to underestimates of seabird density, particularly from visual aerial survey methods.

Smoothed density maps were generated for each species using Kernel Density Estimation ("KDE"). A single width parameter of 40km was used and the calculation truncated at 36km to remove the worst of edge effects. Methods developed by Certain *et al.* (2015) were used to assemble a number of factors that affect the sensitivity of different seabird species to oil pollution, offering improvements to methods developed by others (e.g. Williams *et al.* 1994). These were: proportion sitting on water; oiling proportion of tideline corpses; habitat flexibility; proportion of the biogeographical population in the UK in winter or summer (separately); status on the list of Birds of Conservation Concern; status on EU Birds Directive annexes; annual breeding productivity; and adult survival rates. Certain *et al.* (2015) recommended that these factors should be combined separately as two groups: those factors that relate to the species sensitivity to a human pressure; and those that affect their sensitivity to human pressures in general. Certain *et al.* (2015) then recommended that these two groups of factors should be combined by multiplication. Within each of these two types of factors, Certain *et al.* (2015) identified that there were primary factors that directly controlled the species sensitivity, and aggravation factors that can increase a sensitivity that already exists; they argued that the aggravation factors should be an exponential of the primary factors. Within each primary or aggravation factor there might be multiple factors, for example in our case, amount of time sitting on the water and oiling proportion of tideline corpses where are different measures of the likelihood that an individual of a particular species might encounter oil pollution. Certain *et al.* (2015) identified two methods for combining these factors: either by averaging or by multiplication, and provided guidance for which of these method to use.

The authors followed the methods for combining different factors recommended by Certain *et al.* (2015), and provided a detailed explanation and justification for why particular decisions were taken. We calculated the sensitivity of seabirds to oil pollution at each location by dividing the seabird density by 1 – species sensitivity score and summing these rather than the method of summing the proportion of each species at each location divided by 1 – species sensitivity score as recommended by Certain *et al.* (2015). We concluded that the method we used is better suited to the type of decision-making required for planning for and direct response to oil pollution than the method proposed by Certain *et al.* (2015).

We summarised the sensitivity scores from the smoothed density data within each Department for Energy and Climate Change ("DECC") Offshore Oil Licence Block using the median, minimum and maximum values. We also calculated an index of data uncertainty using measures of total survey effort; total number of independent samples; the number of years of survey; the most recent year of survey; and whether any data were collected with incomplete species information within each DECC Offshore Oil Licence Block.

The report presents figures showing the location of survey effort collected by each survey platform in each month, monthly maps showing the smoothed seabird sensitivity to oil pollution are presented in an appendix to the main report. An account describing the location of the most sensitive concentrations of seabirds to oil pollution in each month of the year, using maps of the median, minimum and maximum seabird sensitivity to oil pollution and the data confidence index score in each DECC Offshore Oil Licence Block. The text descriptions for each month relate information about the geographical patterns of seabird sensitivity to oil pollution information about changes to seabird biological activity in each month.

The biases in the different survey methods are discussed and the effects of this on the quality of the merged data are highlighted. There were a large number of gaps in the survey data used in the analysis and also poor data quality in much of the UKCS, which affected the ability to assess seabird sensitivity to oil pollution in many key areas. Different analytical methods to counter these gaps are discussed and in most cases are dismissed. Data smoothing was found to be useful for preparing summaries at the level of the oil licence block, but difficult to interpret in that form. The method for combining seabird abundance with the sensitivity scores for each species is discussed. While the method of Certain *et al.* (2015) is more complex than previous methods for spatial measures of sensitivity, the method is based upon sound mathematical principles. More important, perhaps, is the setting of thresholds for describing the differences between low, moderate, high, very high and extremely high sensitivity to oil pollution.

Overall, it was found to be very difficult to compare the results of the analysis with previous analyses, which are compiled using completely different data. Part of the reason is because different sensitivity thresholds were used, but mainly because of the very large gaps in coverage in the current analysis. Mostly, where data overlapped, the outputs from the analysis seemed to make sense and show a degree of similarity in the location of the highest sensitivity areas. One difference of significance was noted where one of the regions where seabird concentrations were identified as being the most sensitive to oil pollution in the 1990s was revealed to have relatively low sensitivity in the current analysis.

This report concludes that the analysis of new data and revision to the methods has succeeded in providing a new assessment of the sensitivity of seabird concentrations to oil pollution. It concludes that the Certain *et al.* (2015) method is an appropriate method and represents the relationship between seabird sensitivity and abundance well, and that the way that this was adapted to accommodate the way that the information generated by this report might be used was also appropriate and should be used in future analyses.

Biases in visual aerial survey methods were difficult to control, and this report recommends that in the future, if such data are to be used for such an analysis that comparison surveys between visual and digital aerial survey methods should be used to control for biases in the visual aerial survey technique.

The acute problem of data gaps and low data quality are highlighted and the potential for these gaps to hide some large changes in the location of sensitive seabird concentrations to oil pollution, particularly in the oil exploration and production areas around the UK are a significant issue, and this report recommends that steps are taken to address the most important data gaps and areas with poor data quality.

1 Introduction

1 Seabirds are particularly sensitive to the effects of oil pollution, and there are many oil pollution incidents which have resulted in mass mortality of seabirds (e.g. Munilla et al. 2011, Votier et al 2005). Seabird mortality occurs from the ingestion of oil, which results in liver and other organ failure, as well as contamination of plumage, which destroys the insulating properties, leading to hypothermia (Alonso-Alvarez et al. 2007). Seabird populations may also suffer long-term impacts of reduce population size following an acute incident (Heubeck 1987), mainly on account of their low annual reproductive output which means that reduced populations take a longer time to recover.

2 However, the effect of oil pollution on seabirds is not uniform and depends on the numbers of seabirds at sea around the site of the incident. It also has an unequal effect on different seabird species, with pursuit diving seabirds such as seaducks (Anatidae), divers (Gaviidae), cormorants (Phalacracoracidae), grebes (Podicepididae) and auks (Alcidae) more susceptible than more aerial species such as gulls (Laridae). Most of the serious incidents at sea have resulted from discharge of oil during transportation (accidentally and deliberately) rather than during offshore oil exploration and production (Burger 1997).

3 Seabird surveys were begun at sea during the 1970s to provide information on the potential impacts of new exploration and production of offshore oil reserves in the North Sea (Stone *et al.*1995). The first attempt to provide maps showing the most sensitive seabird concentrations to oil pollution based upon seabird density data at sea was carried out by King and Sanger (1979) in the United States of America ("USA") and further developed by Tasker and Pienkowski (1987) in the form of an Oil Vulnerability Index ("OVI") for use in the North Sea. The connection between seabird density data and the differential sensitivity of different seabird species to oil pollution using the OVI was formalised for seabirds by Williams *et al.* (1994). This method was used to calculate seabird sensitivity outwith the North Sea by Webb *et al.* (1995) and even to waters in the south-west Atlantic by White *et al.* (2001). The Joint Nature Conservation Committee ("JNCC") (1999) provided an analysis which presented sensitivity scores at the scale of oil licence blocks using the same methods as Webb *et al.* 1995, but at the scale of the oil licence block instead of the larger ¼ International Council for the Exploration of the Sea ("ICES") rectangle. These documents were developed in order to provide a simple assessment of the sensitivity of seabird concentrations at sea to oil pollution for contingency planning for offshore oil and gas exploration and production projects, and inform priorities for pollution control in the event of specific oil spillages.

4 The technique for calculating indices of sensitivity of seabird concentration to oil pollution developed by Williams *et al.* (1994) has since been applied to other human pressures. Garthe and Hüppop (2004) used a similar method to calculate seabird sensitivity to different potential impacts of offshore wind farms in Germany. Furness *et al.* (2013) and Bradbury *et al.* (2014) extended and adapted this method to assess seabird sensitivity to offshore wind farms in Scottish and English waters respectively, while Furness and Tasker (2000) developed an index to describe the sensitivity of seabird concentrations to reduced sandeel availability and discussed in the context of fishing interactions. All of these indices are theoretical assessments of the potential impact of human pressures, which cannot be tested easily by experimental methods. Regardless, these indices provide a method for making expert judgement of the likely effects and impacts of a human pressure more objective.

5 Certain *et al.* (2015) took the processes for combining different factors into a single index of sensitivity and proposed improved methods based upon the likely mathematical relationship between different classes of factors. Certain *et al.* (2015) highlight the implicit, but overlooked, assumptions of the simple arithmetic summation of rank scores across a diverse range of different factor types, which involve hierarchical and contingent relationships that are overlooked in the earlier index formulation. Instead of the mostly linear

methods developed by Williams *et al* (1994) and others, they recommended exponential relationships which match better to the numerical ranges over which seabird abundance varies. This technique forms the basis of the approach used in this report.

6 Since the 1980s and 1990s when seabird survey effort at sea peaked, the rate at which new survey data for seabirds at sea were collected and added to large databases has declined around the United Kingdom ("UK") and in the North Sea (Pollock and Barton 2006; Webb *et al.* 2014), especially for boat-based survey offshore. This has raised concerns about whether increasing dependence on out-of-date seabird distribution data is still reliable for calculating indices of seabird sensitivity to oil pollution. Around the UK, boat-based survey programmes to collect new data to replenish the European Seabirds At Sea ("ESAS") Database were greatly reduced in about 2000.

7 Meanwhile, two programmes of visual aerial surveys commenced in 2000 to collect data, mainly in shallow inshore waters in England to inform the placement of offshore wind farms and also of potential Special Protection Areas ("SPA")[1] for inshore waterbirds. Surveys around the UK developed further in 2009 with the emergence of high-resolution digital aerial survey techniques which offered less biased estimates of abundance (Buckland *et al.* 2012).

8 A study to examine how seabird abundance has changed compared to historical data off the east coast of Scotland (Webb *et al.* 2014) concluded that for some species, there have been considerable changes in abundance, whereas for others, the abundance first increased followed by a decrease since the last assessment of the sensitivity of seabird concentration to oil pollution. The same report recommended that surveys of less than 15 years old and certainly no more than 20 years be used to assess the sensitivity of seabird concentrations to oil pollution. Webb *et al.* (2014) assessed coverage of new survey during the last 20 years and identified some significant gaps in coverage in certain areas and at particular times of the year. Many of these gaps overlapped with oil and gas exploration and development areas.

9 In spite of the apparent gaps, the long gap since the last seabird oil sensitivity analysis in 1999 led Webb *et al.* (2014) to make a number of recommendations, of which the following is pertinent to this report:

> "*Revise and update maps of seabird distribution and of the sensitivity of seabird concentrations to oil pollution using only data in ESAS collected since the start of 1995. Any analysis must also consider the number of years over which the data have been collected and represent the underlying variance in the data*".

10 The provenance of this report is a direct result of that recommendation. The objective of this project were defined as:

> "*The objective of the project is to update the Seabird OSI for the United Kingdom Continental Shelf, using the best available data to support the OSI factors and density data. The completed OSI will be made publically available through a web-based Geographical Information Systems ("GIS") tool*".

11 The report is needed by a number of stakeholders who are required to consider the potential effects of oil pollution on seabirds in the UK's seas. The report and its GIS companion provide a tool for assessing the potential effects and impacts of oil pollution when planning new projects that could increase the risk of oil pollution at sea, for updating existing contingency plans, and for use in the response to a live oil pollution incident at sea. The potential users of this report and companion GIS tool are likely to vary in their expertise and experience of the impacts of oil pollution on seabirds, and are likely to be seabird scientists, nature conservationists in statutory nature conservation bodies and non-governmental organisations, civil

[1] A Special Protection Areas ("SPA") is a site designated under European Council ("EC") Directive 2009/147/EC on the conservation of wild birds ("the Birds Directive")

servants in government departments such as the Maritime and Coastguard Agency ("MCA") and the Department of Energy and Climate Change ("DECC"), executives in oil companies and their representatives in environmental consultancies, and professionals within umbrella bodies such as Oil and Gas UK.

12 This report describes an analysis of seabird abundance data from within and at least 100km beyond the UKCS boundary using updated methods for assessing seabird oil sensitivity, presenting the methods used and the assumptions made. The Seabird Oil Sensitivity Index ("SOSI") is presented for each month at the scale of the DECC Offshore Oil Licence Blocks within the UKCS.

13 We have also presented measures of uncertainty in the data at the scale of the Oil Licence Block. Some compromises were necessary: it was not possible to build a web-based application for presenting seabird oil sensitivity indices within the timescale agreed for this project, and for similar reasons, it was not possible to use stochastic methods for representing the variance in the underlying data. However, an alternative method is provided for representing the range of seabird oil sensitivity index scores.

14 A companion to this is a full set of downloadable GIS data containing the same information and also the underlying seabird density data used to generate these data.

2 Methods

2.1 Overview

15 In this report, a single measure of the sensitivity of seabird concentrations to offshore oil pollution around the United Kingdom has been assembled, based upon the principles of Tasker and Pienkowski (1987) and developed by Williams *et al.* (1994). We have further refined the methods according to Certain *et al.* (2015).

16 The method for creating monthly maps of the sensitivity of offshore seabird concentrations to oil pollution is driven by combining seabird abundance data with individual seabird species sensitivity index values, then summing these at each location to give an overall sensitivity value for all seabirds. The detail behind this process is given below. The selection of data used in the analysis, and the justification behind these selections is given in Section 2.3, with the methods for processing these data and correcting for known biases in the different seabird survey methods in Section 2.4. The final part of preparing the data is to create grid maps of distribution for each species in each month using a density mapping method and is described in Section 2.5.

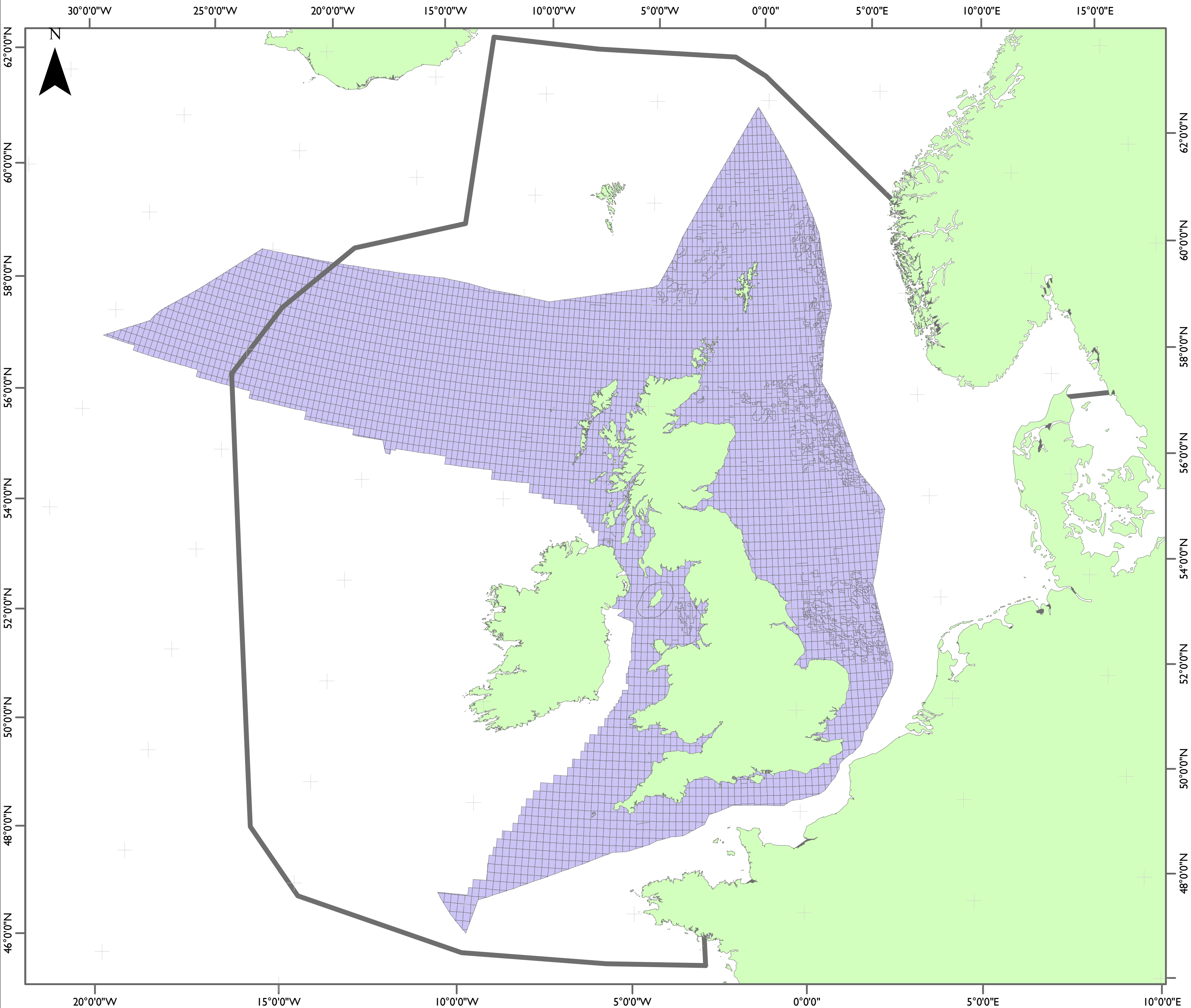
17 A number of different factors were used to describe the sensitivity of individual seabird species to oil pollution; the process for selecting these measures and then populating the tables for each species is given in Section 2.6. The final step of applying these species scores to the seabird density data and presenting these is described in Section 2.7

18 In addition to providing a fine scale representation of the sensitivity of seabird concentrations to oil pollution, we have summarised this information for each offshore oil licence block, where available. The process for summarising these data is given in Section 2.8. An additional set of information is also provided at the scale of the oil licence block is the uncertainty behind this assessment of sensitivity; the method for calculating this is presented in Section 2.9.

2.2 Study area

19 The limits of the study area used for this analysis is shown in Figure 1, along with the sea area of the DECC Offshore Licence Blocks within the limits of the UKCS. The Blocks are used for licensing exploration and production of oil and gas deposits around the United Kingdom. A larger study area was used than the limits of the UKCS because of the need for information over a wide radius around sites of oil spillages, which may drift with tide and wind.

Figure 1 Study area used for analysis of seabird oil sensitivity around the UK and the location for DECC Offshore Oil Licence Blocks



LEGEND

Survey area

DECC Offshore Oil Licence Blocks

0 250 500

Kilometres

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CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Study area used for analysis of seabird oil sensitivity around the UK and the location of DECC Offshore Oil Licence Blocks

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PLOT SIZE A4

DATUM WGS84

PROJECTION UTM30N

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2.3 Survey data

20 Three different types of seabird survey data were considered for inclusion in this analysis: boat-based line transect data; visual aerial line transect data; and digital video strip transect data. A description of the survey methods and the data used for each of these survey platforms is given in Sections 2.3.1 to 2.3.3. No data were used that were collected prior to 1 January 1995, in line with the recommendations of Pollock and Barton (2006) and Webb et al. (2014). Although the latter authors recommended a maximum age of 15 years for data used in analyses such as these, they also acknowledged that there was a case for using data up to 20 years old.

21 A large amount of data on seabird distribution is being accumulated from tracking studies of individual seabirds at sea using geo-locators, Global Positioning System ("GPS") and satellite tags in an online databases (http://www.seabirdtracking.org/). These studies have contributed greatly to our understanding of individual movements of seabirds but fall short when attempting to describe seabird populations and seabird concentrations as is required for this project. The main short-comings of these data are their focus on the movements of adult birds and their focus on the breeding season. This means that there are relatively little data available covering the non-breeding season and non-breeding full-grown or immature seabirds. Furthermore, data for some species is limited by their suitability for carrying tags (e.g. on account of their size, their foraging behaviour or their behaviour in response to the tags). In order to include tracking data to determine the sensitivity of seabird concentrations to oil pollution, data would be needed for all species and all age classes in reasonable sample sizes within and outwith the study area.

2.3.1 Boat-based data

22 The boat-based data used in this analysis were all derived from boat-based surveys and were supplied to the ESAS Database as of August 2015. The ESAS Database (Reid and Camphuysen 1998) provides a centralised fixed database of seabird and marine mammal surveys conducted using standardised line transect methods (Tasker *et al.* 1984; Webb and Durinck 1992; Camphuysen *et al*. 2004) and since 1995, has been carried out by observers trained to standards laid down by the ESAS Co-ordinating Group.

23 The most recent survey data used were collected in February and March 2015 and were complete for those submitted for the UK contributions to the database. Contributions from other participating countries were less contemporary, with the most recent being from August 2011; any such data not included in the database were considered to be low priority for inclusion given that they were relatively small datasets, mostly fall outside the UKCS waters and inclusion would have caused significant time constraints for the project.

24 A number of datasets have been submitted to a repository managed by The Crown Estate in support of applications for offshore wind farms, but have not been submitted for inclusion in the ESAS Database. None of these were used in this analysis. For the most part, they were not included in the ESAS Database because they did not satisfy at least one of the qualifying standards; in many cases the data were insufficiently well managed to allow rapid amalgamation with the ESAS Database; and in many cases, the developments are still subject to approval in or a developmental phase and the data owners are therefore understandably reluctant to grant approval for uses other than those initially commissioned.

2.3.2 Visual aerial data

25 A large set of visual aerial data were collected around the UK between 2000 and 2011 by WWT Consulting and JNCC. Both survey teams used identical methods described by Kahlert *et al.* (2000) and also by Camphuysen *et al.* (2004). All data collected by these two groups during the temporal limits of this project were included for this analysis.

2.3.3 Digital aerial data

26 High-resolution digital video aerial survey data were first collected in the UK in 2009 using methods described by Buckland *et al.* (2012) and standards established by Thaxter and Burton (2009). Digital video aerial surveys are now used by the majority of offshore renewable energy developers, as well as statutory and Government bodies.

27 Some of the earliest data were collected using both digital video and stills cameras set to record images with a resolution of 3cm Ground Sample Distance ("GSD") which gave low rates of identification to species level compared to more recent surveys, in which the resolution was 2cm GSD. The project's Steering Group therefore agreed not to use the data in which 3cm GSD imagery was collected to avoid complicating the analysis on account of identification rates to species.

28 The data used in the analysis had already been submitted to the ESAS Database, were commissioned by Government bodies or were collected for offshore wind energy projects that are not no longer under consideration for consent by the regulator or being actively developed. Digital aerial data not used in the analysis were data that had been submitted for assessment as part of an Environmental Statement ("ES") but developments were still under consideration and therefore commercially confidential, and digital aerial data (both digital video and stills) collected at 3cm GSD resolution.

2.4 Data processing

29 All data were imported into a Paradox database and organised into a separate files according to the survey platform type in preparation for correction of biases (see Section2.4.1).

30 Boat-based data were divided into samples at the time of data collection. Data were collected continuously along a line transect and separated into non-independent samples of uniform duration. These samples, generally referred to as 'Poskeys' in the ESAS Database, vary in duration between surveys and are usually 1, 2, 5 or rarely 10 minutes long. The spatial length of these samples further varies according to the speed of the ship. Visual and digital aerial data were also collected continuously along the transect line, but were divided into 1km non-independent samples (visual) and 0.5km non-independent samples (digital), with shorter samples at the end of each transect. The samples are treated as being non-independent because of the likely temporal autocorrelation between samples.

31 A number of filters were applied in order to remove data that might be considered least representative of true seabird abundance in the study area. These were:

- Surveys older than 20 years (1 January 1995) as recommended by Webb *et al.* (2014) and Pollock and Barton (2006);
- Surveys from boats in which no information was collected on the distance of birds from the transect line for sitting birds and no 'snapshot' data for flying birds;
- Surveys with ship speed of less than six (6) kilometres per hour ("km/hr") in order to remove data in which large numbers of ship associates might be present as recommended by Tasker *et al.* (1984);
- Bird observations in which the behaviour was recorded as dead, on land or as associated with the observation platform;
- Surveys from boats in which the sea state was greater than five (5). Camphuysen *et al.* (2004) recommended that surveys from boats should be carried out in sea states of four (4) or less.

However, this recommendation related to surveys carried out from relatively small boats used for wind farm surveys compared to those used in the ESAS database;

- Visual aerial surveys with sea state greater than three (3) as recommended by Camphuysen *et al.*(2004); and
- Digital video aerial surveys with sea state greater than five (5) as recommended by Thaxter and Burton (2009).

32 After corrections were applied for known biases in the data (see Section2.4.1), the three different databases for each survey platform were combined. The sheer size of this combined database meant that there were performance issues and it was necessary to summarise the sum of the observations and the sum of the effort data in two (2) minutes (') of latitude and four (4) minutes of longitude blocks (approximately 2km x 2km dimension). The composite database was then used as the source data for density mapping.

2.4.1 Bias correction

33 All platforms and methods for seabird survey are biased in some way which need to be accounted for if these data are to be combined into a single resource. Most biases are at least acknowledged, even if not fully understood, and can be accounted for in some way. Each of these are described below, and the method for correcting them within the section for each of the survey platforms.

2.4.1.1 Boat-based data

34 Uncorrected abundance estimates from seabird and marine mammal surveys are known to be biased because there is an unequal probability that birds are detected by observers at different distances from the boat or the transect line (Buckland *et al.* 2001; Camphuysen *et al.* 2004). In ESAS-standard boat-based surveys, observers record the distance of each sitting bird from the transect line in four distance bands (Webb and Durinck 1992) and these data can be used to estimate the numbers that have been missed at greater distances from the transect line using simple detection correction factors (e.g. Stone *et al.* 1995; Skov *et al* 1995) or by more complex modelling of detection probabilities using distance software (Thomas *et al.* 2010). It is not possible to measure the distance of flying birds accurately at sea (Buckland *et al.* 2001) and is prone to additional bias because of responsive movement to the ship, therefore no correction for bias in detection rates is possible for flying birds.

35 This report used detection correction factors ("DCFs") that could be applied to the density calculations of sitting birds, using methods similar to those employed by Stone *et al.* (1995) and Kober *et al.* (2010). We assumed that all birds are detected in the two distance bands closest to the transect line (0 – 50m and 50 – 100m) and that all flying birds were detected. Both assumptions are likely to be incorrect, and would result in underestimates of abundance from boat-based surveys. We used the two nearest distance bands rather than just the nearest, because there is often a peak in detections in the second nearest band (see Appendix A for guillemot and razorbill), almost certainly caused by responsive movement to the approaching boat or ship. If there were perfect detection, the sum of the birds in the nearest two distance bands would be about 1/3 of the total number in all distance bands because they are 1/3 of the of all bands combined. We calculated the DCF as:

$$DCF = 3(N_a + N_b) / (N_a + N_b + N_c + N_d) \qquad \text{Equation 1}$$

Where N_a = number in Band A (0 – 50m), N_b = number in Band B (50 – 100m), N_c = number in Band C (100 – 200m) and N_d = number in Band D (200 – 300m), 36 We estimated the effects of four co-variates on the DCFs by visual inspection, in which it was assumed that the effect of distance on detection rates increased with increasing sea state; increased in months with shorter day length; decreased when more observers were present on watch; and decreased when binoculars were used to detect birds. A minimum sample size of 100 was required for the assessment of each sub-category. If there was no visual relationship apparent, the DCF was calculated across all values of the covariate, rather than separately for each value of the covariate. When sample sizes were too small for a particular component value for one of the co-variates we used an average of values either side (bracketing) and in the case of species with small sample sizes, we used the measurements for the entire species group. We did not use a geographical component for this analysis as this is likely to duplicate month and sea state DCFs. No relationship was found for any species for Month, Number of Observers or Use of Binoculars, and the DCFs were calculated for each species using Sea State only. A full list of DCFs used in the calculation is presented in Appendix A.

37 A number of seabirds are known to show responsive movement to the presence of survey ships. It is assumed that responsive movement away from the ship is controlled for by training of observers who are required to look far ahead of the ship to detect escape flight or diving before the ship approaches. However, scavenging seabird species are known to exhibit attraction to fishing vessels (e.g. Skov and Durinck 2001) and this phenomenon is known to affect observations from non-fishing vessels used for seabird surveys (e.g. Hyrenbach *et al.* 2007), causing over-estimates of abundance for these species. Kober *et al.* (2010) attempted to control for this effect in ESAS boat-based data by comparing at sea population estimates with expected numbers at sea based upon population studies. They applied a scaling factor to density estimates for certain scavenging species to account for apparent over-estimates of abundance. We have applied the same scaling factors used by Kober *et al.* (2010), and these are tabulated in Appendix A.

38 As stated previously, it is assumed that all flying birds and all birds sitting on the water in the nearest two distance bands to the transect line are detected, and that this assumption is likely to lead to an underestimate of seabird abundance in boat-based surveys. A further assumption is that there is no effect of availability bias on abundance estimates from boats. This is the bias caused by birds being underwater during the period when the boat passes. While there is usually plenty of time for a surveyor to detect sitting birds between dives, but for some species with long dive times, such as common guillemots *Uria aalge*, there is a chance of a small proportion of dives being missed. This is usually thought to be insignificant during seabird surveys from boats.

2.4.1.2 Visual aerial data

39 Visual surveys from aircraft are thought to be vulnerable to the same biases as in ship-based surveys with the exception of responsive movement towards the observation platform. As with boat-based surveys, the detection probability for sitting and flying seabirds decreases at greater distances from the aircraft (Kahlert *et al.* 2000).

40 As with boat-based surveys, a simple method was used to calculate a scaling factor for observations by assuming that all objects were detected in the distance band closest to the transect line. We calculated the scaling factor ("*SF*") for visual aerial surveys to be:

$$SF = \frac{N_A}{W_A} \times \frac{W_T}{N_T} \qquad \text{Equation 2}$$

Where N_A = number of birds recorded in Band A (44–163m), W_A = width of Band A (119m), W_T = total width of transect (956m), and N_T = total number recorded in all bands (44–1000m). The values calculated for each species and species group are provided in Appendix A. While Equation 2 appears very different to Equation 1, its derivation is based on exactly the same principles.

41 Insufficient data were supplied for the sea state or sun glare during these surveys, so the effect of these co-variates upon detection rates could not be investigated. The effect of day length (month) was not found to influence the size of the scaling factor based upon visual observation.

42 As with boat-based surveys, this report assumes that all objects on the transect line were detected, which is unlikely to be true for these surveys and consequently, all abundances are likely to be underestimates. Availability bias is likely to be a factor in visual aerial surveys. The effect of availability bias is likely to be complex and related to the distance of the objects from the transect line, and vary between observation positions in the aircraft. For example, observations carried out from a Partenavia Observer aircraft with bubble windows, are likely to give a wider search area and higher probability of detection than observations from a conventional Partenavia without bubble windows. No previous study has attempted to estimate availability perception bias for seabirds in visual aerial survey, and this goes beyond what could possibly be achieved in this study. This will have resulted in a further underestimate of the abundance of diving seabird species: seaducks (Anatidae), divers (Gaviidae), cormorants (Phalacrocoracidae), grebes (Podicepididae) and auks (Alcidae), but was considered better than excluding this large body of data from the analysis.

2.4.1.3 Digital video aerial data

43 Digital video aerial surveys differ from visual surveys because the probability of detecting birds is equal across the entire strip transect. Furthermore, the efficiency of detection can be managed by a double blind review process. All video footage is reviewed by a trained operator, and 20% is subjected to a blind review by an auditor who is one of the most experienced reviewers. If there is less than 90% agreement between reviewer and auditor, then all video footage processed by that operator is subjected to a re-review. In fact, the average agreement rate achieved is about to 97%. For this reason, we did not apply a scaling factor to account for variation in detection efficiency.

44 Digital video aerial surveys can be prone to the effects of availability bias, which occurs because seabirds are submerged during the time window when video cameras are scanning the sea and therefore not available for detection. The time required for the video cameras to detect diving seabirds is close to instantaneous, and is equal to the percentage of time at sea spent underwater. We assumed that availability bias is uniform geographically, even though this may not be the case in reality, and used a generic method for correcting for availability bias. We did this by dividing the total abundance of diving species by the scaling factor, which were sourced mostly from calculations in Forewind (2013) with additions where possible from other literature (see Appendix A for full details).

2.5 Density mapping

45 The density maps have been derived using a Watson-Nadaraya type kernel regression technique (also known as kernel density estimation ("KDE")) (Simonoff 1996). In KDE, a small 'window' function (the kernel) is used to calculate a local density at each point in the study area. To evaluate the density at a given point, the kernel is centred on that point and all the observations within the window are summed according to the window function to obtain a local count. The total area of the transect(s) intersecting the window is then summed to obtain a local measure of effort. By dividing the local count by the local effort, a local density estimate is obtained. To build a density map, the study area is covered with a fine mesh of study points approximately 3km apart and the density is calculated at each point in the mesh in turn.

46 Kernel techniques are robust but not as complex as other density estimation techniques, because they have few parameters. As a result, they are arguably the easiest density surface technique to reproduce independently. The only variables are the size and shape of the kernel or window function. Here, we have used a Gaussian window function, which has the advantages of being smooth, rotationally symmetric and

easy to compute. The shape of the Gaussian window can potentially be two-dimensional, but in our case was determined by a single 'bandwidth' parameter; the selection of this parameter is the only variable in the computation of the density maps.

47 The ideal method for determining a bandwidth parameter would be to calculate this for all species and each month using a 'leave-one-out cross validation method' (Simonoff 1996). However, given the agreed programme for this study, the Project Steering Group agreed to use a single bandwidth parameter of 40km. However, given that there was a tendency for this procedure to produce unlikely estimate at the border with regions with no effort, we truncated the calculation at 36km. These distances provided the best compromise between providing information in unsurveyed areas and realistic values.

2.6 Species oil sensitivity scores

48 The purpose of this project was to provide an updated measurement of the sensitivity of seabird concentrations to oil pollution, and the original intention was to improve on the methods of Williams *et al.* (1994) in doing so. The main strengths of the method described by Williams *et al.* (1994) was that it could be interpreted easily by non-specialists; it derived species sensitivity scores by a process of peer review and that it made a direct connection between the individual species sensitivity scores to their density. The main weakness of this approach is there is no critical examination of the role that different components (factors) in the individual species sensitivity scores and what their mathematical relationship should be. Certain *et al.* (2015) reviewed the approach of Garthe and Hüppop (2004) and others, all of which were based upon the technique first developed by Williams *et al.* (1994), and carried out a critical analysis of the different factors used to describe a species' overall sensitivity to a given human pressure. They also advocated a disaggregation of the sensitivity scores and the abundance measures.

49 Certain *et al.* (2015) and Williams *et al.* (1994) used a different terminology from that used in this report to refer to the effect of pressures on seabirds. In this report, we have adopted the terms described in Tillin *et al.* (2010):

- *Sensitivity*: A measure of tolerance (or intolerance) to changes in environmental conditions (this is in place of Williams *et al.* (1994) who referred to this as vulnerability but Certain *et al.* (2015) used this only in the context of generic species sensitivity and distinguished this from sensitivity of the individual to the pressure and referred to that as vulnerability);
- *Resistance (Intolerance/tolerance)*: Response to change whether element can absorb disturbance or stress without changing character;
- *Resilience (Recoverability)*: The ability of a system to recover from disturbance or stress;
- *Vulnerability*: Vulnerability is a measure of the degree of exposure of a receptor to a pressure to which it is sensitive. Term was used by Williams *et al.* (1994) and Certain *et al.* (2015) for what we refer to as sensitivity;
- *Pressure*: The mechanism through which an activity has an effect on any part of the ecosystem'. The nature of the pressure is determined by activity type, intensity and distribution;
- *Impact*: The effects (or consequences) of a pressure on a component; and
- *Exposure*: The action of a pressure on a receptor, with regard to the extent, magnitude and duration of the pressure.

50 In order to calculate species sensitivity scores, we used and adapted the methods described by Certain *et al.* (2015). The principle of this method is to base the index upon the likelihood that an individual of the species will be exposed to a specific pressure and apply a group of factors based upon the likely impact of that pressure on the individual, having encountered it in the first place. They refer to these as "primary factors that directly control the vulnerability (sic), and aggravation factors that can increase a vulnerability

(sic) that already exists". They used the term vulnerability factors where we prefer the use of sensitivity factors (see previous paragraph). They also apply the same principle to generic pressures at the species level in what they refer to as a sensitivity factor.

51 They recommended using the following formula for calculating these scores (r) for individual and species level sensitivity factors separately:

$$r = a^{1-g/(g+\gamma)} \qquad \text{Equation 3}$$

$$a \in [0,1], \qquad g \in [0,1], \qquad \gamma \in [0.1, 1]$$

Where a = any group of primary factors, g = any group of aggravation factors and γ = a variable parameter. The symbol ∈ describes the range of values that are permissible, and it should be noted that the maximum value of 1 produces a very different effect from the maximum of 5 for each factor used by Williams *et al.* (1994) when used in Equation 3.

52 Certain *et al.* (2015) recommend that parameter γ be set at 0.5 but is used to increase or decrease the effect of the aggravation factors. We tested a range of different γ values to examine the effect on the final sensitivity maps and found that, because fixed percentiles (rather than fixed absolute values) were used in the presentation of these different γ values, that the end results were imperceptibly different. We saw no reason to use any other value than 0.5.

53 Using the approach of Certain *et al.* (2015), we classified a number of factors that we considered to contribute to each species overall sensitivity to oil pollution at sea, and these are described in Table 1.

54 Certain *et al.* (2015) discussed the merits of two simple ways of combining groups of primary or aggravation factors, either by averaging or multiplication for use in Equation 3. "*When averaging, compensation between factors is allowed, i.e. a low score for one factor can be balanced by a high score for another factor. This may be suitable when several factors of different nature are involved for a given pressure type. Another way of combining factors is multiplication, which may be convenient when factors are interacting, or when they are conditional to each other*". We found that this definition and subsequent explanation was unclear. Certain (pers. comm.) provided an example of how they used multiplication to combine two factors "*the use of multiplication rather mimic(s) a conditional probability type of reasoning. The authors used it for % of time spent flying and % time spent at wind turbine blade height when flying. This is easy to understand: if the bird flies 100% of the time BUT 0% of the time at blade height, well, then the probability of getting hit by a blade is 0% (the product) not 50% (the average). So multiplications were used to illustrate the fact that BOTH conditions should be met for the individual to be at risk*". This clarification provided a good guide for when multiplication might produce a proportionate or disproportionate effects on each other when combined. We will refer to this as the '0-value rule' because if one of the factors is set to 0, the effect on the combined values and consequent effect on the SOSI value changes substantially if multiplication is used instead of averaging; for aggravation factors, the effect of multiplication gives a greater range of values of g than when using averages, and for primary factors the use of multiplication when one of the factors is zero would result in the total SOSI value of the species being set to zero too. When applying the 0-value rule, it is important to consider if the effect of one factor being set to zero is proportionate and realistic.

55 After the sensitivity r is calculated for the individual (i.e. their sensitivity to oil pollution) and to the species to all pressures (referred to as species sensitivity), then the two values are multiplied together to give an overall sensitivity score for each species and species group.

56 Using Table 1, we concluded that the calculation for the SOSI score for each species should be:

$$SOSI_i = \underbrace{(F_1 \times F_2)^{1-\frac{F_3}{F_3+0.5}}}_{\text{individual sensitivity}} \times \underbrace{\left(\frac{F_4+F_5+F_6}{3}\right)^{1-\frac{\left(\frac{F_7+F_8}{2}\right)}{\left(\frac{F_7+F_8}{2}\right)+0.5}}}_{\text{species sensitivity}} \qquad \text{Equation 4}$$

Table 1 Classification of different factors that contribute to the overall sensitivity of seabird species to oil pollution

Classification	Description	Factor type	Factor hierarchy
F_1	*Proportion sitting on water* Also used by Williams *et al.* (1994), this factor is a calculation from the updated ESAS database since 1994. It describes the proportion of time birds of the species spend sitting on the water (compared with flying) and is a measure of the likelihood of exposure to the pressure of oil pollution. Those species that spend a longer proportion of time sitting are more likely to encounter oil pollution and would have a higher score than those with a more aerial lifestyle. A species that never sits on the water would never be likely to be exposed to oil pollution and its relationship to F_2 is therefore considered to be multiplicative.	Individual sensitivity	Primary
F_2	*Proportion of tideline corpses oiled* The same data as was used by Williams *et al.* (1994) is used here. A range of factors will affect the likelihood that a seabird is exposed to oil pollution that is present, and this factor is a measurement of the proportion of seabirds stranded on beaches that have been contaminated with oil. Those with a high percentage than other species (and therefore a high score) are more likely to be exposed in any given oil spill. This factor is considered to have a multiplicative relationship with F_1.	Individual sensitivity	Primary
F_3	*Habitat flexibility* Used instead of Williams *et al.* (1994) factor d of 'reliance on the marine environment'. We considered that a species ability to resist exposure to oil pollution rested more on its ability to locate alternate feeding sites rather than simply whether it could switch to feeding on land. For this factor, a species that occupies habitats that are restricted in their geographical extent will have lower resistance and be impacted by oil pollution more than a	Individual sensitivity	Aggravation

Classification	Description	Factor type	Factor hierarchy
	species which is relatively free-ranging over extensive habitats.		
F_4	*Proportion of biogeographical population in the UK (winter or summer separately)* Williams *et al.* (1994) only used one measure of a species sensitivity according to its conservation status, and that was its biogeographical population size. We followed Furness *et al.* (2013) by using a factor that expressed the importance of UK waters for the conservation of the species, where a species with a low proportion in UK waters would be given a low score compared to one where the UK was responsible for protecting a higher proportion. Arguably, this could be used as a multiplier, because this factor potentially interacts with the other primary factors for species sensitivity. However, we combined this with the other primary factors by averaging the values based on the '0-value rule' (see above) where if this factor were 0, it would effectively have set the whole SOSI score to 0 even though the species might be present and was sensitive according to other factors.	Species sensitivity	Primary
F_5	*Birds of Conservation Concern status* This factor was used by Furness *et al.* (2013) and reflects a wider interpretation of the species conservation status in the UK than F_4, and therefore its sensitivity to pressures as a whole. We combined this factor with the other primary species sensitivity factors because they have a compensatory relationship.	Species sensitivity	Primary
F_6	*Presence on EC Birds Directive Annexes* This factor was also used by Furness *et al.* (2013) and by Certain *et al.* (2015) and reflects the species conservation status at a European level rather than just the UK level as is the case for F_5. We combined this factor with the other primary species sensitivity factors by averaging because they have a compensatory relationship.	Species sensitivity	Primary
F_7	*Potential annual productivity* This factor provides a measure of the species' resilience to pressures. In the event of exposure to a pressure of any sort, the species' resilience will be lower if it cannot return its population levels to un-impacted levels quickly if it has low potential reproductive output. It therefore	Species sensitivity	Aggravation

Classification	Description	Factor type	Factor hierarchy
	increases or decreases a species' sensitivity to pressures and should be considered an aggravation factor. This factor is grouped with F_8 with which there is a compensatory relationship, therefore they are grouped using an average. We used the values method of Williams *et al.* (1994) which added three sub-factors of mean clutch size, maximum clutch size and age at first breeding, which is similar to the effect of averaging those values.		
F_8	*Adult survival rate* This factor is also a measure of the resilience of each species to pressures. Those species with high adult survival rates are affected more by non-selective mortality incidents than species with low adult survivorship because the individual invests more in its lifetime than its annual reproductive capability. An individual of a species with high annual survival attempts to replicate itself within the population over its inevitable long average life span, therefore the impact of a mortality incident that affects adults in the population will be greater for species with high adult survival rate than those with a low adult survival rate. This factor is partially compensatory with F_7, so is averaged rather than multiplied.	Species sensitivity	Aggravation

57 The combined SOSI scores for each species and species group is given in Table 2. The methods for calculating the individual factors are detailed in Appendix B.

Table 2 Factor scores and species-specific SOSI scores in winter and summer (see Table 1 for description of each factor) and compared with the values used by Williams *et al.* (1994).

Species	Williams et *al.* (1994)	F1	F2	F3	F4 (Winter)	F4 (Summer)	F5	F6	F7	F8	SOSI (winter)	SOSI (summer)
Red-throated diver	29	1	1	0.8	0.4	0.4	0.4	1	0.8	0.6	0.808	0.808
Black-throated diver	29	1	1	0.8	0.2	0.2	0.8	1	0.8	0.6	0.845	0.845
Great Northern diver	29	1	1	1	1	0.2	0.8	1	1	0.8	0.976	0.865
Diver sp.	29	1	1	0.8	0.6	0.2	0.8	1	0.8	0.8	0.918	0.856
Great crested grebe	23	1	0.6	0.8	0.4	0.4	0.2	0.6	0.4	0.2	0.463	0.463
Red-necked grebe	26	1	0.6	0.8	0.2	0.2	1	0.6	0.4	0.2	0.597	0.597
Slavonian grebe	26	1	0.6	0.8	0.4	0.4	1	1	0.6	0.2	0.726	0.726
Grebe sp.	25	1	0.6	0.8	0.2	0.4	0.6	0.6	0.6	0.2	0.538	0.579
Fulmar	18	0.6	0.6	0.2	0.2	0.6	0.8	0.6	1	1	0.391	0.421
Cory's shearwater	15	0.4	0.6	0.2	0.2	0.2	0.2	1	1	1	0.280	0.280
Great shearwater	12	0.4	0.6	0.2	0.2	0.2	0.2	1	1	1	0.280	0.280
Sooty shearwater	19	0.4	0.6	0.2	0.2	0.2	0.4	0.6	1	1	0.266	0.266
Manx shearwater	23	0.8	0.6	0.2	0.2	1	0.8	0.6	1	0.8	0.472	0.547
Balearic shearwater	23	0.8	0.6	0.2	0.2	0.2	1	1	1	1	0.534	0.534
Shearwater sp.	21	0.8	0.6	0.2	0.2	0.6	0.8	0.6	1	1	0.480	0.517
European storm-petrel	18	0.4	0.2	0.2	0.2	0.4	0.8	1	1	1	0.144	0.148
Leach's storm-petrel	18	0.4	0.2	0.2	0.2	0.2	0.8	1	1	1	0.144	0.144
Gannet	22	0.6	0.6	0.2	0.2	1	0.8	0.6	1	1	0.391	0.447
Cormorant	20	0.8	0.6	0.6	0.8	0.4	0.4	0.6	0.6	0.8	0.579	0.521
Shag	24	1	0.8	0.6	1	0.8	1	0.6	0.6	0.8	0.851	0.823
Shag/cormorant	22	0.8	0.8	0.6	0.8	0.6	0.8	0.6	0.6	0.8	0.717	0.689

Species	Williams et *al.* (1994)	F1	F2	F3	F4 (Winter)	F4 (Summer)	F5	F6	F7	F8	SOSI (winter)	SOSI (summer)
Scaup	20	1	0.4	0.8	0.4	0.2	1	0.6	0.2	0.6	0.561	0.529
Common eider	16	1	0.6	0.8	0.4	0.4	0.8	0.6	0.4	0.8	0.651	0.651
Long-tailed duck	17	1	0.6	0.8	0.2	0.2	1	0.6	0.2	0.2	0.570	0.570
Common scoter	19	1	0.8	0.8	0.4	0.2	1	0.6	0.2	0.4	0.712	0.667
Scoter sp.	N/A	1	0.8	0.8	0.4	0.2	1	0.6	0.2	0.4	0.712	0.667
Velvet scoter	21	1	0.8	0.6	0.2	0.2	1	0.6	0.2	0.4	0.657	0.657
Goldeneye	16	1	0.6	0.8	0.4	0.2	0.8	0.6	0.2	0.4	0.597	0.555
Red-breasted merganser	21	1	0.4	0.6	0.4	0.4	0.2	0.6	0.2	0.6	0.396	0.396
Goosander	21	1	0.6	0.8	0.4	0.4	0.2	0.6	0.2	0.2	0.427	0.427
Duck sp.	18.5	1	0.6	0.6	0.4	0.2	0.6	0.6	0.2	0.4	0.535	0.492
Grey phalarope	19	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.4	1	0.063	0.063
Pomarine skua	19	0.4	0.4	0.4	0.2	0.2	0.2	0.6	0.8	1	0.244	0.244
Arctic skua	24	0.6	0.4	0.4	0.2	0.4	1	0.6	0.8	1	0.377	0.392
Long-tailed skua	21	0.6	0.4	0.4	0.2	0.2	0.2	0.6	0.8	1	0.306	0.306
Great skua	25	0.6	0.6	0.4	0.4	1	0.8	0.6	1	0.8	0.472	0.523
Skua sp.	23	0.6	0.4	0.4	0.2	0.4	0.8	0.6	1	1	0.367	0.382
Mediterranean gull	17	0.6	0.4	0.4	0.2	0.2	0.8	1	0.8	0.6	0.382	0.382
Little gull	24	0.6	0.4	0.2	0.6	0.2	0.4	1	0.8	0.6	0.305	0.278
Sabine's gull	21	0.6	0.4	0.2	0.2	0.2	0.2	0.6	0.8	0.8	0.236	0.236
Black-headed gull	11	0.8	0.4	0.4	1	0.4	0.8	0.6	0.8	0.6	0.484	0.429
Common gull	13	0.8	0.4	0.4	0.8	0.4	0.8	0.6	0.8	0.6	0.467	0.429
Small gull sp.	15	1	0.4	0.2	0.6	0.2	0.8	0.6	0.8	0.6	0.439	0.400
Lesser black-backed gull	19	0.8	0.4	0.2	0.6	1	0.8	0.6	0.8	0.8	0.379	0.407
Herring gull	15	0.8	0.4	0.2	0.6	0.6	1	0.6	0.8	0.6	0.389	0.389

Species	Williams et *al.* (1994)	F1	F2	F3	F4 (Winter)	F4 (Summer)	F5	F6	F7	F8	SOSI (winter)	SOSI (summer)
Glaucous gull	17	0.4	0.4	0.2	0.2	0.2	0.8	0.6	0.8	0.6	0.208	0.208
Great black-backed gull	21	0.8	0.4	0.4	0.6	0.6	0.8	0.6	0.8	1	0.459	0.459
Large gull sp.	18.5	0.8	0.4	0.2	0.6	0.6	0.8	0.6	0.8	0.8	0.379	0.379
Black-backed gull	20	0.6	0.4	0.2	0.6	0.6	0.8	0.6	0.8	1	0.312	0.312
Kittiwake	17	0.8	0.4	0.4	0.2	0.6	1	0.6	0.8	0.8	0.436	0.471
Gull sp.	17	1	0.4	0.2	0.4	0.4	0.8	0.6	0.8	0.8	0.427	0.427
Sandwich tern	20	0.4	0.2	0.6	0.2	0.6	0.8	1	0.8	0.8	0.271	0.291
Roseate tern	N/A	0.6	0.2	0.6	0.2	0.4	1	1	0.8	0.8	0.339	0.350
Common tern	20	0.6	0.2	0.6	0.2	0.4	0.8	1	0.8	0.8	0.326	0.339
Arctic tern	16	0.4	0.2	0.6	0.2	0.4	0.8	1	0.8	0.6	0.268	0.279
Common/Arctic tern	16	0.4	0.2	0.6	0.2	0.4	0.8	1	0.8	0.8	0.271	0.282
Little tern	19	0.6	0.2	0.8	0.2	0.4	0.8	1	0.8	0.6	0.374	0.389
Black tern	18	0.4	0.2	0.2	0.2	0.2	0.4	1	0.8	0.4	0.124	0.124
Tern sp.	17.5	0.2	0.2	0.6	0.2	0.2	0.8	1	0.8	0.8	0.198	0.198
Guillemot	22	1	1	0.6	0.4	0.8	0.8	0.6	1	1	0.843	0.902
Guillemot/razorbill	23	1	1	0.6	0.2	0.8	0.8	0.6	1	1	0.811	0.902
Razorbill	24	1	1	0.6	0.2	0.6	0.8	0.6	1	0.8	0.799	0.865
Black guillemot	29	1	1	0.8	0.2	0.2	0.8	0.2	1	0.8	0.721	0.721
Little auk	22	1	1	0.4	0.2	0.2	0.2	0.6	1	0.6	0.655	0.655
Puffin	21	1	1	0.6	0.2	0.4	1	0.6	1	1	0.843	0.874
Auk sp.	24	1	1	0.6	0.2	0.4	0.8	0.6	1	1	0.811	0.843

2.7 Assembling oil sensitivity scores

58 We applied the species sensitivity scores to geographical locations by applying the formula (Formula 5) to the smoothed density estimates for each species and summed these scores together. The use of the density divided by (1 – species SOSI score) is adapted from Certain *et al.* (2015) who proposed this type of approach because it places greater emphasis on the most vulnerable species compared to the method of Williams *et al.* (1994) which multiplied the species SOSI score by the natural logarithm of the density. The winter value of the SOSI score was used for the months of October, November, December, January, February and March while the summer value of the SOSI score was applied for the months of April, May, June, July, August and September. Certain *et al.* (2015) recommended that instead of applying the sensitivity score *r* to the actual abundance of each species, that it be applied instead to the proportion of each species within the overall seabird community at any given location, and that this be overlaid separately from the abundance data. We did not follow their recommendation because: the use of overlaid maps or panels of maps as recommended by Certain *et al.* (2015) would require additional interpretation by the non-specialist; and because this approach is best suited to a binary 'Go / No Go' decision-making process, whereas the assessment process for oil spill planning and response needs to be based upon a continuous oil sensitivity score. The community approach recommended by Certain *et al.* (2015) uses the proportion of each species at each location, which correlates with the species density at each location, so using density instead of proportion at each location provides a good alternative in Equation 5.

$$SOSI_j = \sum_i^S \frac{\widehat{D}_{ij}}{1 - SOSI_i} \quad \text{Equation 5}$$

Where $SOSI_j$ = overall SOSI score at location j, $\widehat{D}_{ij}$ = density of species *i* (number/km²) at location *j*, $SOSI_i$ = SOSI score for species *i*.

59 We presented the analysis separately for each individual month for several reasons, but mainly because: in oil spill planning, one mitigation measure is avoidance of high risk activities at a particular time of the year, and loss of detail in seasonal maps for example would make application of this measure more difficult; seabird seasons are not uniform for different species, so combining months compromises the meaning of each season for different seabird species; and it is a simple task for a non-specialist to interpret gaps in coverage (the main advantage of seasonal maps) and look at adjacent months to potentially use that information instead.

2.8 Summarising by oil licence block

60 A spatial join was performed in ArcGIS 10.3 (ESRI 2015) between a layer of DECC Offshore Oil Licence Blocks (DECC 2015) and the smoothed SOSI scores for any given month. This assigns multiple approximately 3km x 3km non-independent samples to each Licence Block for each month. Within each individual 10' N by 12' E/W licence block, median, minimum and maximum SOSI score was calculated. The median and not the mean value was used to summarise the central point of the data owing to the skewed nature of the SOSI scores (see Appendix C). The same join was performed on a layer for the individual species density values, and the median of the smoothed density values was calculated for each individual licence block too. These calculations ignored subdivisions of the licence blocks (e.g. where exploration or production licences have been granted to parts of the blocks).

61 We calculated the shading boundaries used in the maps by combining the locational oil sensitivity scores for all months into a single frequency distribution (see Appendix C) to look for appropriate cut-off points.

The frequency plot was a smooth Poisson curve which tended towards using similar percentage cut-offs to those suggested by Garthe and Hüppop (2004) and Certain *et al.* (2015), in which the threshold between low and moderate sensitivity was set at 60% of all median block scores. We then used equal percentage boundaries as cut-offs above that. The cut-off points chosen rely on precedent (although no justification is given by either of the above authors) and good judgement.

2.9 Data uncertainty

62 A number of metrics were used to describe the uncertainty of the SOSI scores in each DECC Offshore Oil Licence Block. These were:

- U_1 the total survey effort (km^2) in any individual oil licence block;
- U_2 the total number of samples obtained in the licence block (number of visits to the block on different days)
- U_3 the number of years of survey in the oil licence block;
- U_4 the most recent year of survey in the oil licence block; and
- U_5 if any survey data did not record all species that were present in the area.

63 A full description of each of these measures of uncertainty is given in Appendix D, as are plots of the distribution of these measures in each month.

64 A single aggregated measure of uncertainty was calculated using the same principles as those for aggregating species sensitivity factors by averaging those that are compensatory and none could be considered to be interacting with others and none passed the '0-value rule'. The aggregated uncertainty score U_a was calculated as:

$$\mathrm{U}_a = \frac{U_1+U_2+U_3+U_4+U_5}{5} \qquad \text{Equation 6}$$

3 Results

3.1 Survey effort

65 The distribution of survey data from different observation platforms are presented in monthly coverage maps in Figures 2 to 13. The monthly survey effort expressed in square kilometres is presented for each observation platform in Table 3.

Table 3 Monthly survey effort expressed in square kilometres for each observation platform

Month	Survey effort (km^2)			
	Boat-based visual surveys	Aerial visual surveys	Digital video aerial surveys	Total
January	6054.81	39,254.00	415.29	45,724.10
February	9015.51	64,156.43	417.11	73,589.05
March	8868.08	55,362.31	424.29	64,654.68
April	7499.92	3431.49	420.22	11,351.63
May	13,248.57	15,657.12	517.83	29,423.52
June	13,446.66	13,902.44	892.78	28,241.89
July	23,624.59	16,717.88	1444.23	41,786.70
August	25,773.53	14,106.59	813.98	40,694.10
September	10,746.83	3257.91	230.19	14,234.92
October	5019.71	8902.03	225.31	14,147.06
November	5826.04	46,850.10	228.64	52,904.79
December	4522.72	31,390.56	417.53	36,330.80

Figure 2 Location of survey effort in January for calculation of seabird oil sensitivity around the UK, and type of survey platform

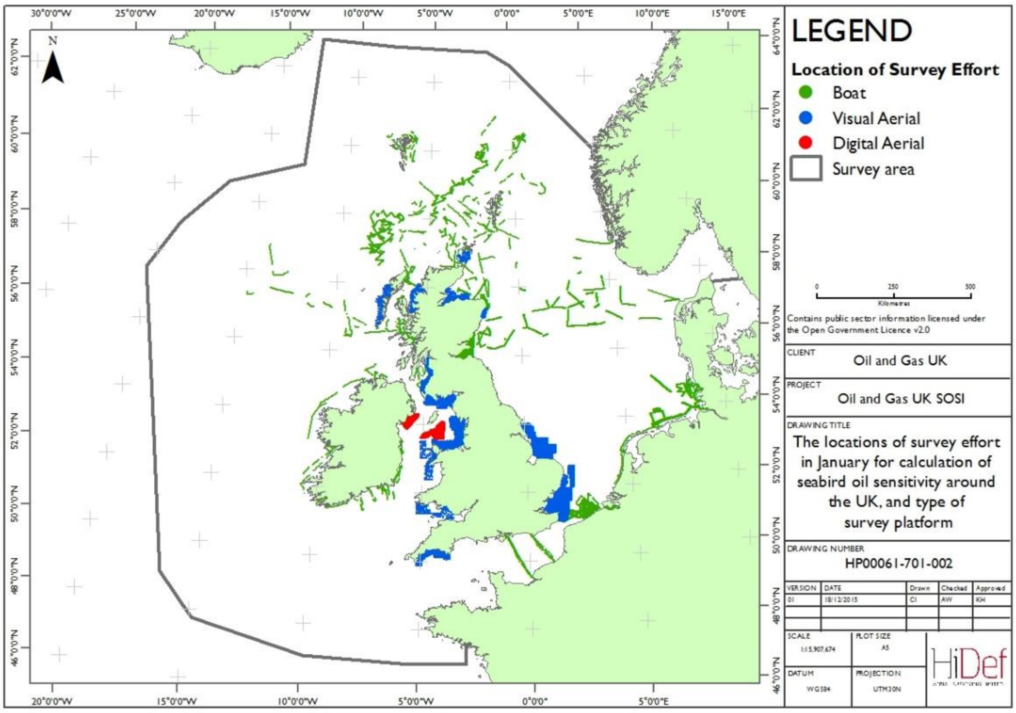


Figure 3 Location of survey effort in February for calculation of seabird oil sensitivity around the UK, and type of survey platform

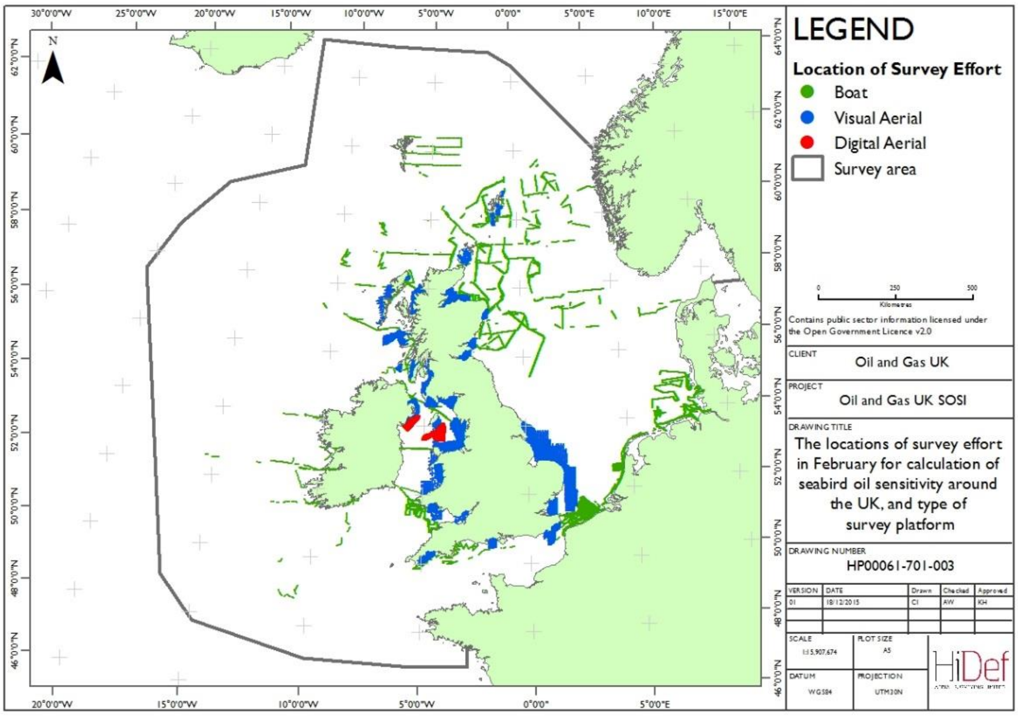


Figure 4 Location of survey effort in March for calculation of seabird oil sensitivity around the UK, and type of survey platform

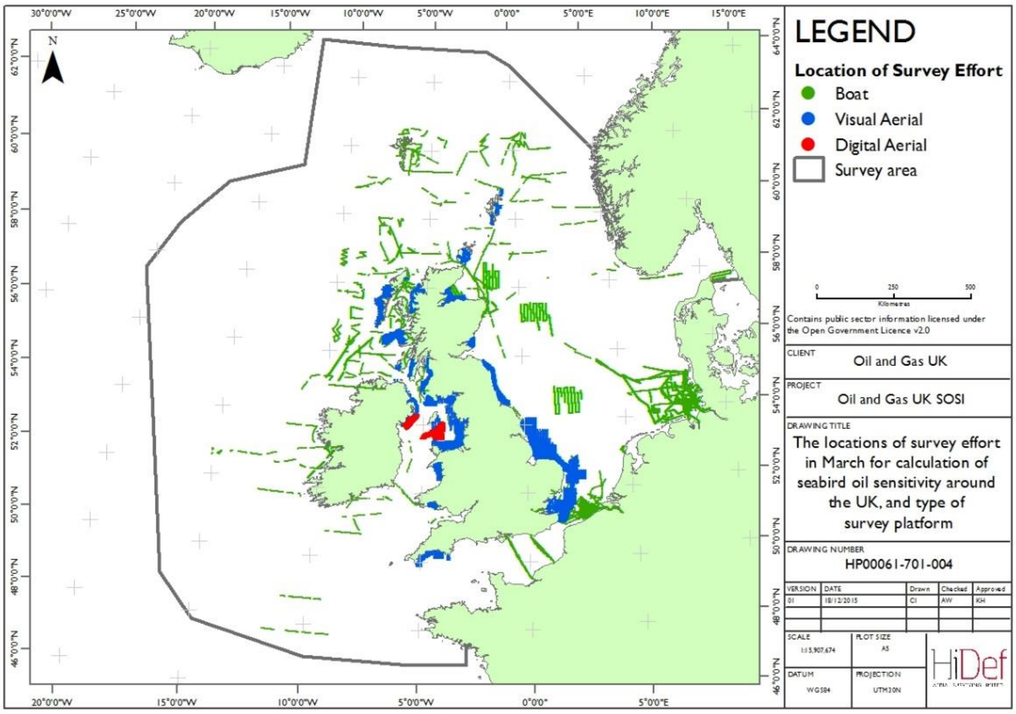


Figure 5 Location of survey effort in April for calculation of seabird oil sensitivity around the UK, and type of survey platform

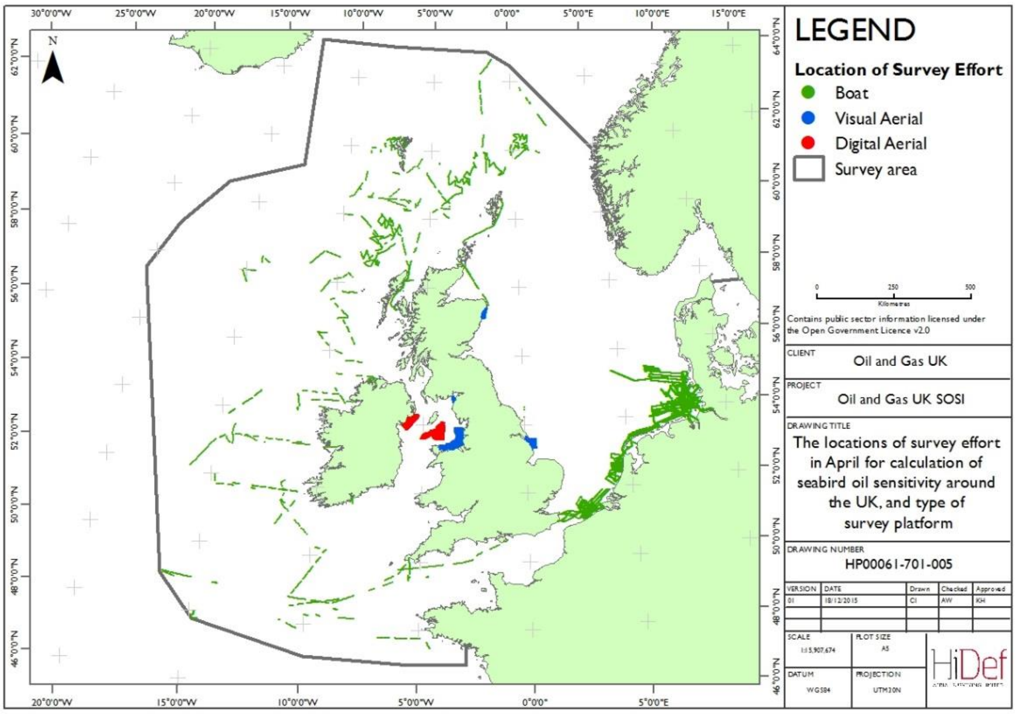


Figure 6 **Location of survey effort in May for calculation of seabird oil sensitivity around the UK, and type of survey platform**

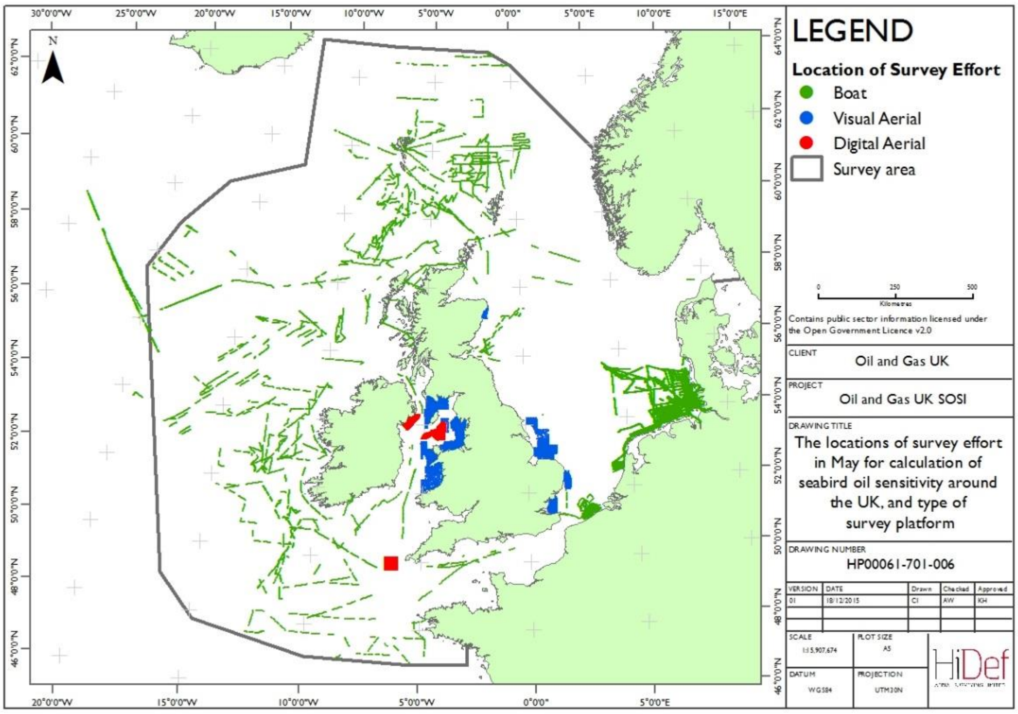


Figure 7 **Location of survey effort in June for calculation of seabird oil sensitivity around the UK, and type of survey platform**

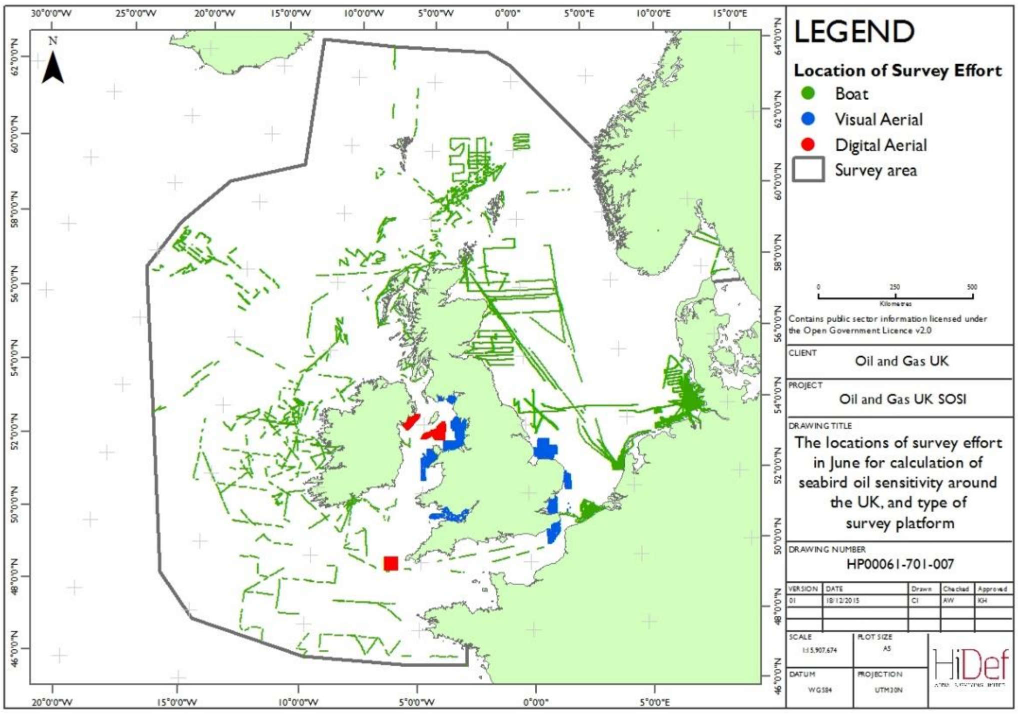


Figure 8 **Location of survey effort in July for calculation of seabird oil sensitivity around the UK, and type of survey platform**

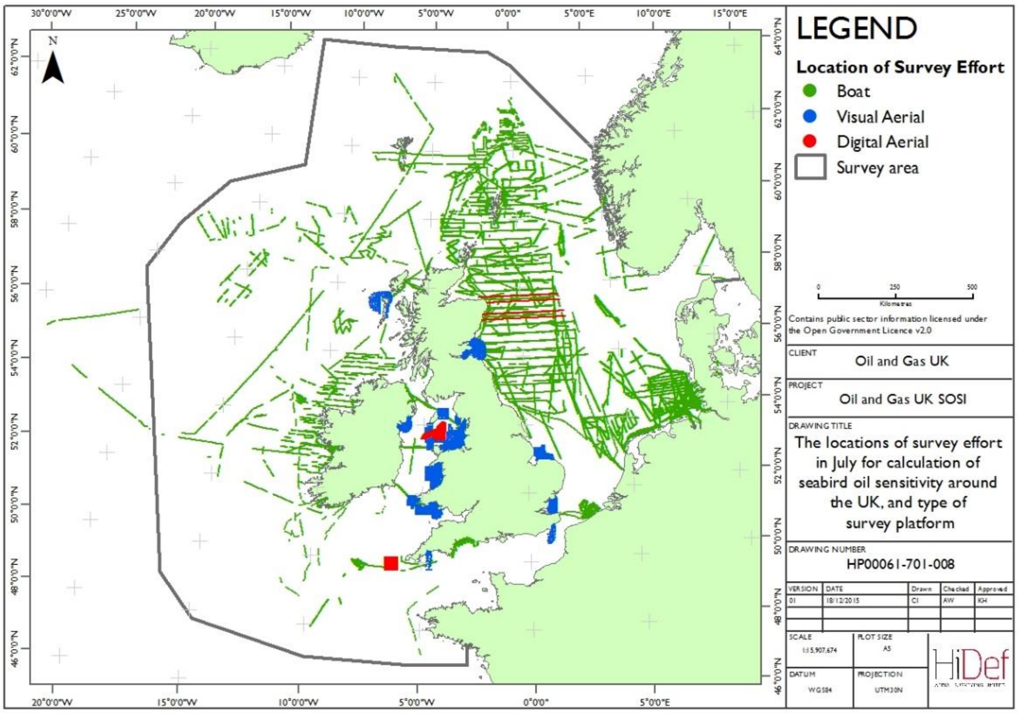


Figure 9 **Location of survey effort in August for calculation of seabird oil sensitivity around the UK, and type of survey platform**

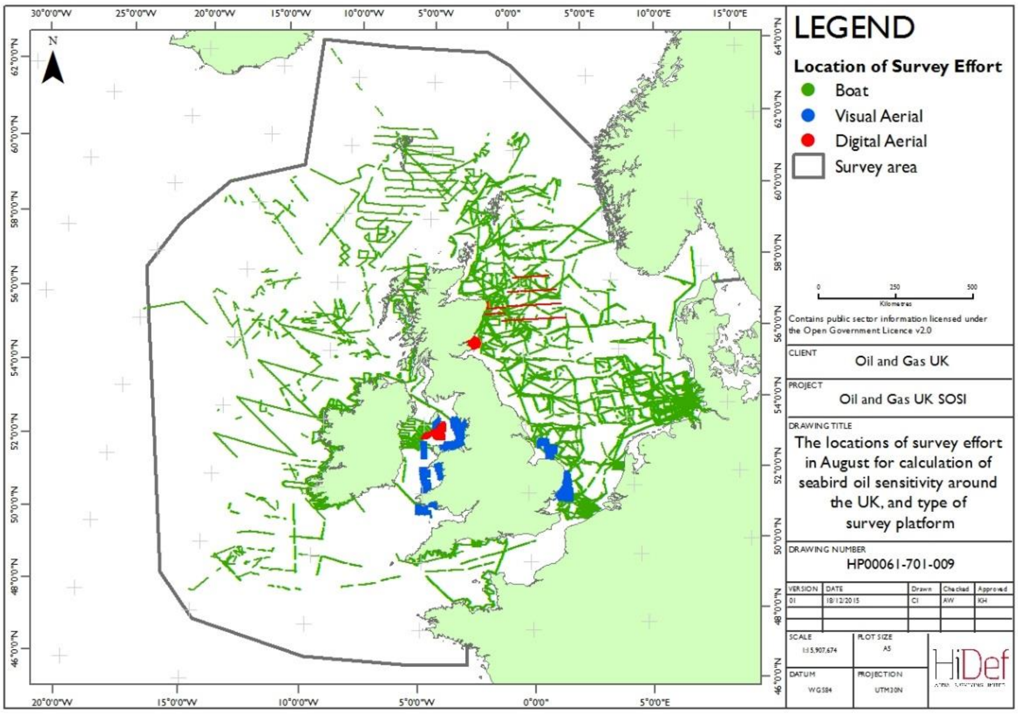


Figure 10 **Location of survey effort in September for calculation of seabird oil sensitivity around the UK, and type of survey platform**

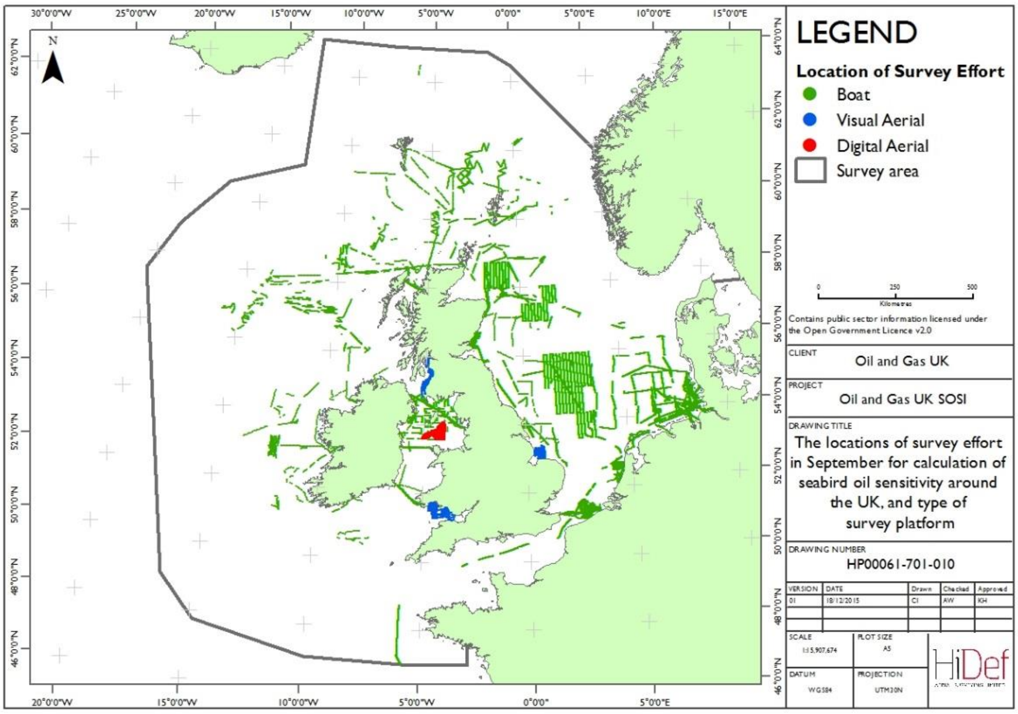


Figure 11 **Location of survey effort in October for calculation of seabird oil sensitivity around the UK, and type of survey platform**

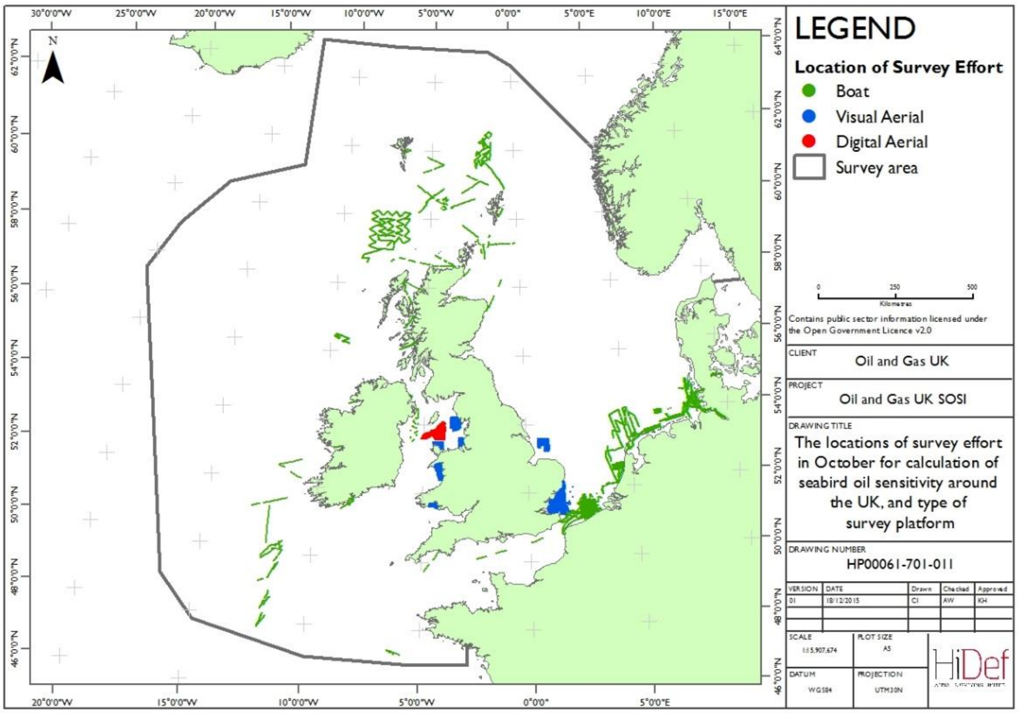


Figure 12 Location of survey effort in November for calculation of seabird oil sensitivity around the UK, and type of survey platform

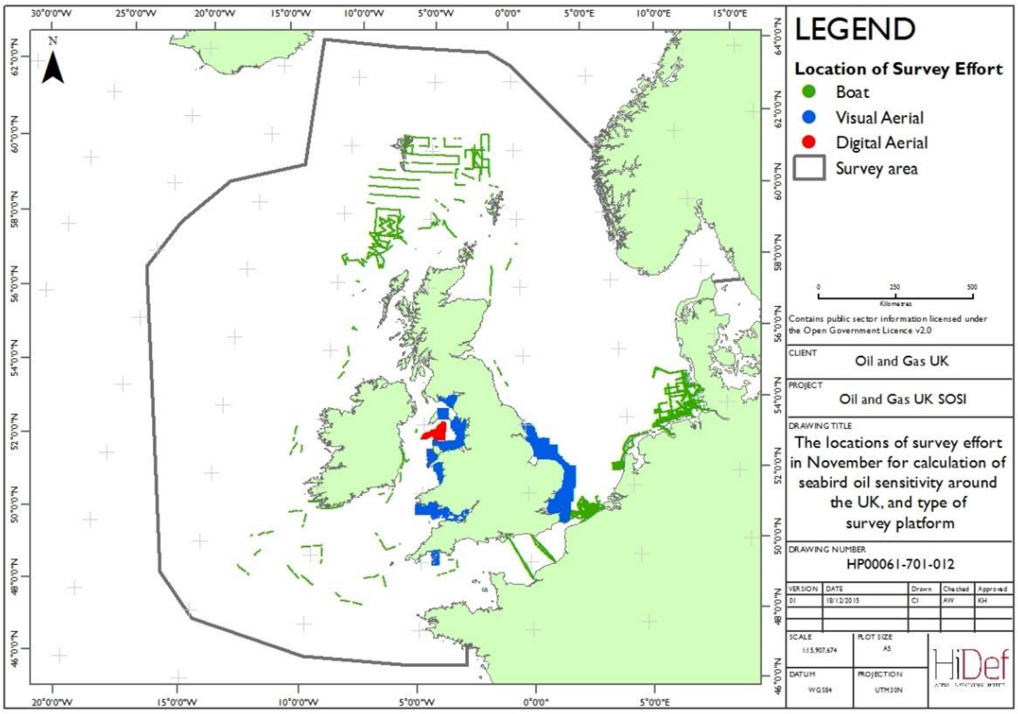
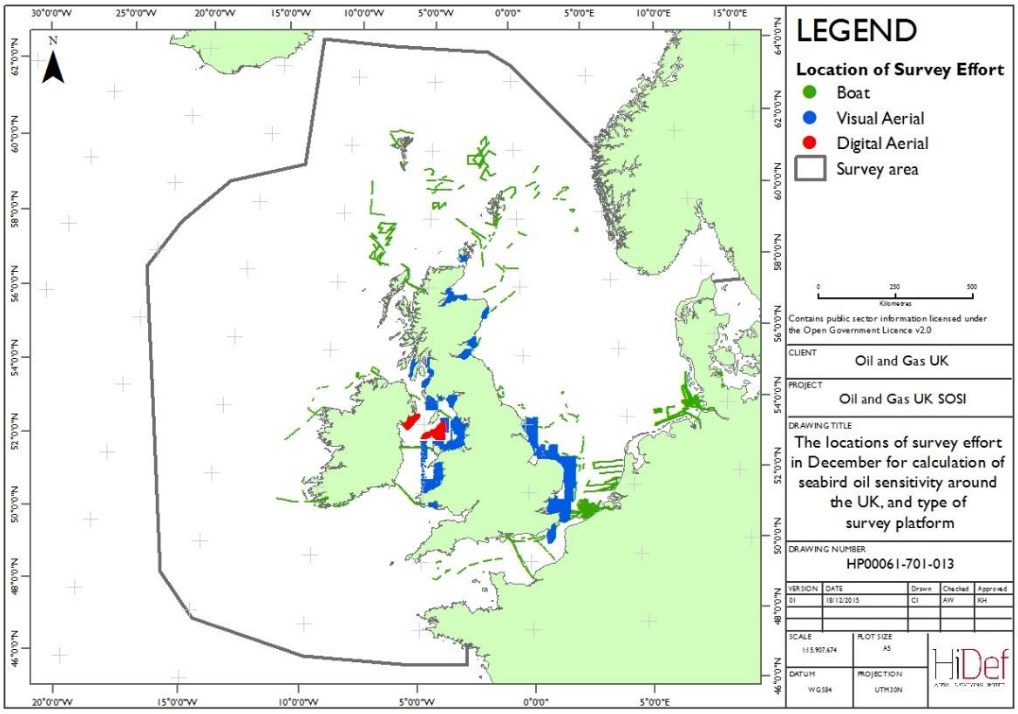


Figure 13 Location of survey effort in December for calculation of seabird oil sensitivity around the UK, and type of survey platform



3.2 Monthly summaries of oil sensitivity

66 For each month of the year, four maps are presented which display the summarised distribution of seabird concentrations that are most sensitive to oil pollution based upon a combination of their abundance and the susceptibility of the component seabird species to the effects of oil pollution. The values presented are the median, minimum and maximum of the smoothed SOSI scores in each Oil Licence Block. The median value represents the central point of the smoothed values calculated for any given block and represents the most likely assessment of seabird sensitivity to oil pollution. The minimum represents an index of the best-case scenario and the maximum represents an index of the worst-case scenario at any location. The minimum and the maximum should not be confused with lower and upper confidence limits to the data, because non-stochastic analysis methods were used which do result in estimates of error in the data

67 As well as the median, minimum and maximum SOSI scores, a map is provided that represents the confidence in the data. A low confidence index score arises because of a number of factors, but mainly because there is low survey effort in that Oil Licence Block; because there is no survey effort in that block and any sensitivity score was calculated by extrapolation from neighbouring blocks; or because at least some survey data used in the calculation did not record all species that were present during the survey.

68 Text is provided to accompany each set of monthly maps. The text is intended to provide an outline interpretation of the most important patterns contained in the maps, so are based mainly upon the maps showing the median SOSI scores. Where possible, references are provided where additional interpretation is necessary. Reference is made to inshore waterbirds, (typically the ducks, divers, grebes, cormorants, terns, black guillemot) and offshore seabirds such as fulmars, shearwaters, storm-petrels, gannets, skuas, gulls and auks).

69 Monthly maps of the smoothed indices of sensitivity of seabird concentrations to oil pollution derived from KDE are presented in Appendix E, Figure E1 to Figure E12. In general, although those maps show a wider geographical spread of sensitivity beyond the UKCS, they are quite difficult to interpret, mainly on the grounds that KDE works best when there are large amounts of data available to use within the width parameter at each predicted location. Consequently, even though steps were taken to minimise edge effects, where predictions within the width parameter are relying on too few data points to make a prediction of abundance at the edges of survey coverage. This leads to a 'blocked' appearance to the maps in most months apart from July (Figure E7 and August (Figure E8). In most months, coverage, and therefore the interpretability of the maps is best in the Irish Sea and in the southern North Sea.

3.3 Seabird oil sensitivity in January

70 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 14, 15 and 16 respectively. The confidence index as a measure of the data quality is presented in Figure 17.

71 In January, peak numbers of inshore waterbirds are found in the shallower waters of the southern North Sea, the Irish Sea and the sheltered waters around Scotland, particularly in the Firth of Forth and the Moray Firth, around Orkney and Shetland and the Outer Hebrides. These inshore waterbirds comprise common eiders *Somateria mollissima*, common scoter *Melanitta nigra*, red-throated divers *Gavia stellata* and great northern divers *G. immer*. These last two species are particularly sensitive to the effects of oil pollution because of the large amount of time they spend sitting on the sea, their relative scarceness and their high conservation status. Shags *Phalacrocorax aristotelis* and cormorants *Ph. carbo* are dispersed around the entire coastline of the UK during the winter months; the former is more likely to be encountered in open coastal areas than the later species.

72 Offshore seabirds' location at sea is largely unconstrained by visits to their nest sites in January. Species such as northern gannets *Morus bassanus* are most abundant in the UKCS off south-west England, and a high proportion of black-legged kittiwakes *Rissa tridactyla* will be dispersed across the North Atlantic. Of the more sensitive species to oil pollution, common guillemots were to be found mainly in the southern North Sea, but were present in small concentrations further north in parts of the central North Sea, to the west of Shetland, around the Minch and Western Isles and in the Irish Sea. Razorbills are usually found in the same places as common guillemots, but with a bias more to the south and west of the UKCS. Small numbers of Atlantic puffins *Fratercula arctica* spend the winter in central North Sea, but most at this time of the year are to be found dispersed across the North Atlantic or in waters south and west of the UKCS.

73 There were some large gaps in the survey effort around the UKCS, with the most important ones in the central North Sea, east of north-eastern England, and to the east of Orkney and Shetland. However, the quality of coverage at locations where a SOSI score is provided is generally poor to the north of the Irish Sea in the west and Flamborough Head at 54°N in the North Sea, with exceptions around the Firth of Forth and in the Moray Firth.

Figure 14 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in January

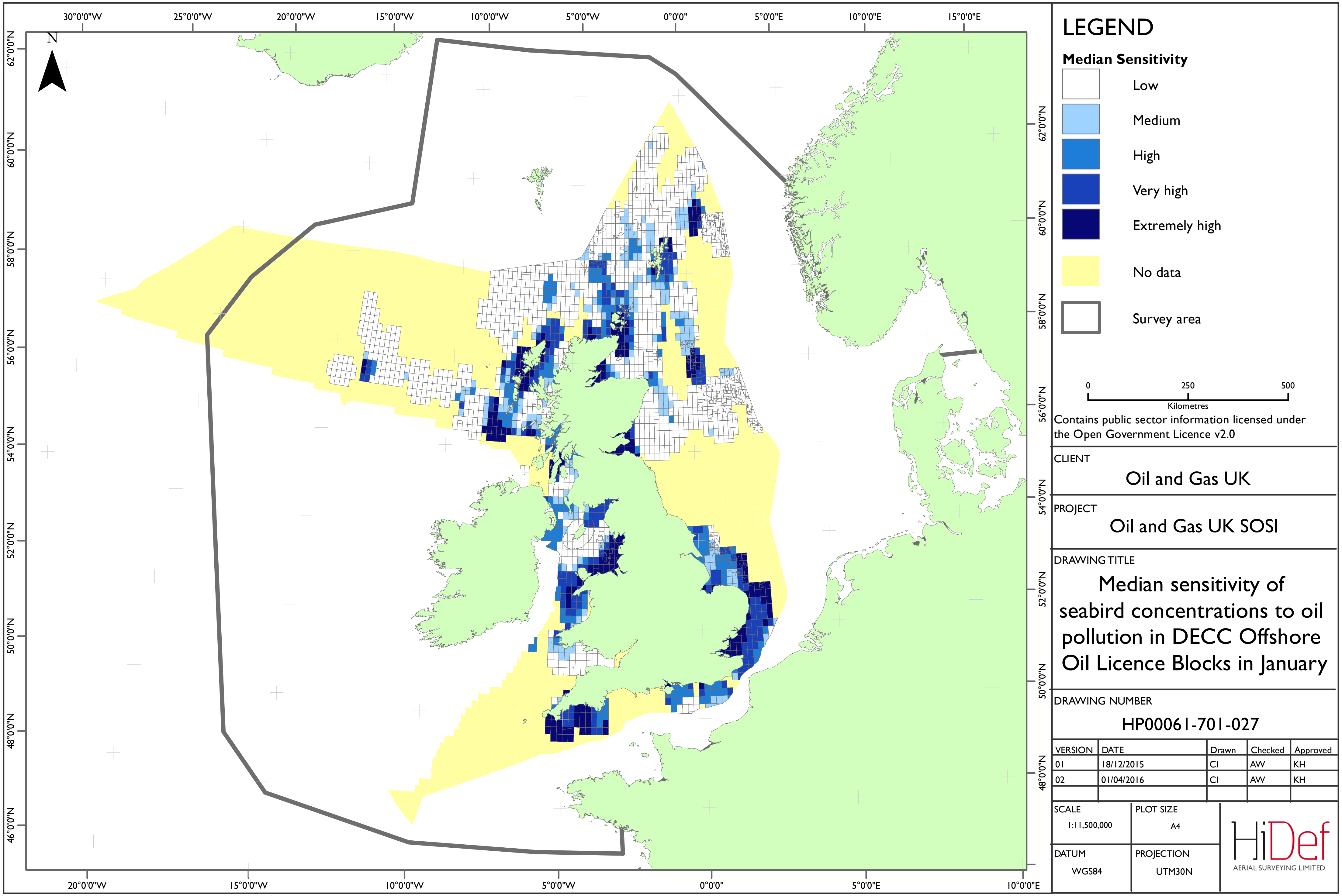
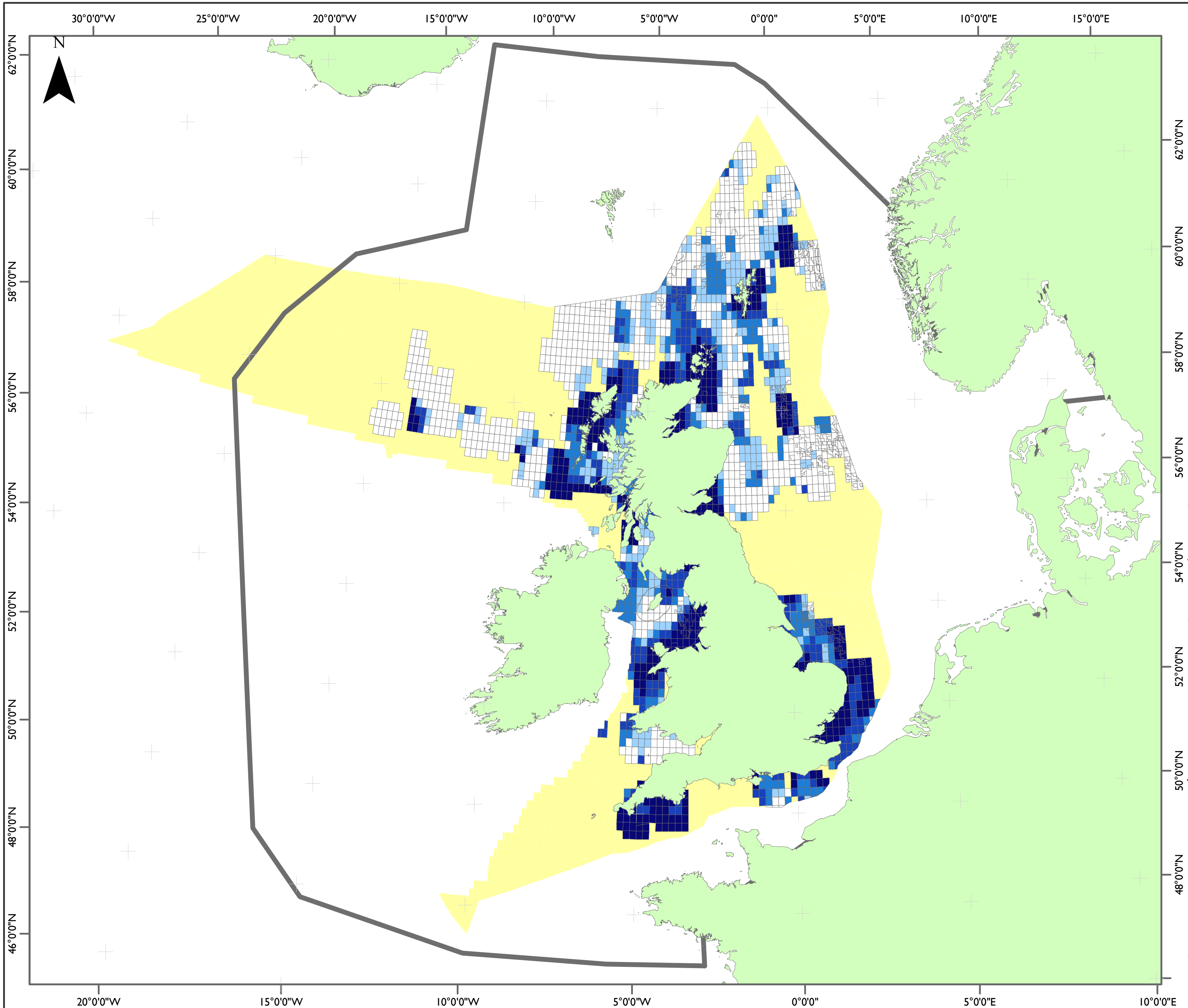


Figure 15 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in January



LEGEND

Maximum sensitivity

Low

Medium

High

Very high

Extremely high

No data

Survey area

0 250 500

Kilometres

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CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in January

DRAWING NUMBER

HP00061-701-028

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE 1:11,500,000

PLOT SIZE A4

DATUM WGS84

PROJECTION UTM30N

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Figure 16 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in January

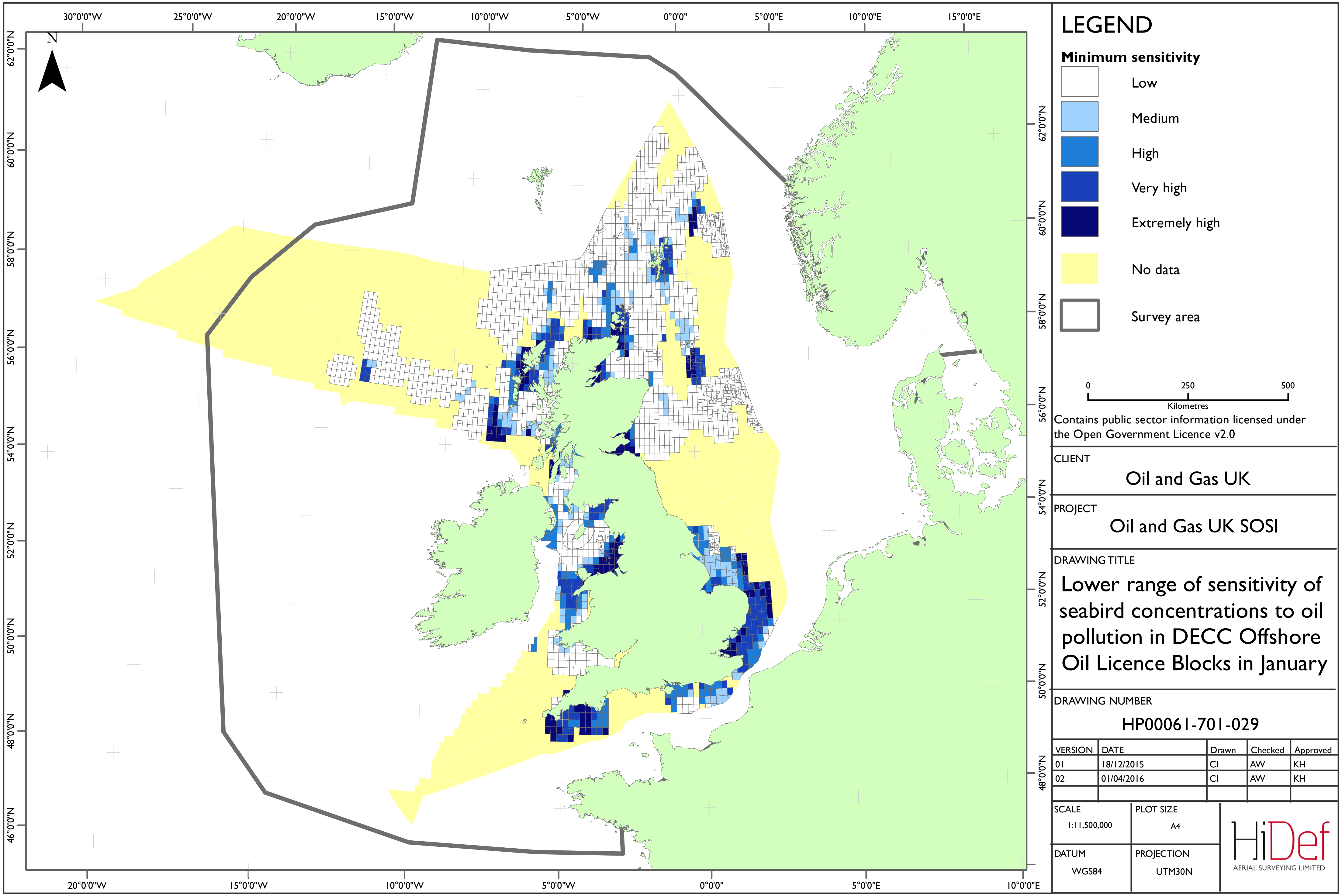
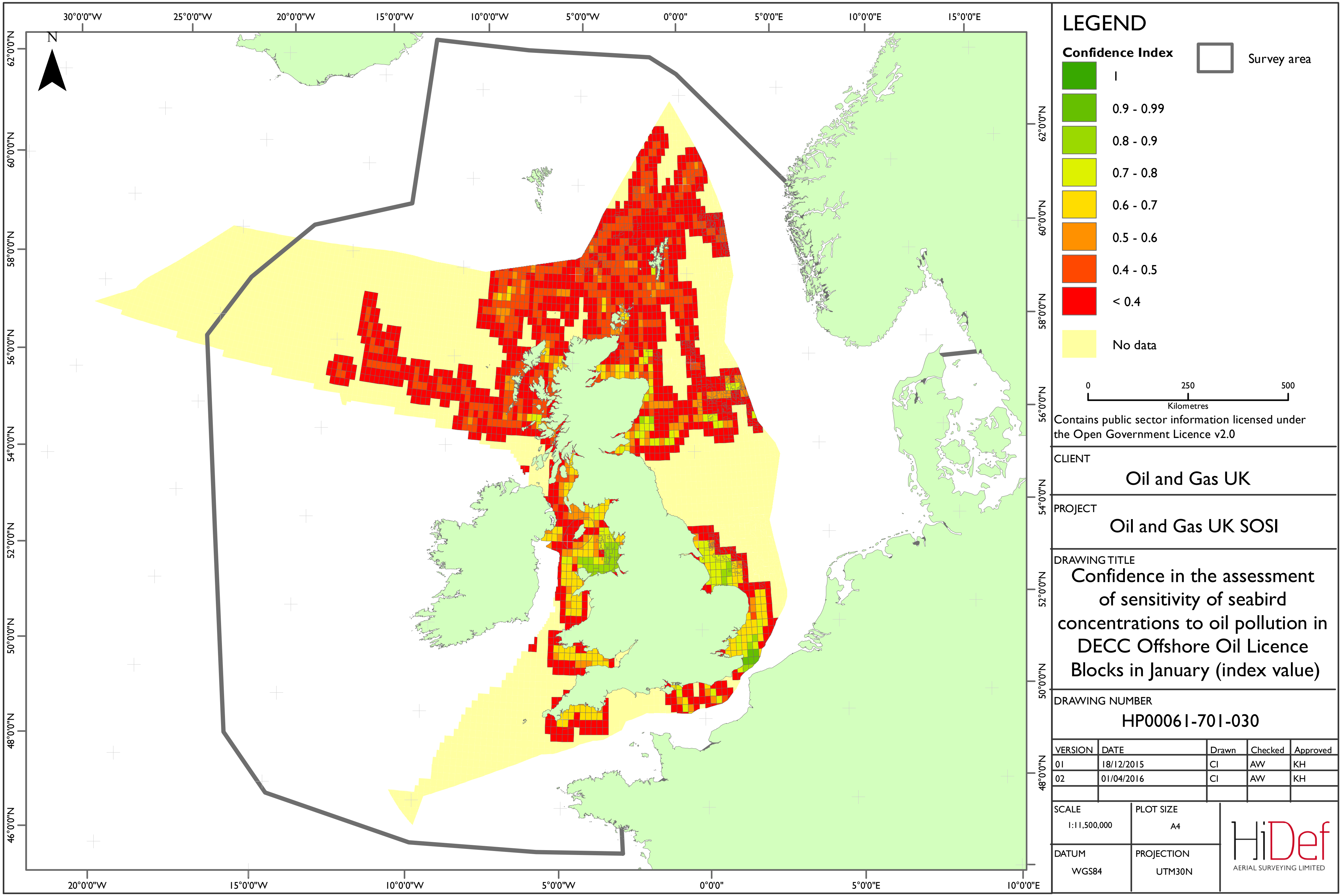


Figure 17 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in January (index value)



3.4 Seabird oil sensitivity in February

74 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 18, 19 and 20 respectively. The confidence index as a measure of the data quality is presented in Figure 21.

75 Inshore waterbirds continue to occur at peak numbers in the same locations as in January, with areas such as sheltered waters of Orkney and Shetland, the Moray Firth, Firth of Forth, Greater Wash, Outer Thames, Liverpool Bay and around the Western Isles of particular importance to the most sensitive species to oil pollution.

76 Offshore seabirds begin to return to their nest sites in the middle of February. These are located mainly around the north of the United Kingdom, especially in Orkney and Shetland and around the Western Isles. Visits to the nest sites will be interspersed with long trips of 100s of km to feeding sites around the colonies. The most sensitive species to oil pollution are the auks, which during February were found mostly in the southern North Sea, around Orkney and Shetland, in the outer Moray Firth, around the west of Scotland and in parts of south-west England around Cornwall and South Devon.

77 Coverage in February is the best of any in the winter period, mainly on account of surveys carried out on International Bottom Trawl Surveys ("IBTS"). The most significant gaps in coverage were present to the east of north-eastern England, to the north and north-west of Shetland and north-west of Orkney. The confidence indices (Figure 21) in areas with coverage are variable but relatively high in many parts of the central North Sea compared to other months, and remain high in the Irish Sea and around south-eastern England. The confidence indices are low close to the median line to the north and west of Orkney and Shetland and around the Western Isles.

Figure 18 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in February

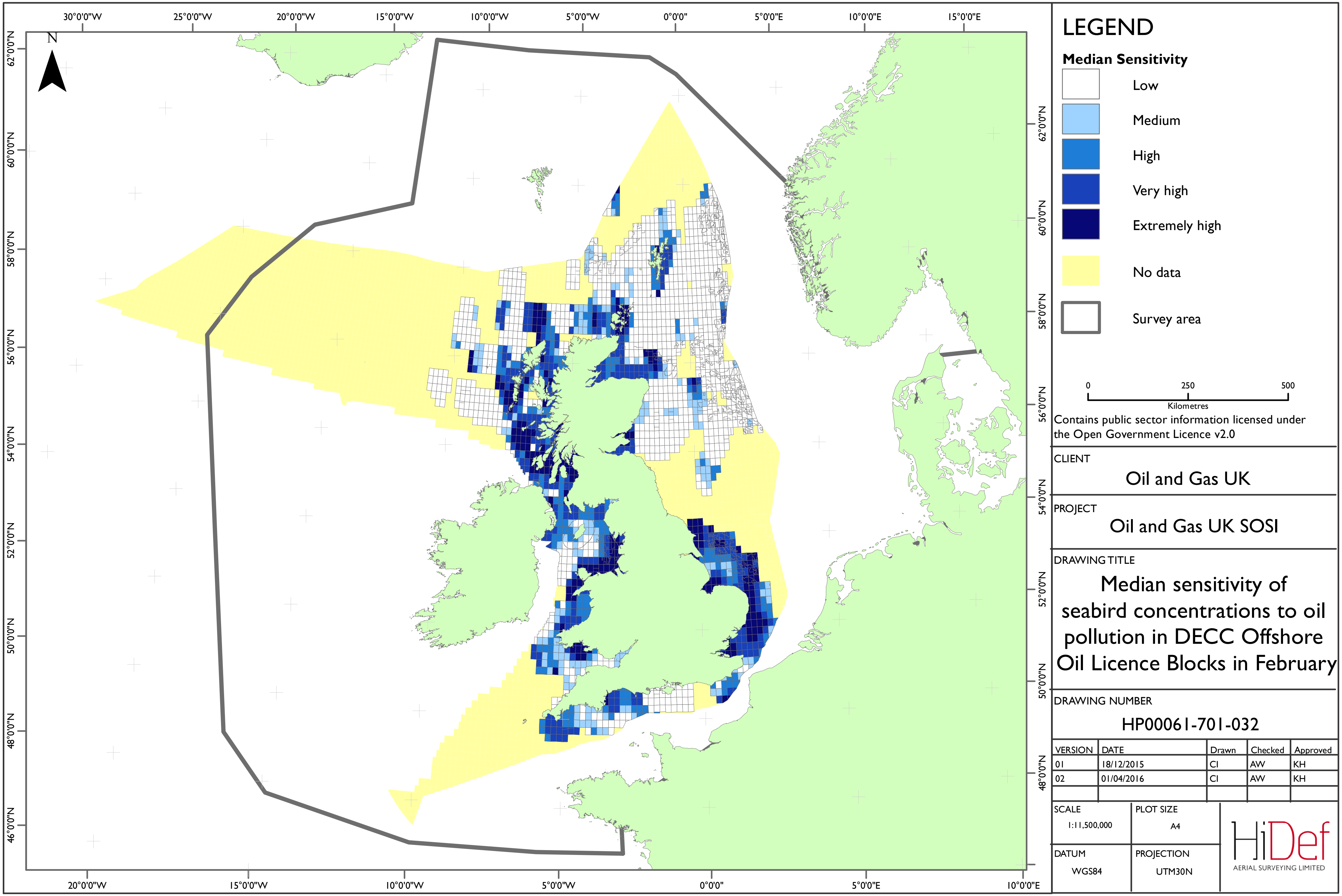
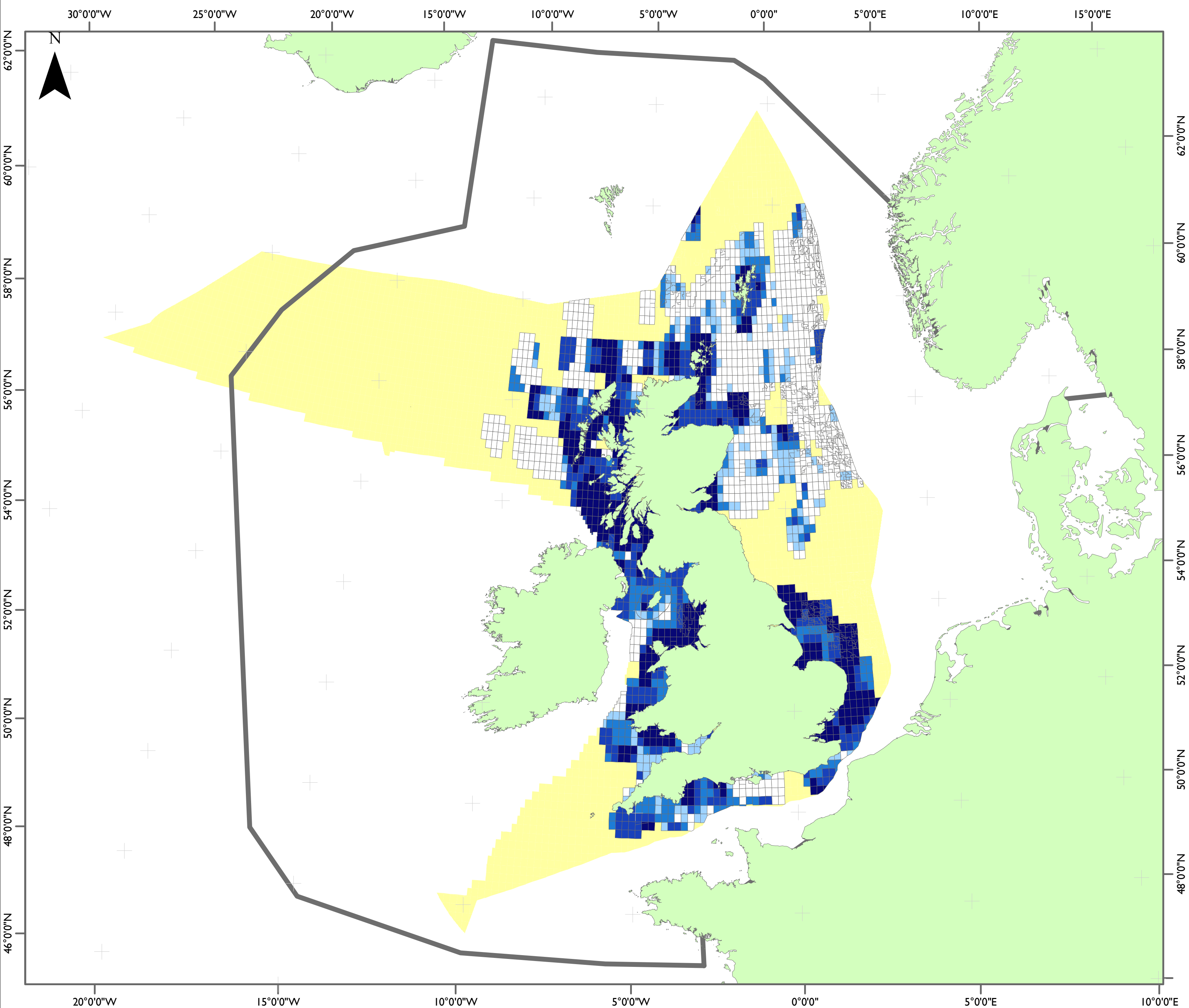


Figure 19 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in February



LEGEND

Maximum sensitivity

Low

Medium

High

Very high

Extremely high

No data

Survey area

0 250 500

Kilometres

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CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in February

DRAWING NUMBER

HP00061-701-033

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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Figure 20 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in February

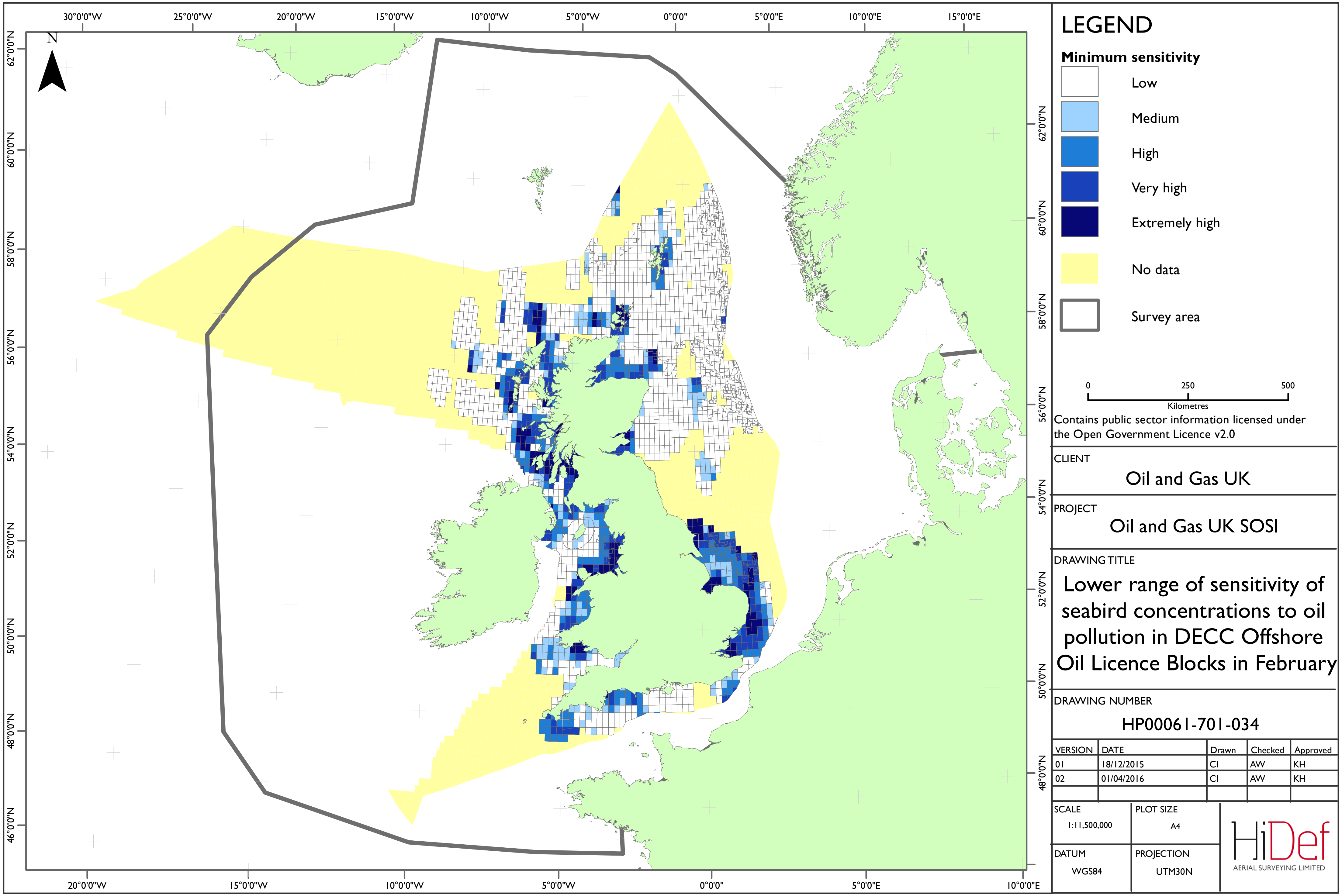
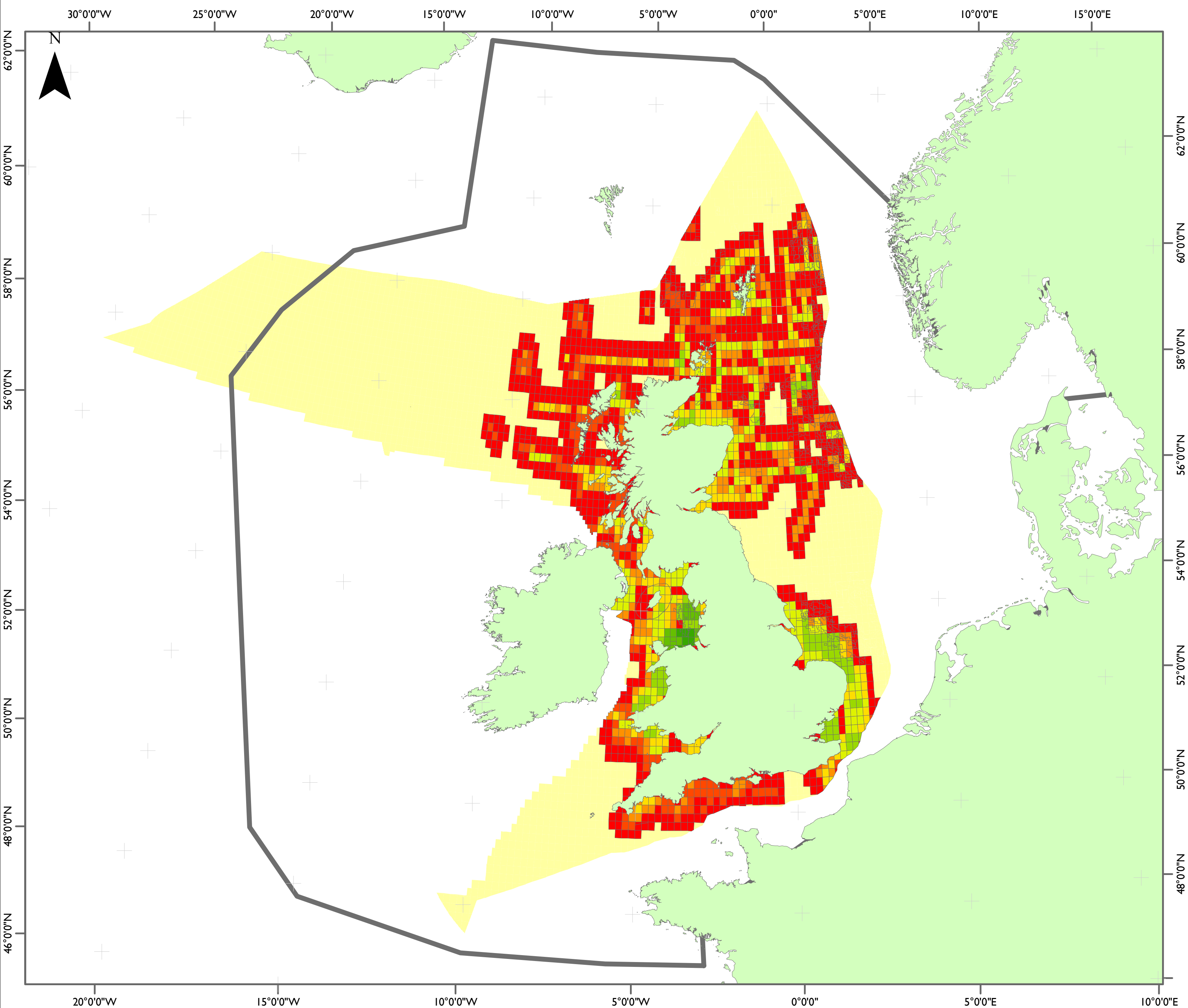


Figure 21 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in February (index value)



LEGEND

Confidence Index

	1
	0.9 - 0.99
	0.8 - 0.9
	0.7 - 0.8
	0.6 - 0.7
	0.5 - 0.6
	0.4 - 0.5
	< 0.4
	No data

Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in February (index value)

DRAWING NUMBER
HP00061-701-035

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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3.5 Seabird oil sensitivity in March

78 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 22, 23 and 24 respectively. The confidence index as a measure of the data quality is presented in Figure 25.

79 Most inshore waterbirds begin to disperse from their traditional wintering areas, and the sensitivity of the seabird concentrations in places such as the outer Wash, outer Thames, Irish Sea, Moray Firth, Firth of Forth and Orkney and Shetland is high or very high. Species such as common scoter start to return to breeding sites in northern Russia, while common eider return to nest in sheltered coastal waters around northern Scotland. Red-throated divers start to return to nest sites close to the coast in northern Scotland, but some, which are likely to be nesting in Greenland, start a partial feather moult at staging locations, such as close to the coast in north-eastern Scotland. Great northern divers begin a full moult of primary and secondary flight feathers and become flightless for a period beginning in March. This species is particularly sensitive to oil pollution at this time of the year in prime locations in Orkney, Shetland, around the Western Isles, Isle of Skye and neighbouring sea-lochs and around the Argyll peninsula. Shags and cormorants start to return to their colonies during March too. Many cormorants nest at inland sites and do not feed at sea during the summer, whereas shags breed mostly around the north and west of the UK. Black guillemots *Cepphus grille* return to their nest sites during March and can be found in highest numbers around the north of Scotland, but especially in Orkney and Shetland.

80 The attendance of offshore seabirds at their nest sites becomes more frequent, and birds in attendance make greater use of feeding areas at sea around their colonies. Areas holding seabird concentrations with the highest sensitivity to oil pollution were found around Orkney and Shetland, and in patches in the northern North Sea, off Northumberland, around the Dogger Bank, in the southern North Sea, around Devon and Cornwall and south-west Wales.

81 Coverage in the UKCS was patchy, with a number of small gaps in the central North Sea, to the west of Orkney and Shetland and north of Shetland. Coverage was also poor in the English Channel and around south-western England. The confidence index scores were low in March, with the exceptions in south-east England, the Irish Sea, around Northumberland, and around the east and west mainland of Scotland.

Figure 22 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March

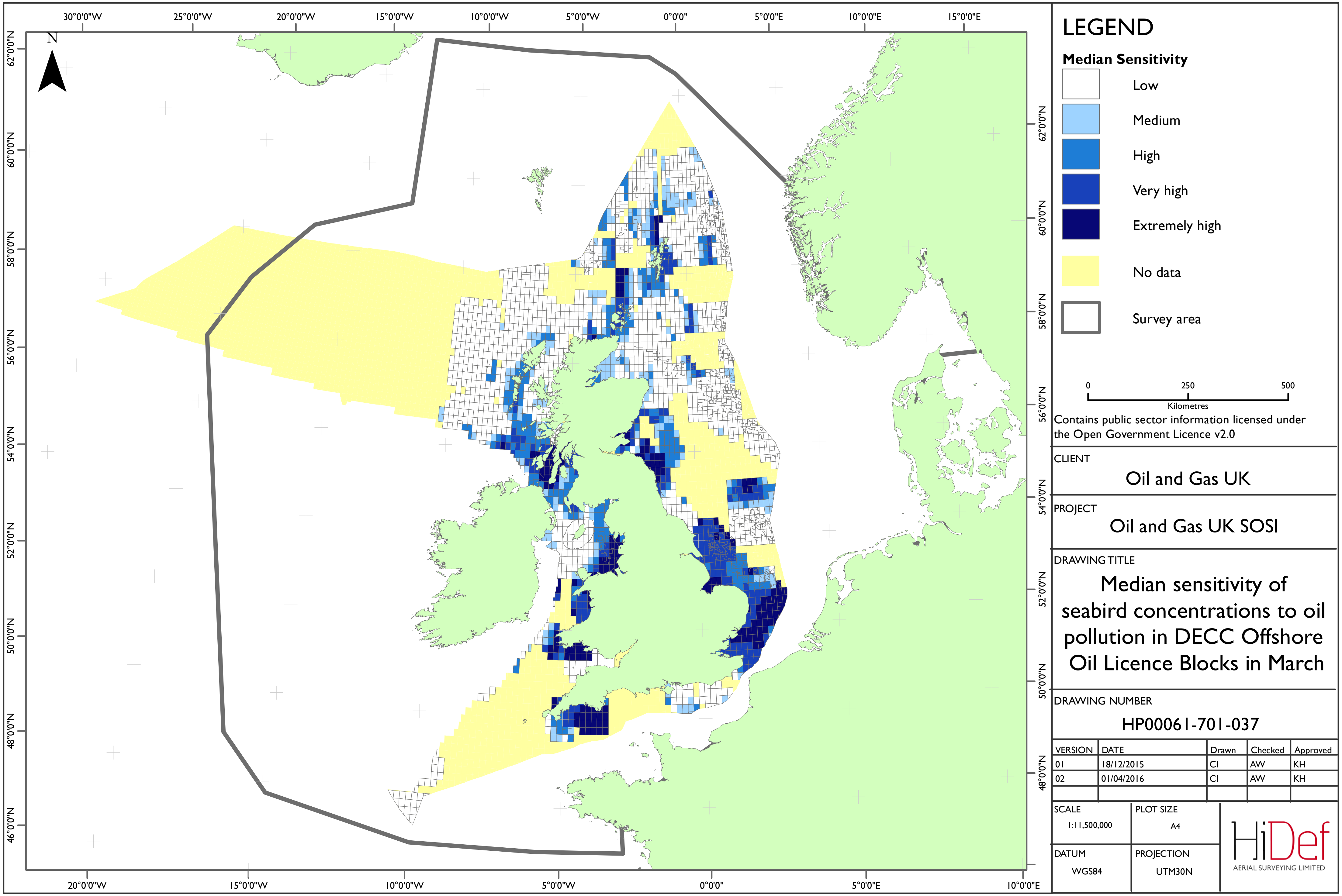
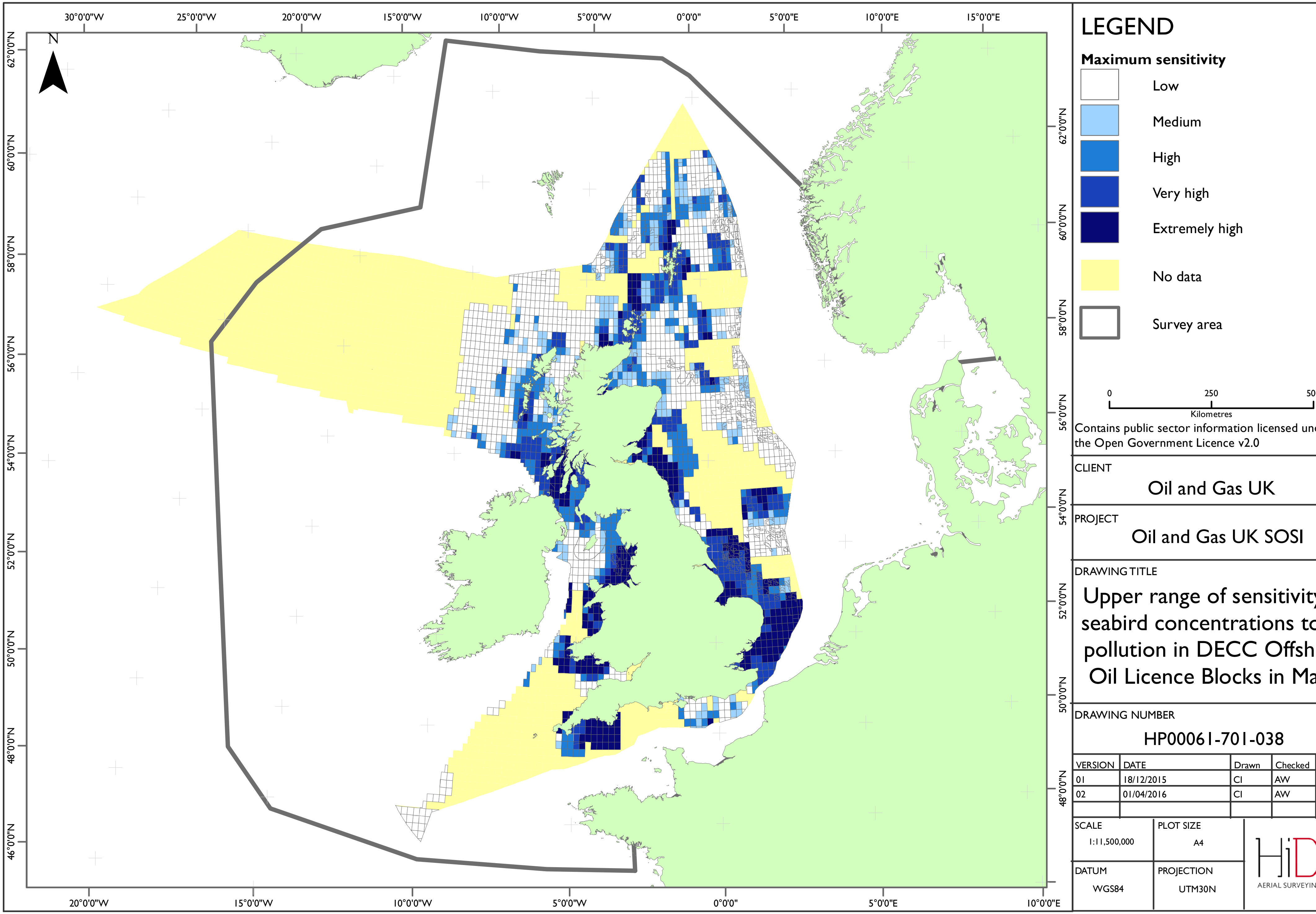


Figure 23 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March



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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March

DRAWING NUMBER
HP00061-701-038

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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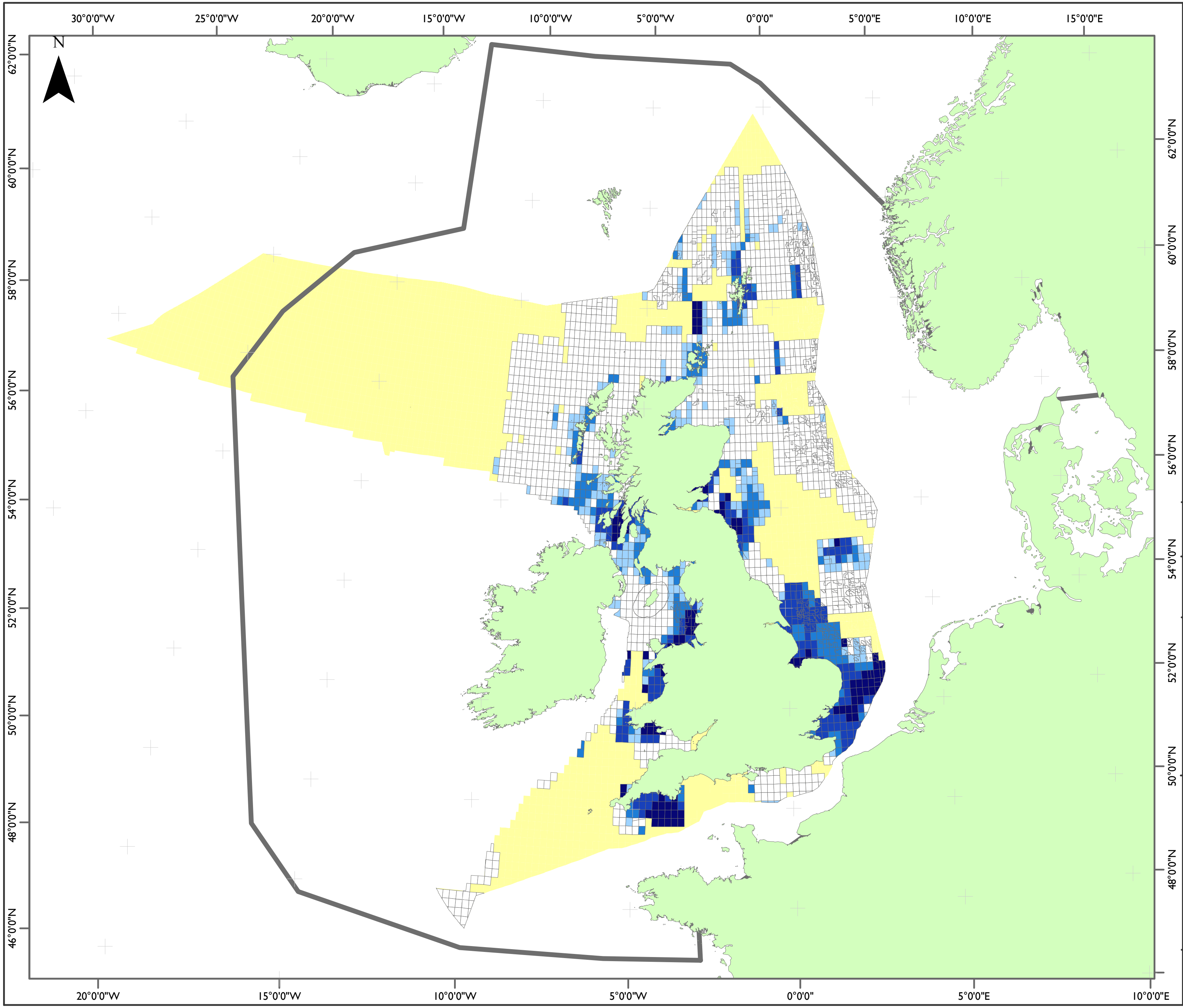
Figure 24 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March



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CLIENT	Oil and Gas UK
PROJECT	Oil and Gas UK SOSI
DRAWING TITLE	Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March
DRAWING NUMBER	HP00061-701-039

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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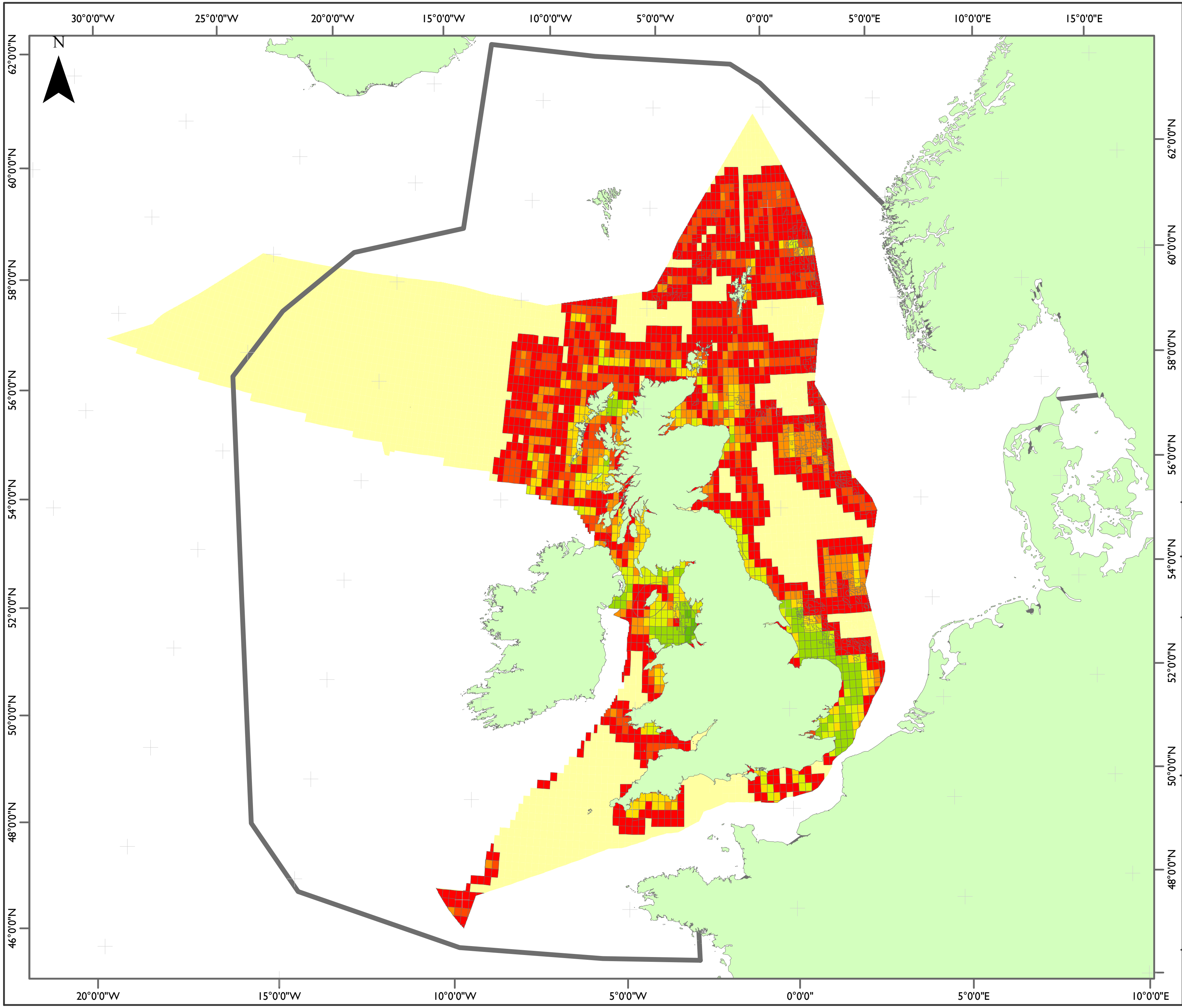
Figure 25 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March (index value)



LEGEND

Confidence Index

- 1
- 0.9 - 0.99
- 0.8 - 0.9
- 0.7 - 0.8
- 0.6 - 0.7
- 0.5 - 0.6
- 0.4 - 0.5
- < 0.4
- No data

Survey area

0 250 500
Kilometres

CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in March (index value)

DRAWING NUMBER
HP00061-701-040

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE 1:11,500,000
PLOT SIZE A4
DATUM WGS84
PROJECTION UTM30N

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3.6 Seabird oil sensitivity in April

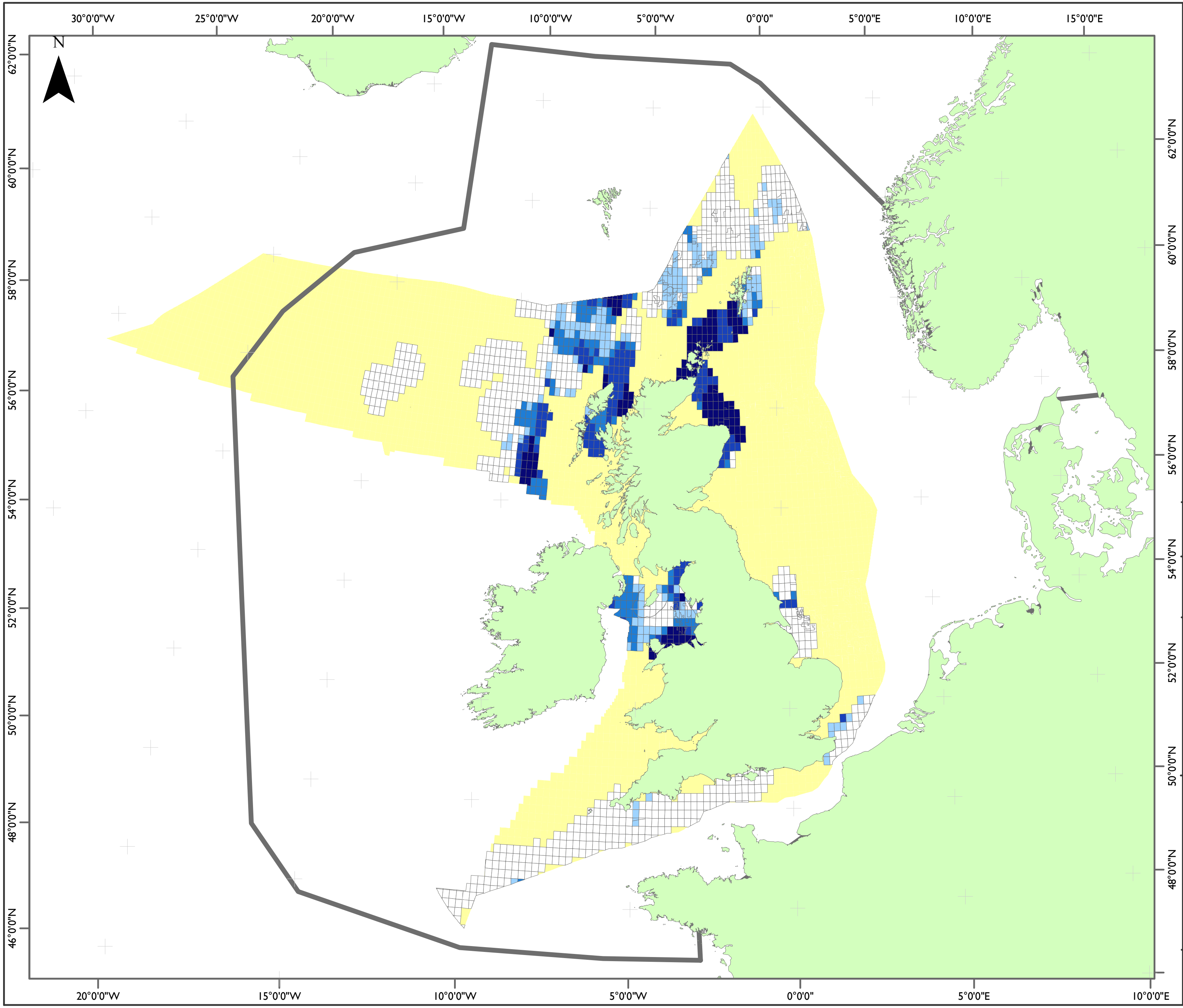
82 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 26, 27 and 28 respectively. The confidence index as a measure of the data quality is presented in Figure 29.

83 Inshore waterbirds mainly have dispersed from their wintering areas in the outer Thames, outer Wash and the Irish Sea. These species are represented mainly in April of pre-breeding common eiders in sheltered areas around the northern Scotland and north-eastern England, nesting red-throated divers around the north of Scotland including Orkney and Shetland, and moulting great northern divers in sheltered waters around the north and west of Scotland. Red-throated divers in partial moult in north-eastern Scotland reach their peak in this month. Black guillemots are present at their nesting areas around the north of Scotland, especially in Orkney and Shetland.

84 Offshore seabirds are in full attendance at their colonies in April, but still make occasional long trips to offshore foraging locations. Areas with highly sensitive concentrations of seabirds to oil pollution were found in the outer Moray Firth, around Orkney and in the Fair Isle Channel, to the north of the Western Isles near to the median line, to the south-west of the Western Isles and in the Minch.

85 Coverage in April was particularly poor, with extensive gaps in offshore areas of the North Sea, west of Shetland and Orkney, around western Scotland and around west Wales. The confidence indices for areas with coverage are also low.

Figure 26 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April



LEGEND

Median Sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April

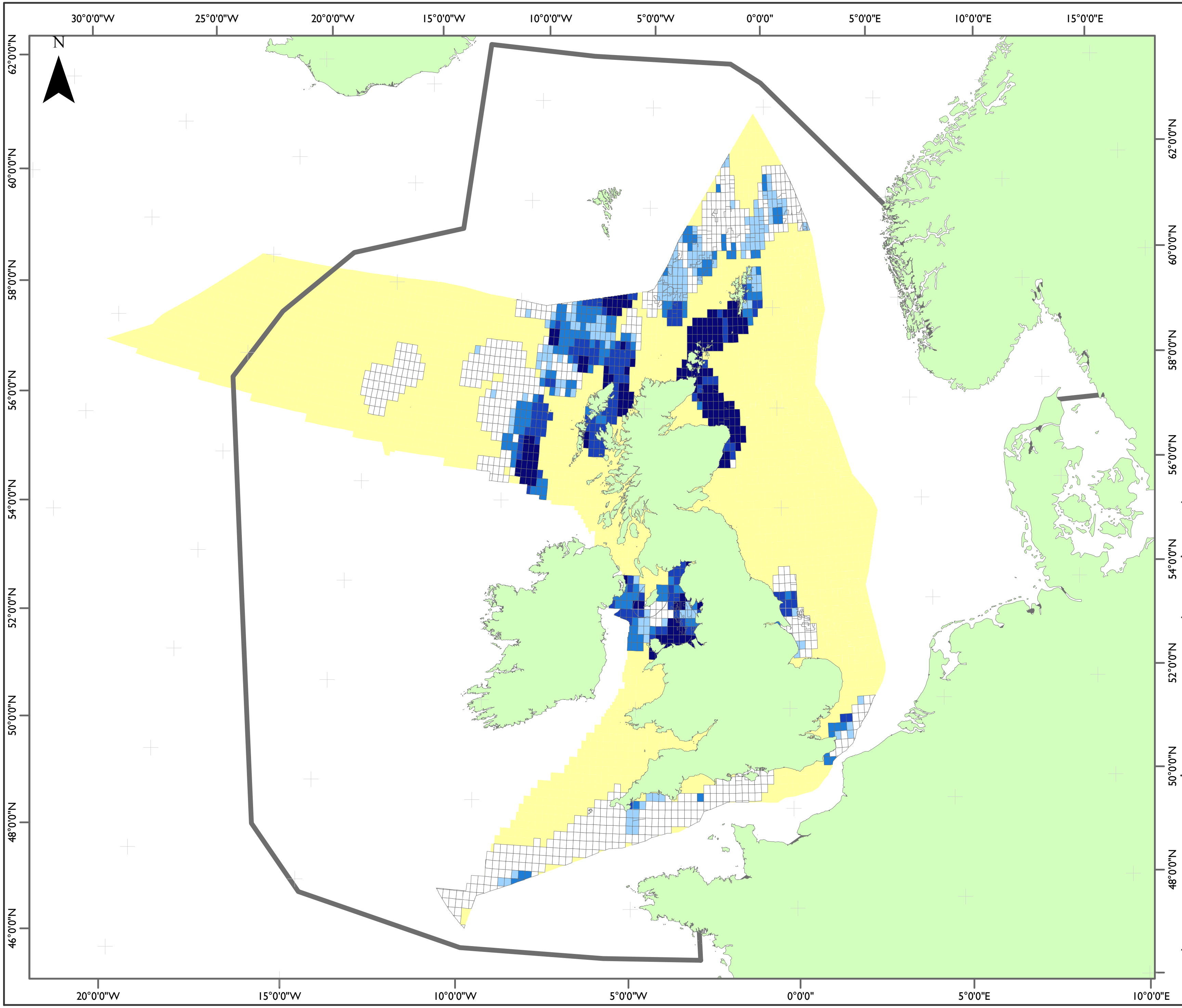
DRAWING NUMBER
HP00061-701-042

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 27 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April



LEGEND

Maximum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April

DRAWING NUMBER
HP00061-701-043

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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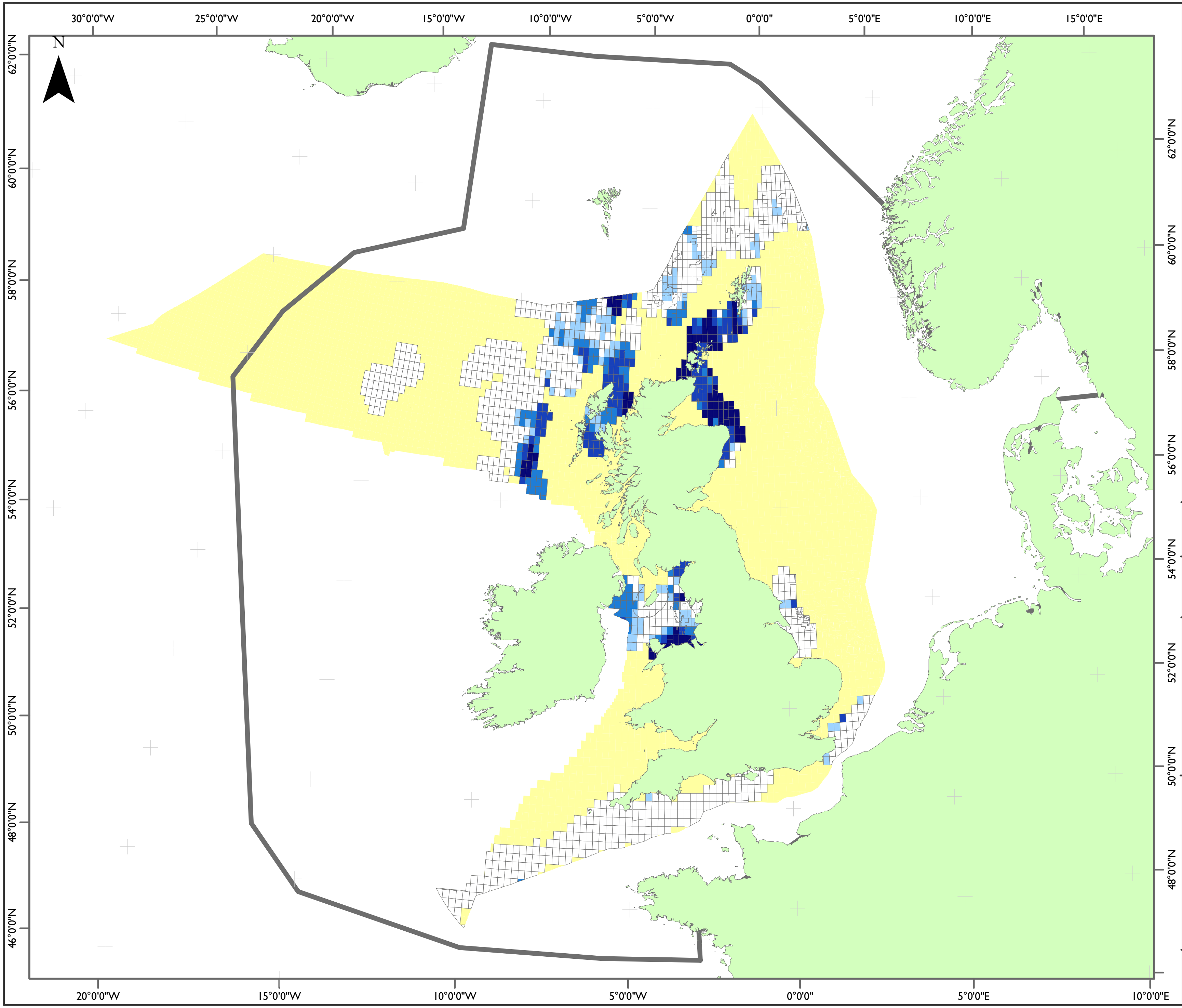
Figure 28 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April



LEGEND

Minimum sensitivity

Low

Medium

High

Very high

Extremely high

No data

Survey area

0 250 500

Kilometres

CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April

DRAWING NUMBER

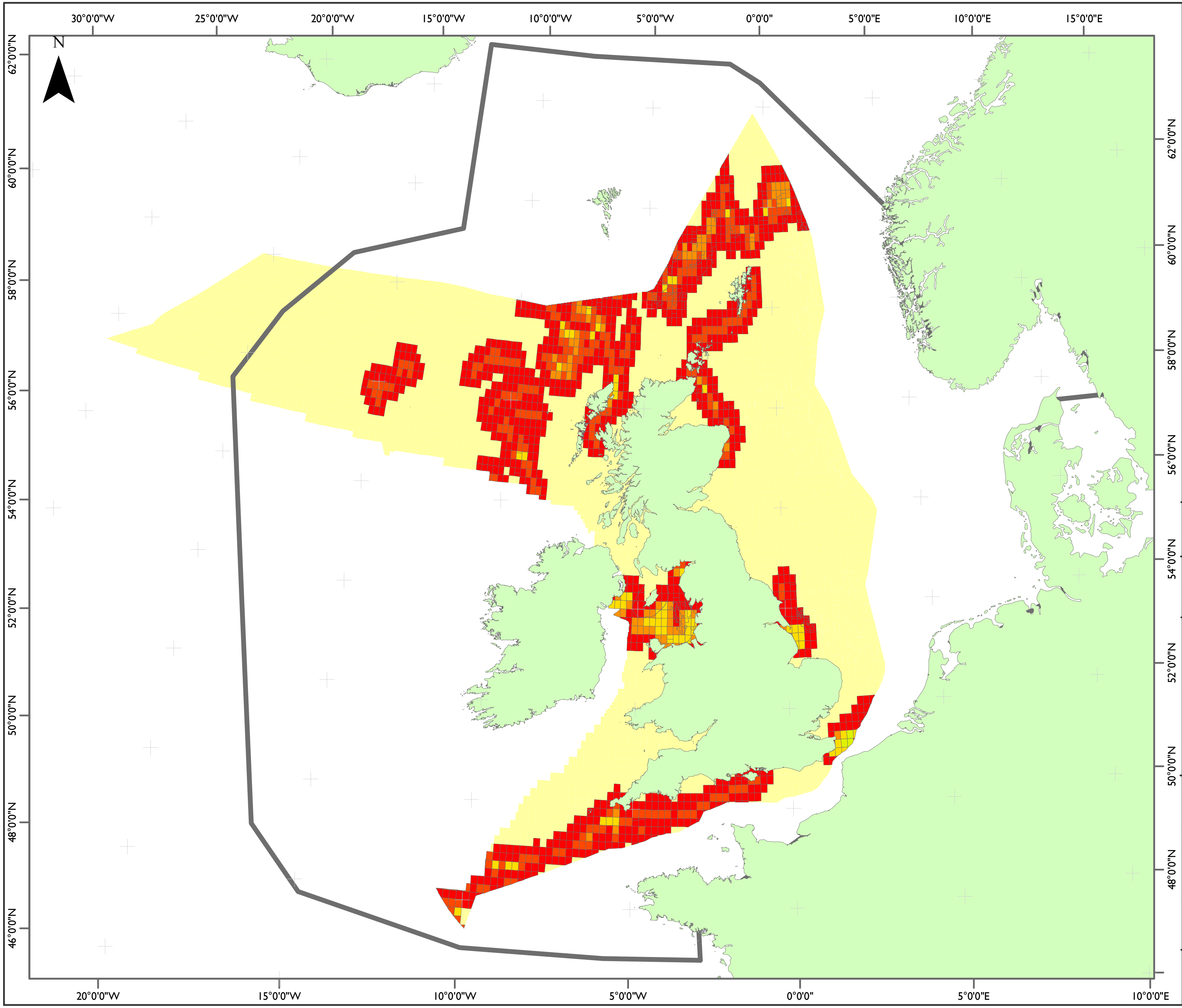
HP00061-701-044

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef AERIAL SURVEYING LIMITED

Figure 29 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April (index value)



LEGEND

Confidence Index

- 1
- 0.9 - 0.99
- 0.8 - 0.9
- 0.7 - 0.8
- 0.6 - 0.7
- 0.5 - 0.6
- 0.4 - 0.5
- < 0.4
- No data

Survey area

0 250 500
Kilometres

CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in April (index value)

DRAWING NUMBER
HP00061-701-045

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

3.7 Seabird oil sensitivity in May

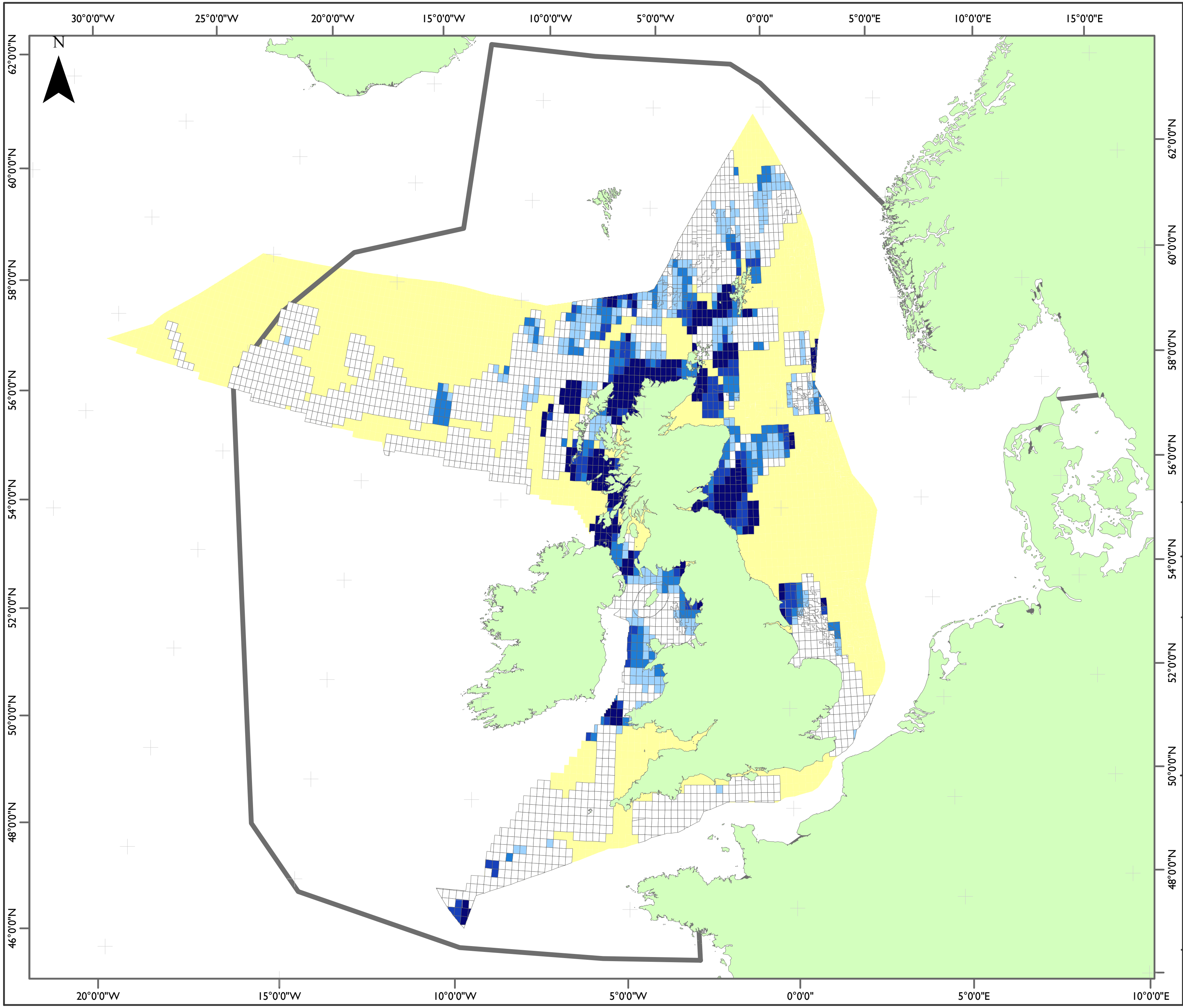
86 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 30, 31 and 32 respectively. The confidence index as a measure of the data quality is presented in Figure 33.

87 The majority of inshore waterbirds in May are common eiders, red-throated divers, European shags and black guillemots around the breeding areas around the North of Scotland, with the first and third of these species with a more southerly distribution than the other species. Some of the concentrations of moulting great northern divers remain in sheltered locations around Orkney and Shetland and around the north and west of mainland Scotland.

88 Offshore seabirds are also to be found around the nesting sites, mainly in the northern and western parts of the UK. All nesting seabird species will have started to incubate eggs in May which means a portion of the overall population will not be at sea, and also limits the distance that some species can travel to forage. Most of the sensitive concentrations of seabirds to oil pollution were found around the largest seabird colonies, such as in the Firth of Forth, Flamborough Head, the outer Moray Firth, in the Fair Isle Channel, to the east of Orkney, around the north of mainland Scotland and in the Minch, around St Kilda, in the Sea of Hebrides, the North Channel and around south-west Wales. An offshore aggregation was found to the north of the Western Isles around the median line.

89 There were significant gaps in coverage to the east of Shetland, Orkney and England in the central North Sea and to the far north of Shetland. There were also some gaps in the Bristol Channel and in the Moray Firth. The confidence index scores for the areas with coverage are low in virtually all regions, with the exception of the Irish Sea, and the Outer Wash.

Figure 30 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May



CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May

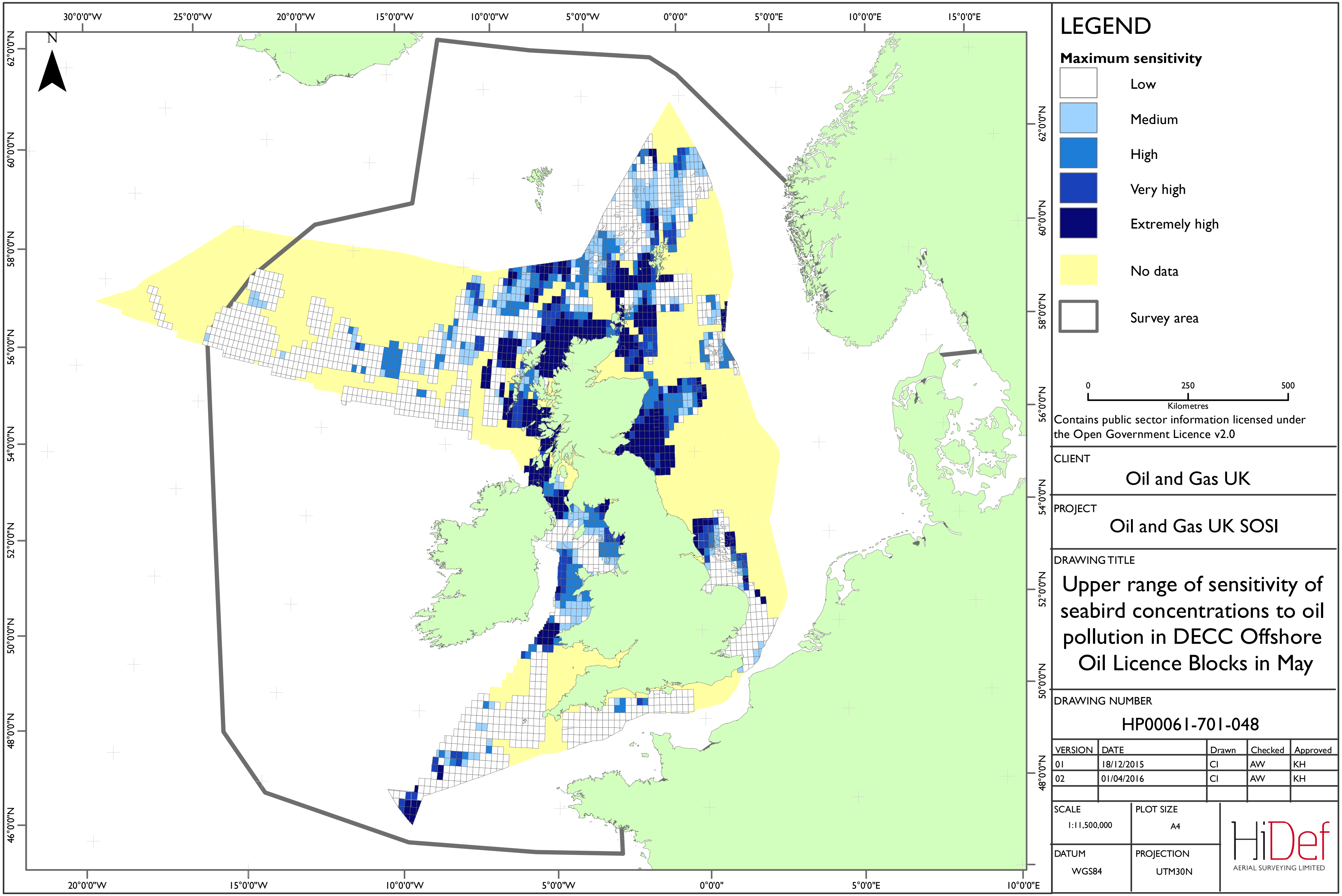
DRAWING NUMBER
HP00061-701-047

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 31 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May



CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May

DRAWING NUMBER
HP00061-701-048

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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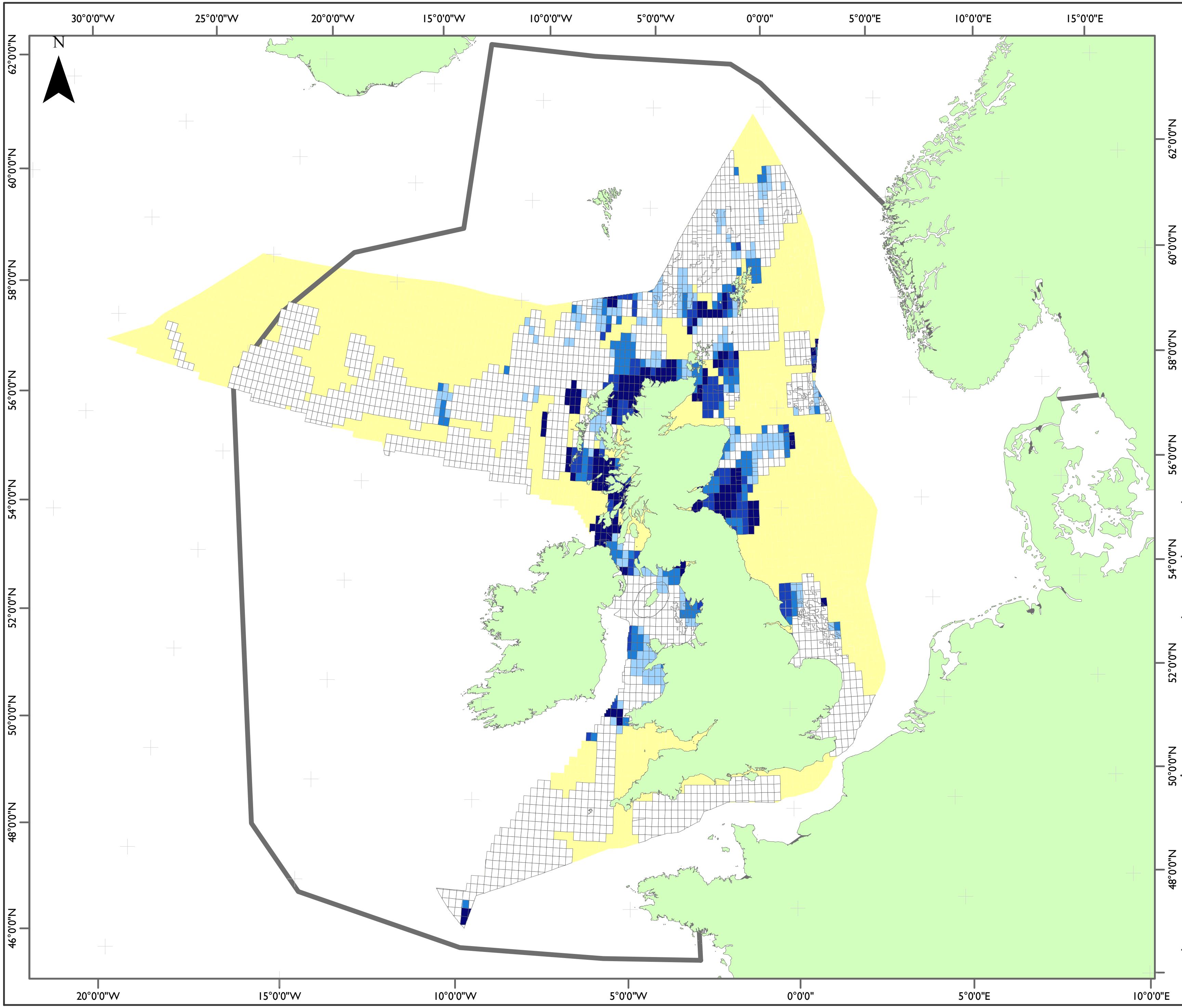
Figure 32 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May



LEGEND

Minimum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May

DRAWING NUMBER
HP00061-701-049

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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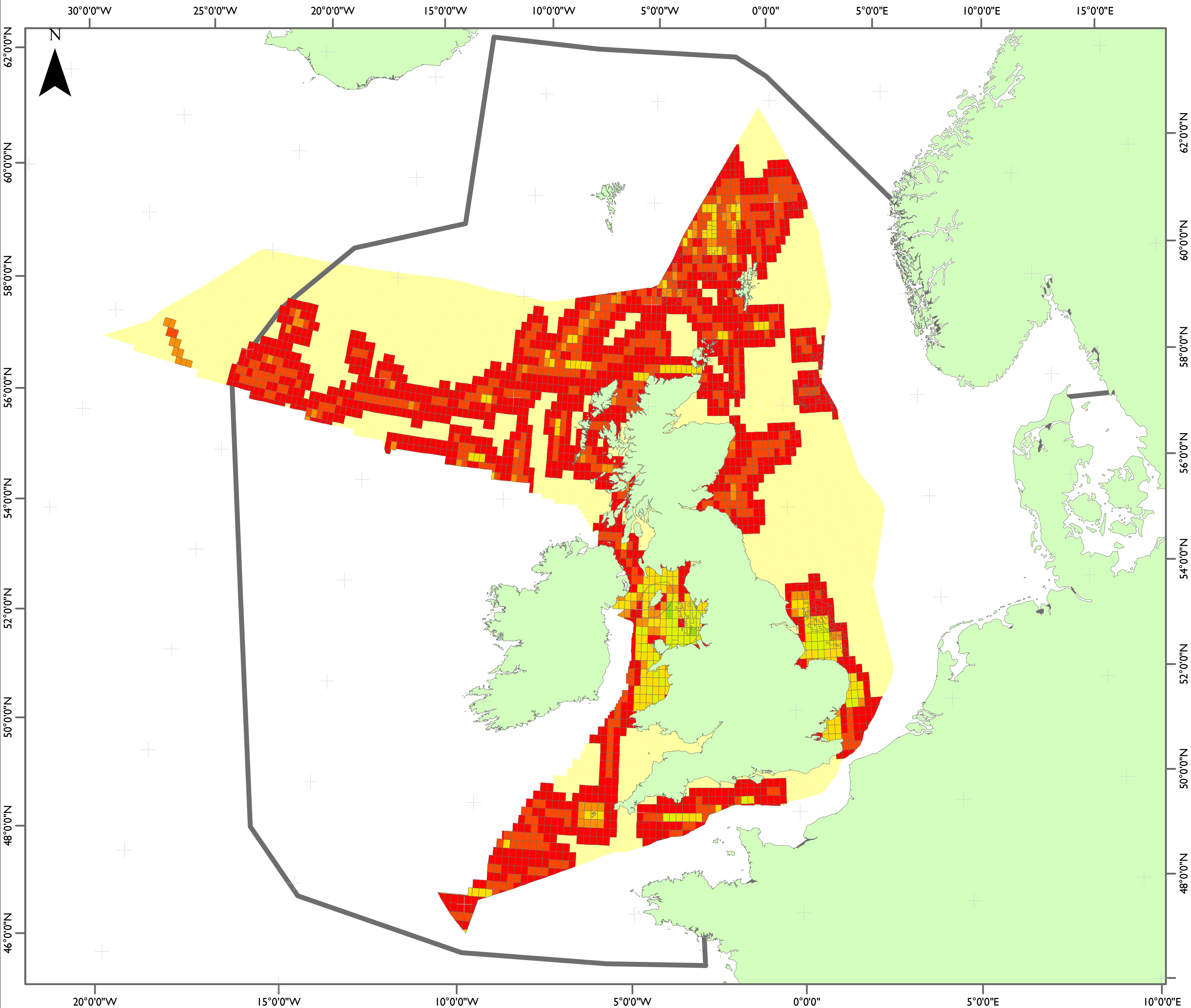
Figure 33 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May (index value)



LEGEND

Confidence Index

	1
	0.9 - 0.99
	0.8 - 0.9
	0.7 - 0.8
	0.6 - 0.7
	0.5 - 0.6
	0.4 - 0.5
	< 0.4
	No data

Survey area

0 250 500
Kilometres

CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in May (index value)

DRAWING NUMBER
HP00061-701-050

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE 1:11,500,000
PLOT SIZE A4
DATUM WGS84
PROJECTION UTM30N

HiDef AERIAL SURVEYING LIMITED

3.8 Seabird oil sensitivity in June

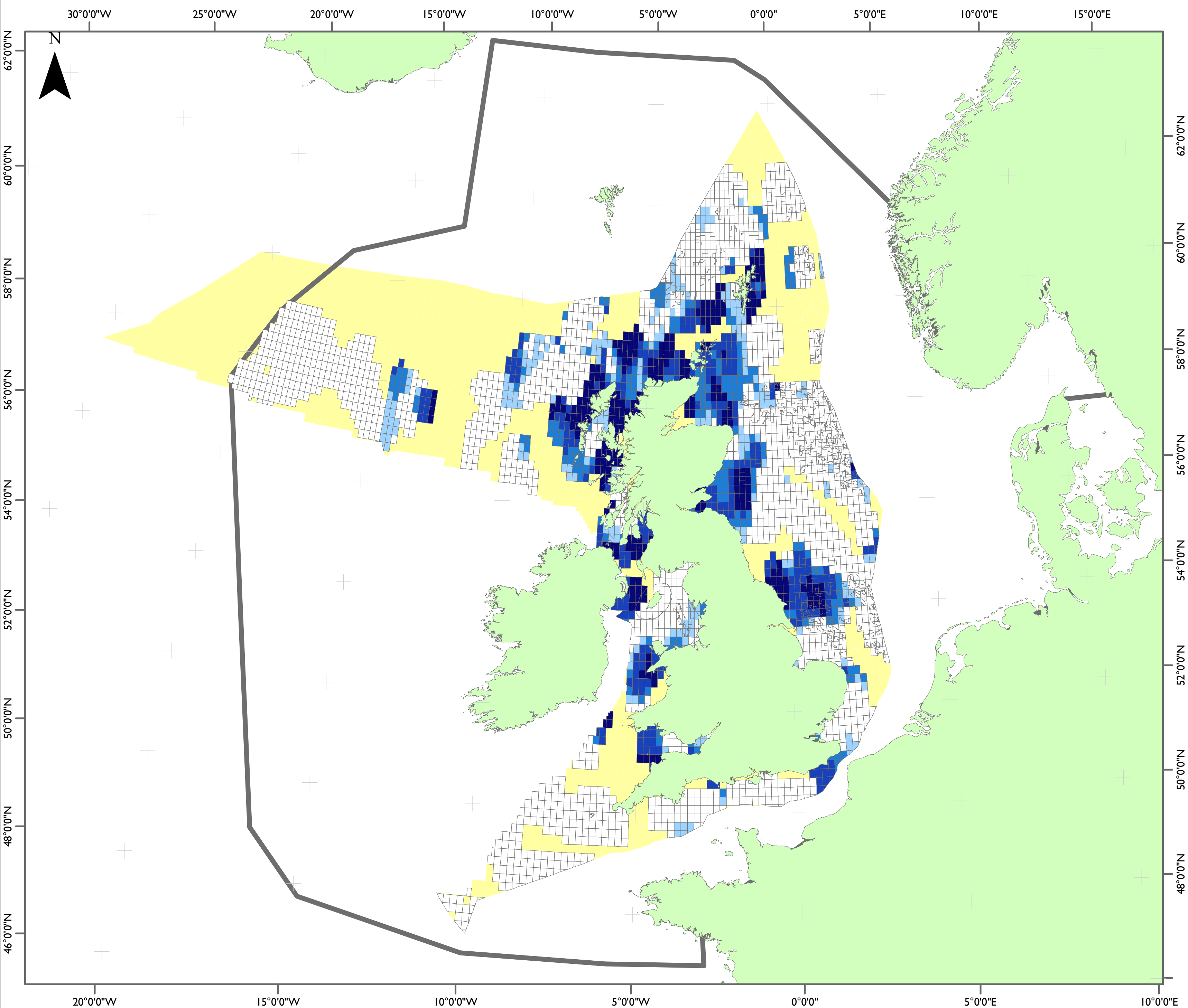
90 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 34, 35 and 36 respectively. The confidence index as a measure of the data quality is presented in Figure 37.

91 The majority of inshore waterbirds in June are common eiders, red-throated divers, European shags and black guillemots around the breeding areas around the North of Scotland, with the first and third of these species with a more southerly distribution than the other species.

92 Offshore seabirds are all nesting in June, and will have started to brood and feed chicks at their colonies. Because of the high attendance rates at the colony, the numbers of adults at sea tend to be relatively low compared to other times of the year. Non-breeding immature birds tend to return to their natal colony at this time of the year. The main sensitive concentrations of seabirds to oil pollution were found mostly close to land around the northern half of Britain. Of particular significance were concentrations around Flamborough Head, the outer Forth, the outer Moray Firth, around Orkney and Shetland, the north of Scotland, around the Western Isles, the Minch, Sea of Hebrides, the North Channel and Firth of Clyde, the northern Irish Sea, and around west Wales. There were few sensitive concentrations to oil pollution in the central North Sea or offshore in general, although smaller concentrations were found on the Rockall Bank and around the shelf edge.

93 Gaps in coverage in June were mostly small and confined to the area to the east of Orkney and Shetland in the central North Sea, and to the far north of Shetland. As in other months the confidence index scores for areas with coverage are generally low. The main exceptions were around the outer Moray Firth and the Firth of Forth, around south-eastern England, in the Irish Sea, in the Bristol Channel and around the Isles of Scilly.

Figure 34 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June



LEGEND

Median Sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June

DRAWING NUMBER
HP00061-701-052

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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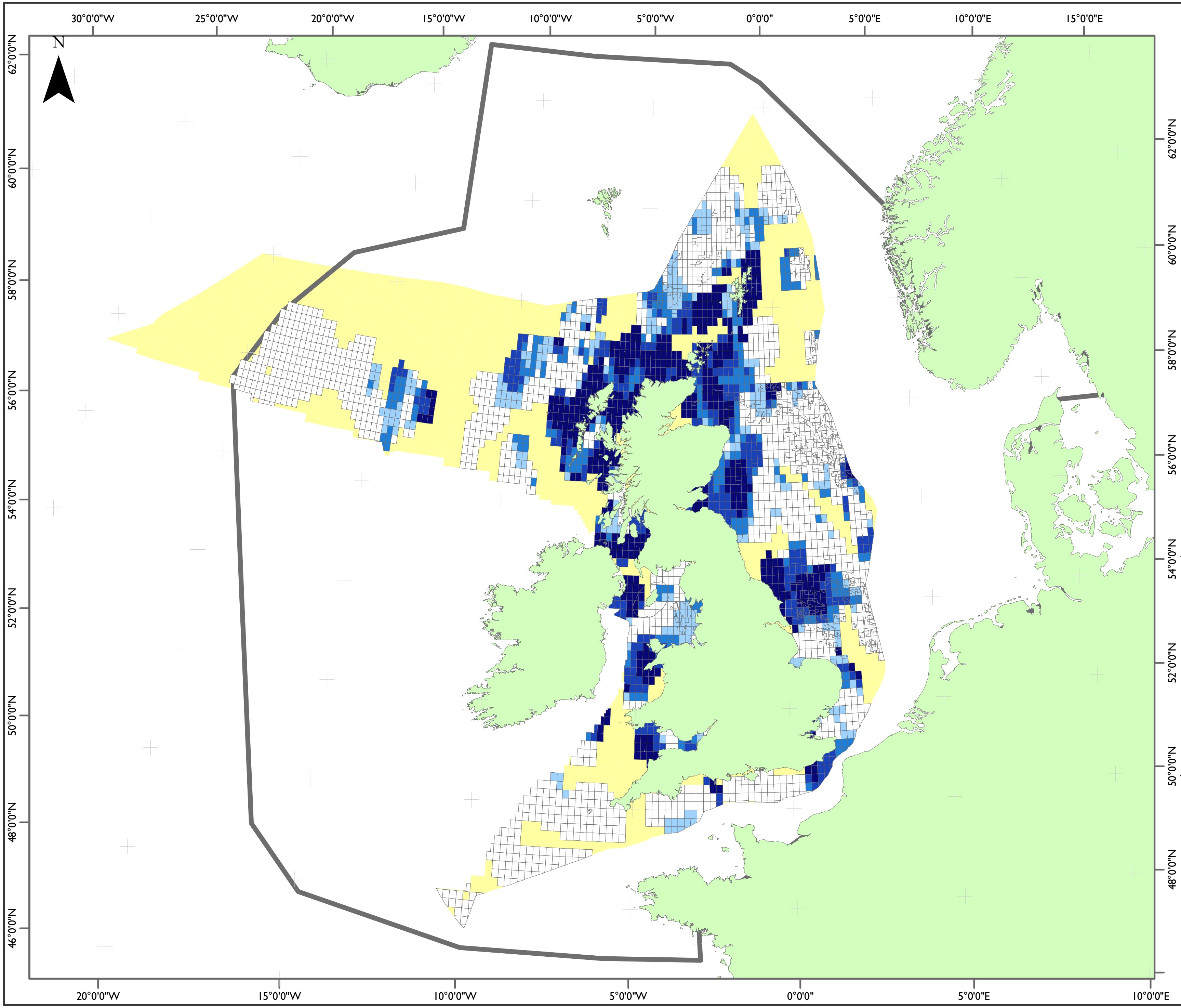
Figure 35 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June



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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June

DRAWING NUMBER
HP00061-701-053

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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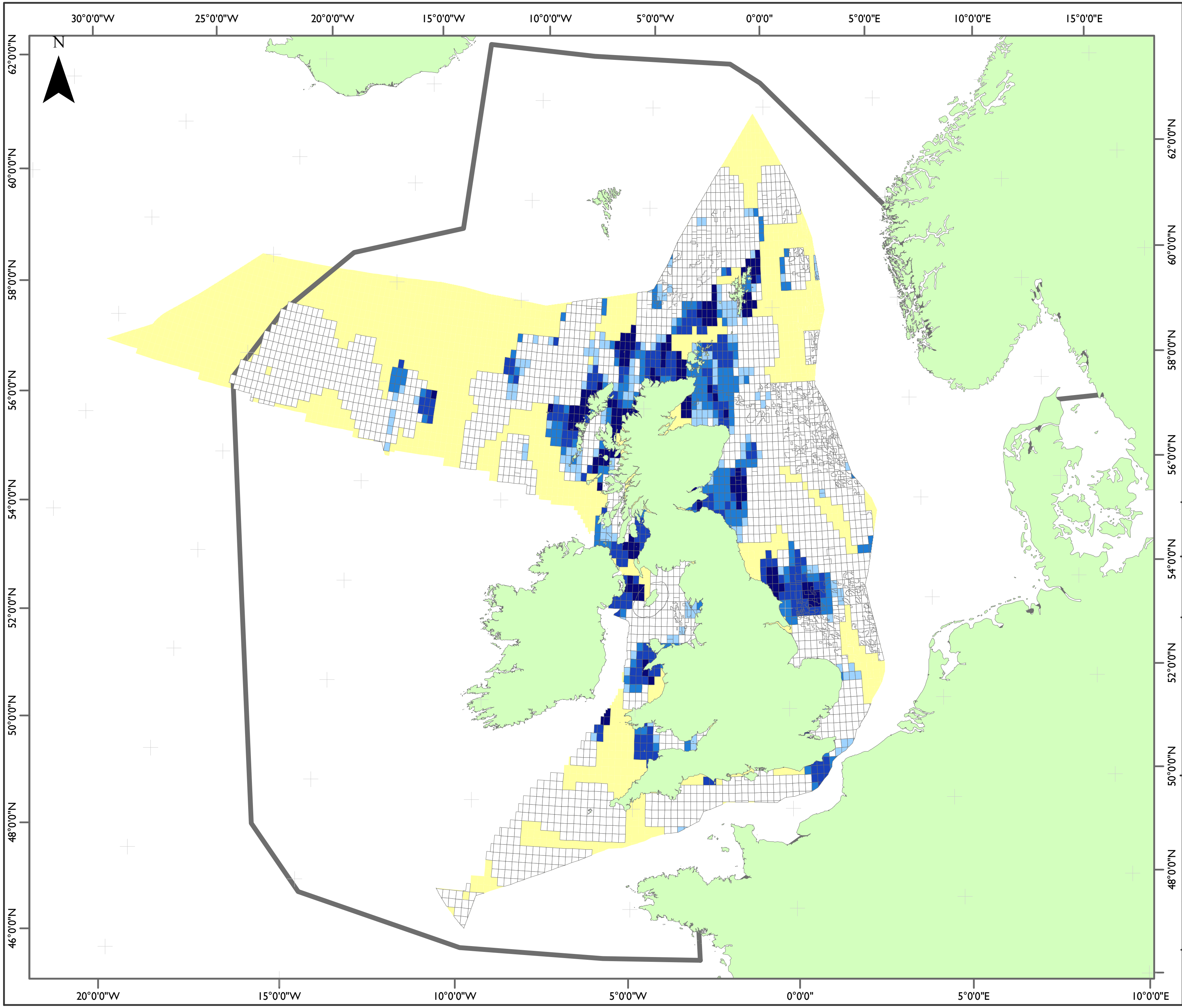
Figure 36 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June



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CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June

DRAWING NUMBER

HP00061-701-054

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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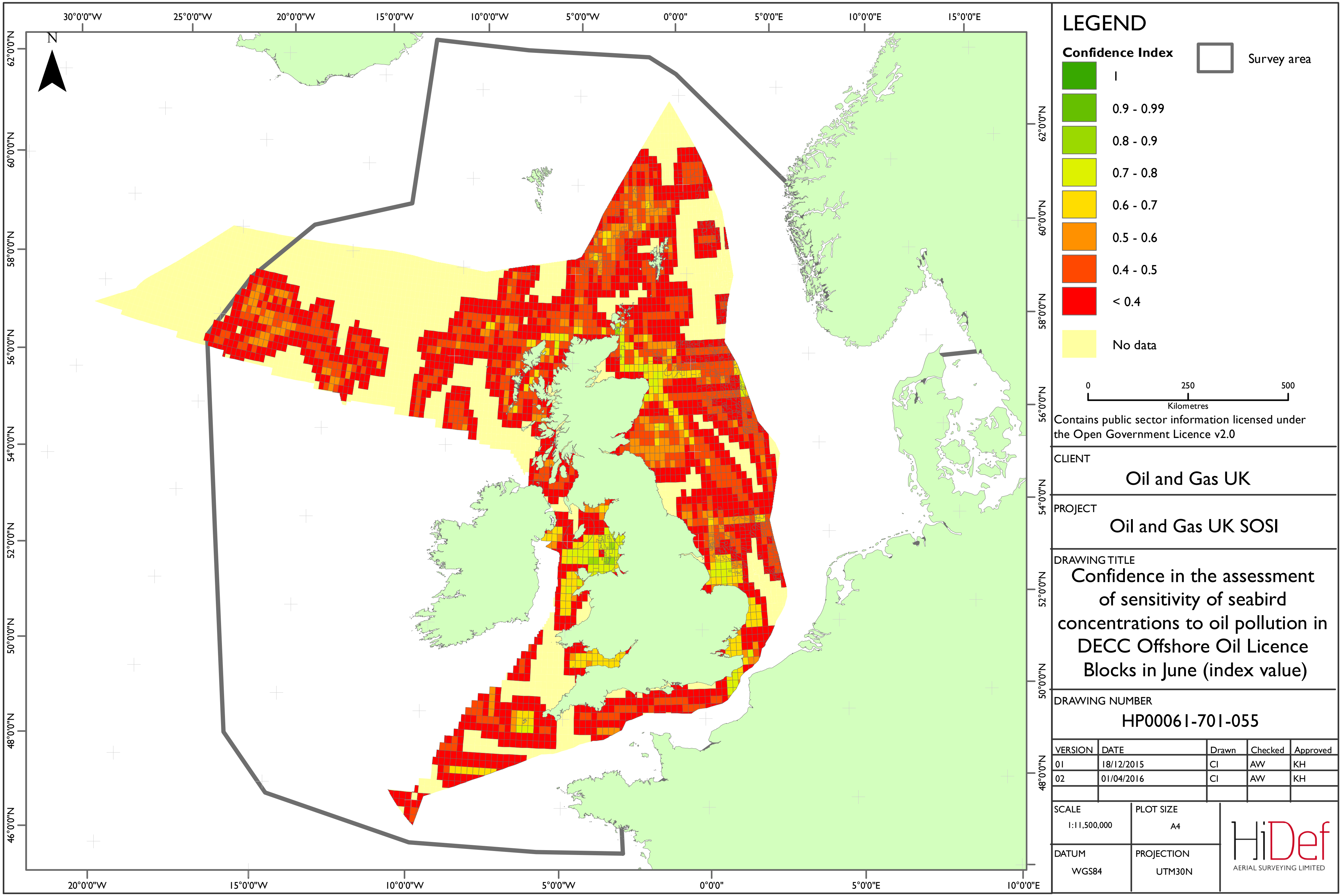
Figure 37 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in June (index value)



3.9 Seabird oil sensitivity in July

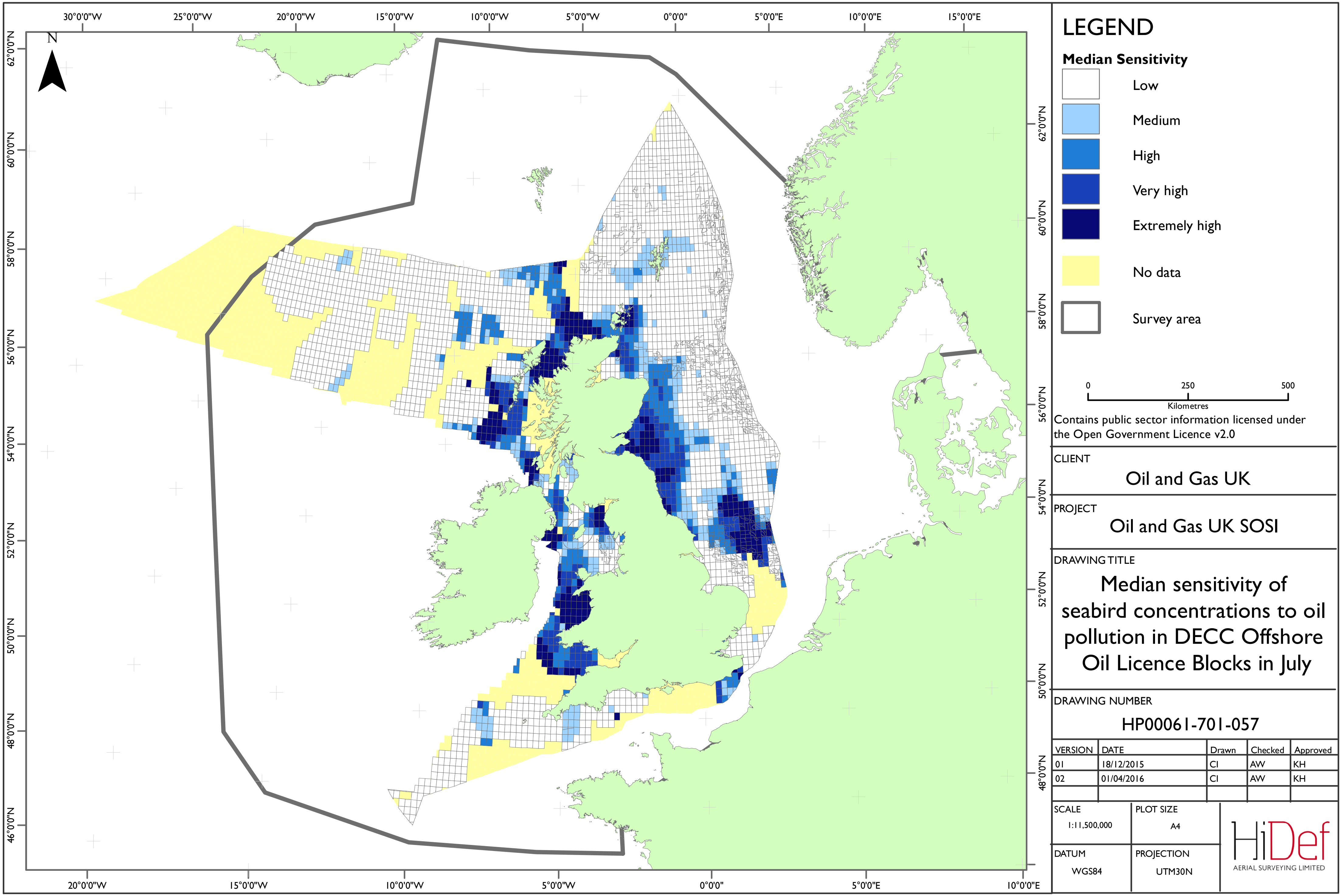
94 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 38, 39 and 40 respectively. The confidence index as a measure of the data quality is presented in Figure 41.

95 Inshore waterbirds in July remain mostly around their breeding sites in sheltered waters in the north of the United Kingdom, comprising mainly common eiders, European shag and red-throated divers. In July, however, some sea-duck species start to form concentrations on the east coast of Scotland and in the eastern Irish Sea where they begin to moult, and become flightless, which renders them especially sensitive to the effects of oil pollution. The main species involved in these movements are common and velvet scoter *Melanitta fusca* and common eider.

96 Offshore seabirds are feeding chicks during July. Most species feed their chicks at the nest site, but common guillemots and razorbills take their chicks to sea during July, usually dispersing rapidly from their colonies. At this time, the adults begin an extended period of moult when they become completely flightless, like their chicks. This renders them especially sensitive to the effects of oil pollution. Most of the highly sensitive concentrations to oil pollution were found near to the main colonies, but only moderately sensitive concentrations were found around Shetland. The main concentrations were found in a broad area around the outer Firth of Forth the outer Moray Firth, the east side of Orkney, off the North of Scotland, in the Minch, around the southern Western Isles, in the North Channel, the north-eastern Irish Sea, in Cardigan Bay and off south-west Wales. Concentrations of high sensitivity were also found further offshore, particularly in a region to the south of the Dogger Bank, and again around the median line to the north of the Western Isles.

97 Survey coverage in July was one of the healthiest, with few gaps in coverage, confined mainly to the west of the Western Isles, around south-western England, the English Channel and to the east of East Anglia. There was high confidence in the survey data in a large part of the central North Sea to the east of Scotland and north-eastern England, in the Irish Sea and around south-west Wales. However, there were large areas with low confidence index scores to the west of Shetland and Orkney and to the west of the Western Isles.

Figure 38 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July



CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July

DRAWING NUMBER
HP00061-701-057

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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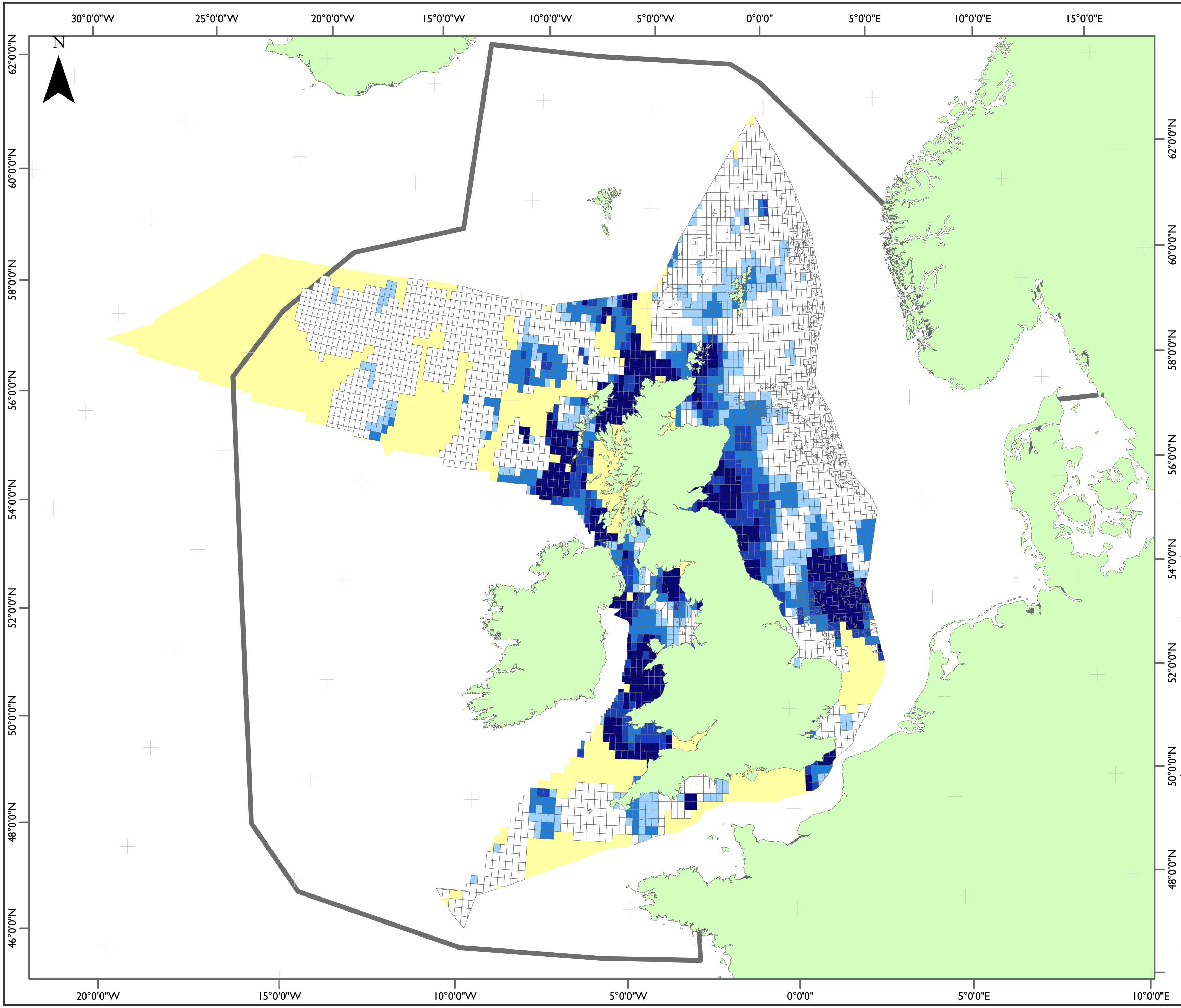
Figure 39 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July



LEGEND

Maximum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July

DRAWING NUMBER
HP00061-701-058

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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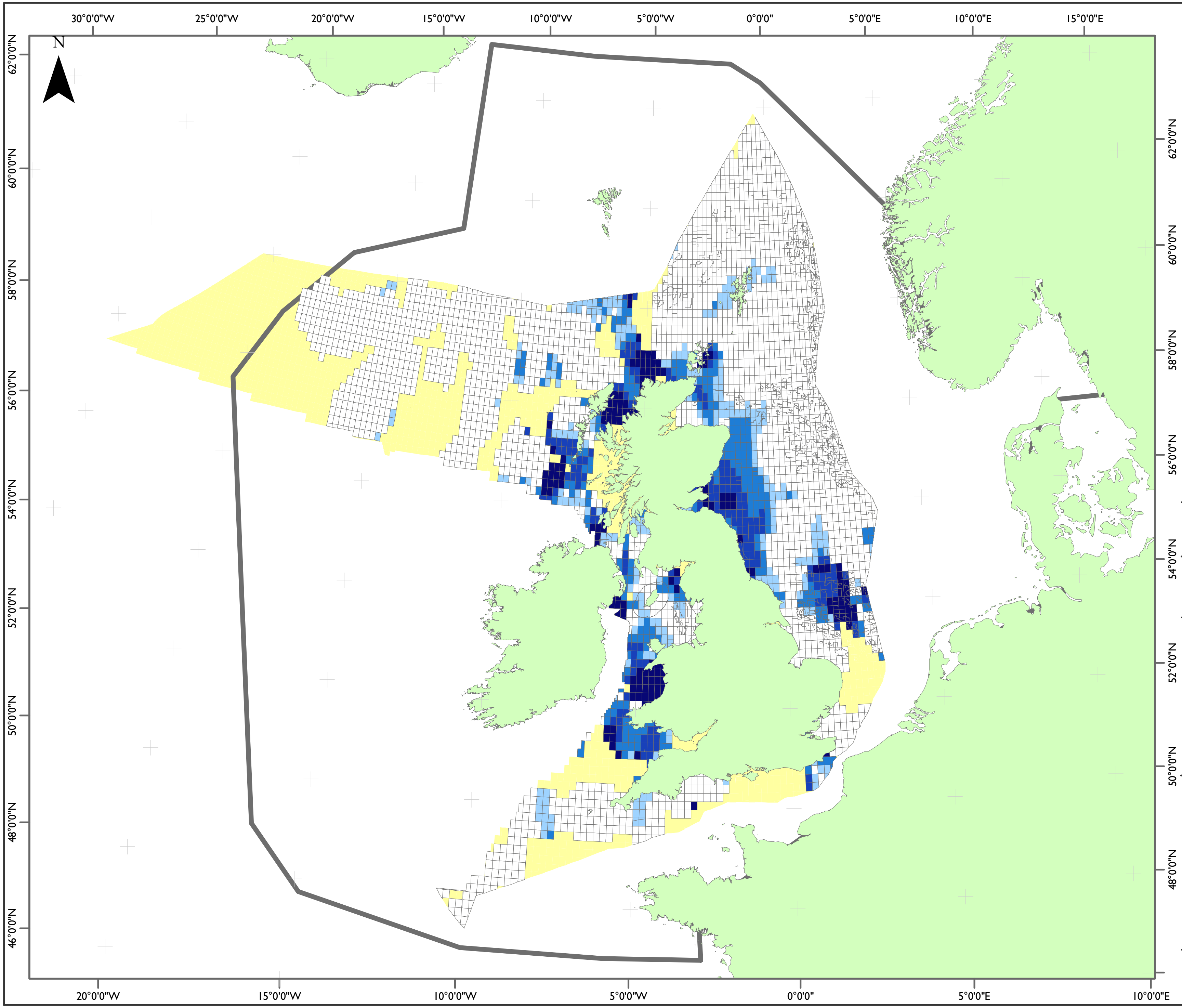
Figure 40 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July



LEGEND

Minimum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July

DRAWING NUMBER
HP00061-701-059

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
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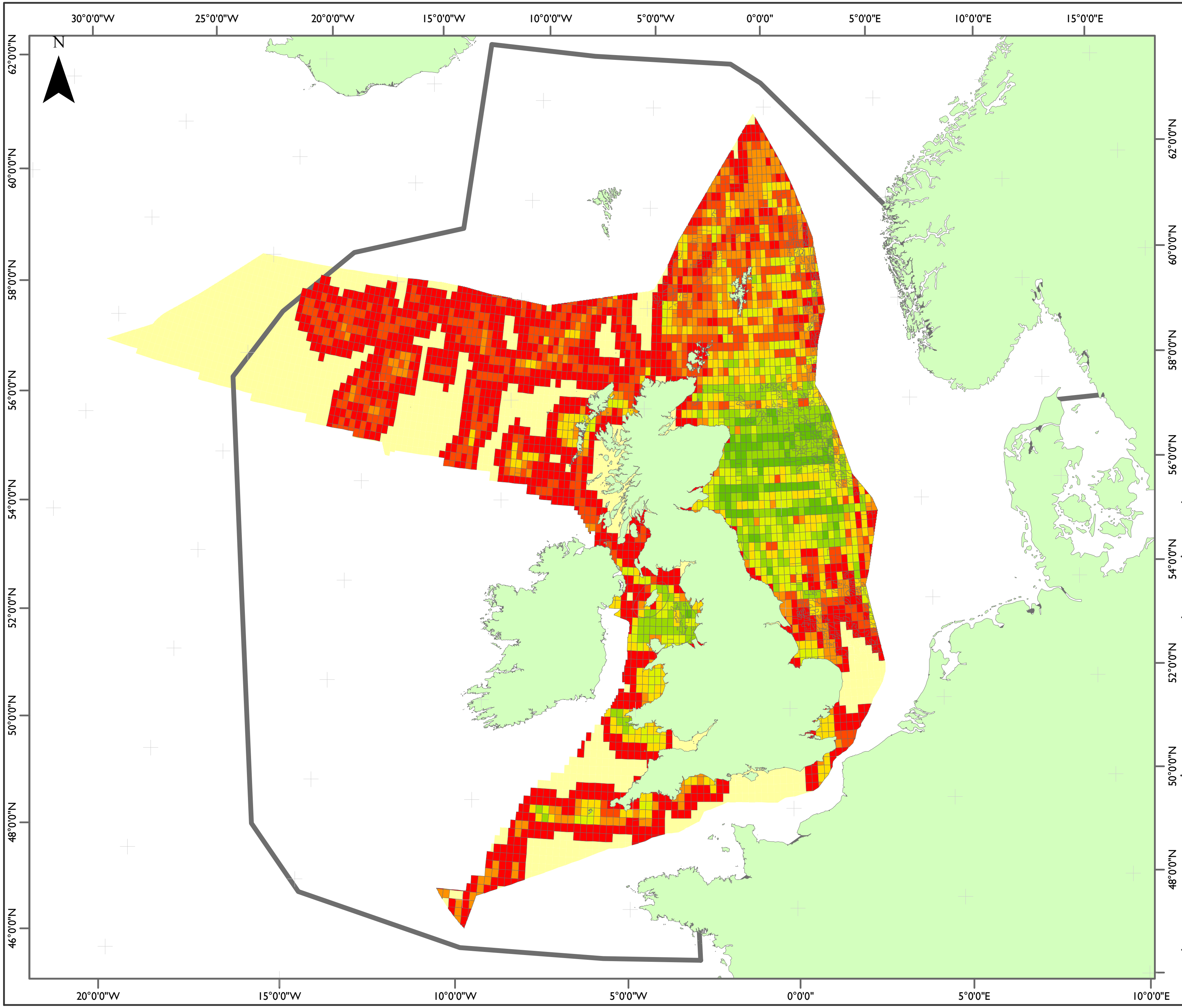
Figure 41 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July (index value)



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CLIENT	Oil and Gas UK
PROJECT	Oil and Gas UK SOSI
DRAWING TITLE	Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in July (index value)
DRAWING NUMBER	HP00061-701-060

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

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3.10 Seabird oil sensitivity in August

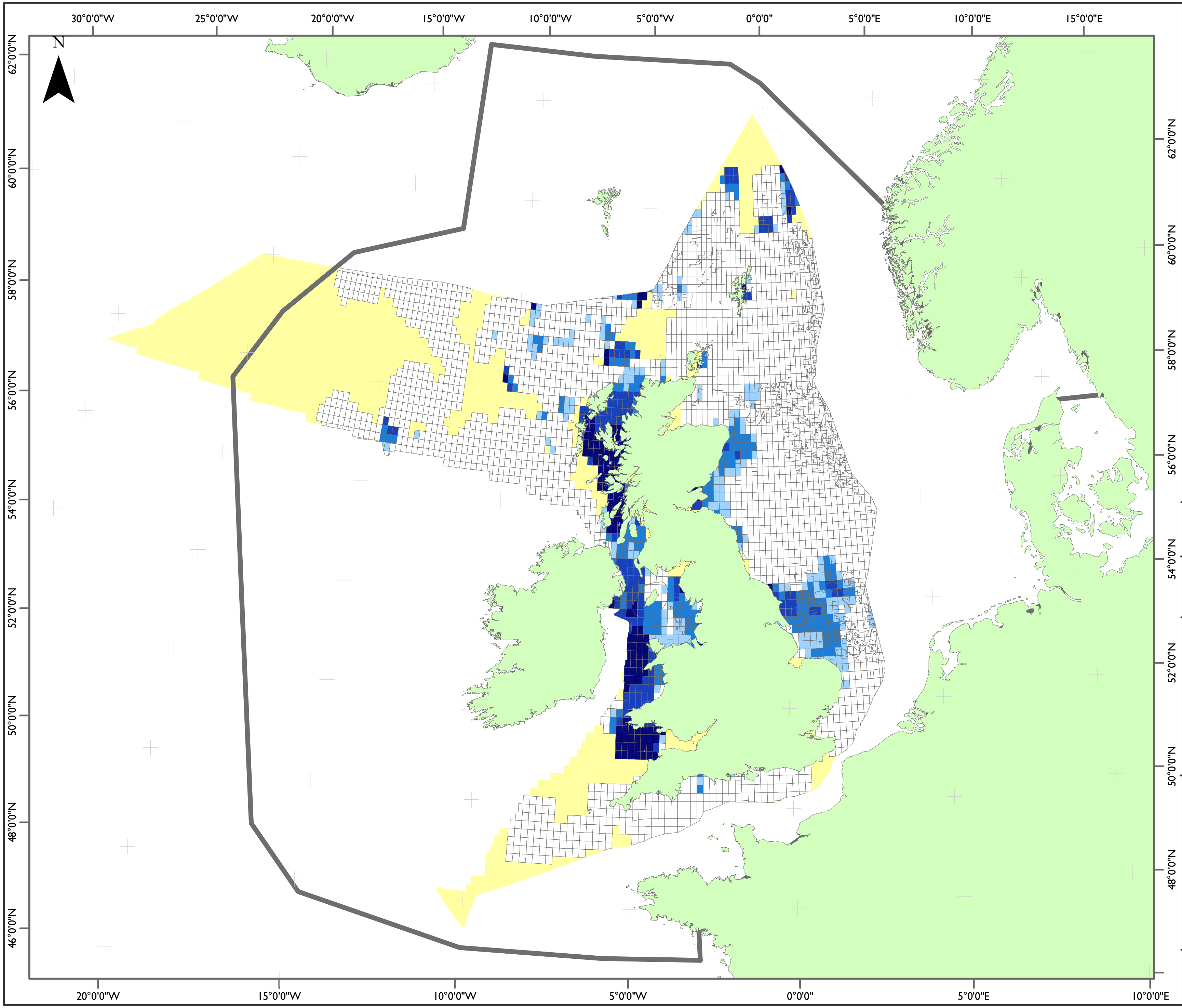
98 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 42, 43 and 44 respectively. The confidence index as a measure of the data quality is presented in Figure 45.

99 Most inshore waterbirds, such as red-throated divers, European shags and black guillemots remain around their nest sites in the north and west of the UK. Common eiders and common and velvet scoters continue to use moult sites around north-eastern Scotland and in the Irish Sea, where they are completely flightless during this period.

100 Almost all offshore seabirds complete breeding during August, and all age classes can be expected to be at sea during the month. Some species, such as Atlantic puffins are known to disperse from the breeding sites quite rapidly during this period into the North Atlantic, however common guillemots and razorbills remain in dense concentrations of moulting adults and similarly flightless chicks. The location of sensitive concentrations to oil pollution suggested that most of these occur on the western side of the UK in the Minch, Sea of Hebrides, inshore waters around Argyll and off west Wales. There were some concentrations also in offshore areas to the north of the Western Isles and to the north-east of Shetland. Somewhat unexpected was the general absence of any sensitive concentrations in central parts of the North Sea and few aggregations near the coast of East Scotland of highest sensitivity.

101 There were few gaps in coverage around the UK. The only gaps were far offshore to the north of Shetland, off the north mainland of Scotland, to the west of the Western Isles, in the southern Sea of Hebrides and west of Cornwall. The confidence in the data was high throughout most of the North Sea and in the eastern Irish Sea, but low further offshore to the west of Orkney and Shetland, west of mainland Scotland and in the English Channel.

Figure 42 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August



LEGEND

Median Sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August

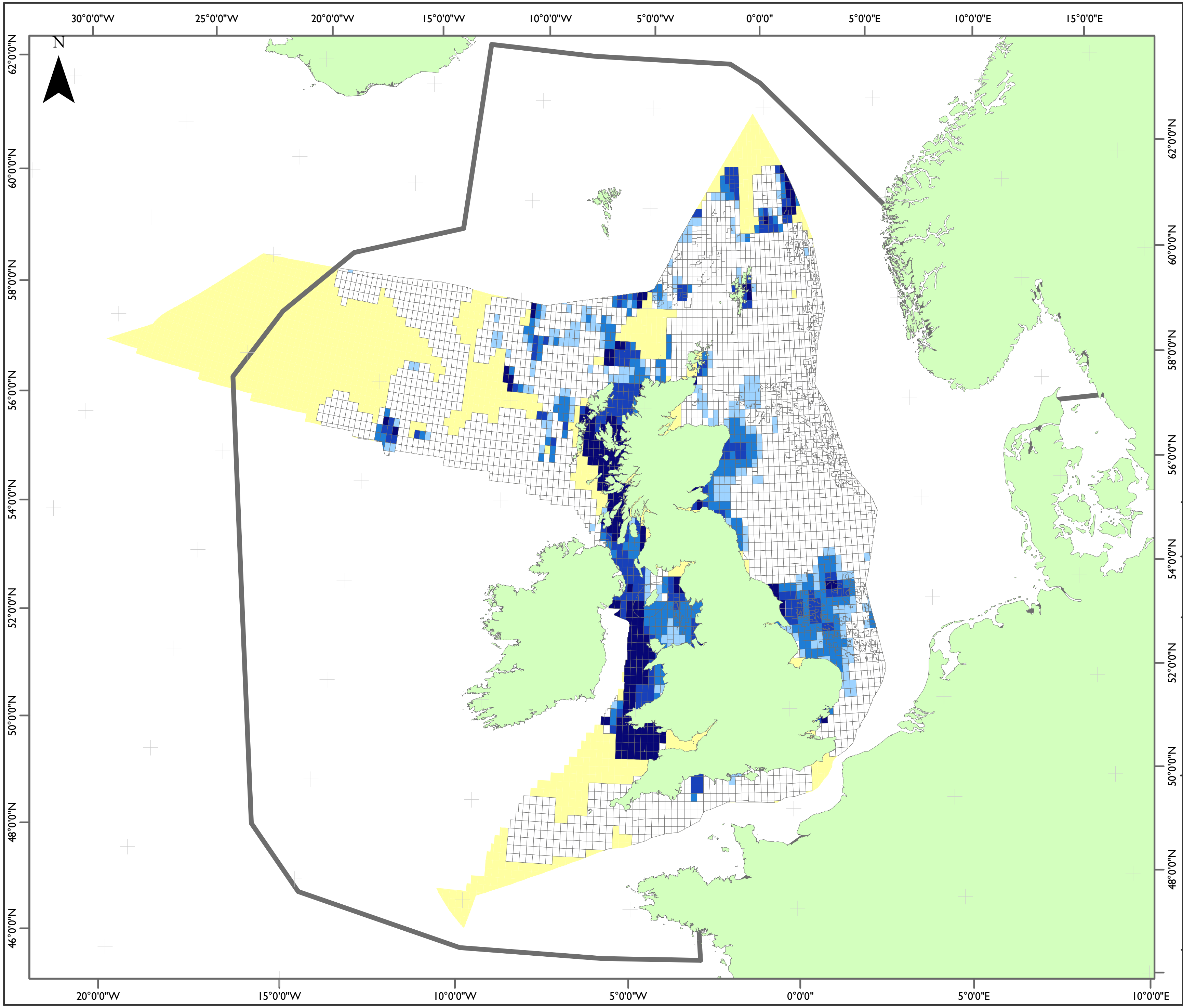
DRAWING NUMBER
HP00061-701-062

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 43 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August



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CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August

DRAWING NUMBER

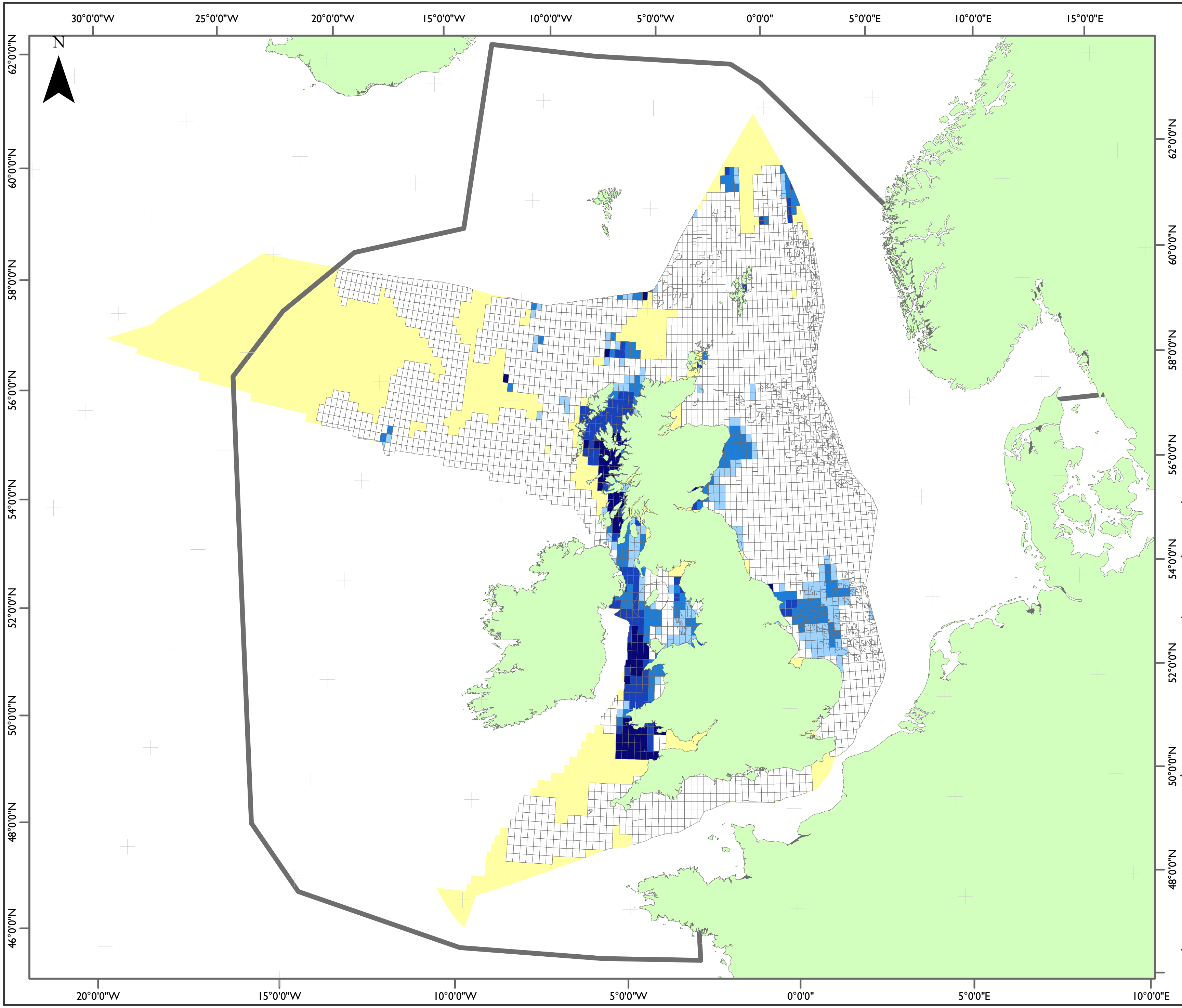
HP00061-701-063

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef AERIAL SURVEYING LIMITED

Figure 44 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August



LEGEND

Minimum sensitivity

Low

Medium

High

Very high

Extremely high

No data

Survey area

0 250 500

Kilometres

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CLIENT

Oil and Gas UK

PROJECT

Oil and Gas UK SOSI

DRAWING TITLE

Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August

DRAWING NUMBER

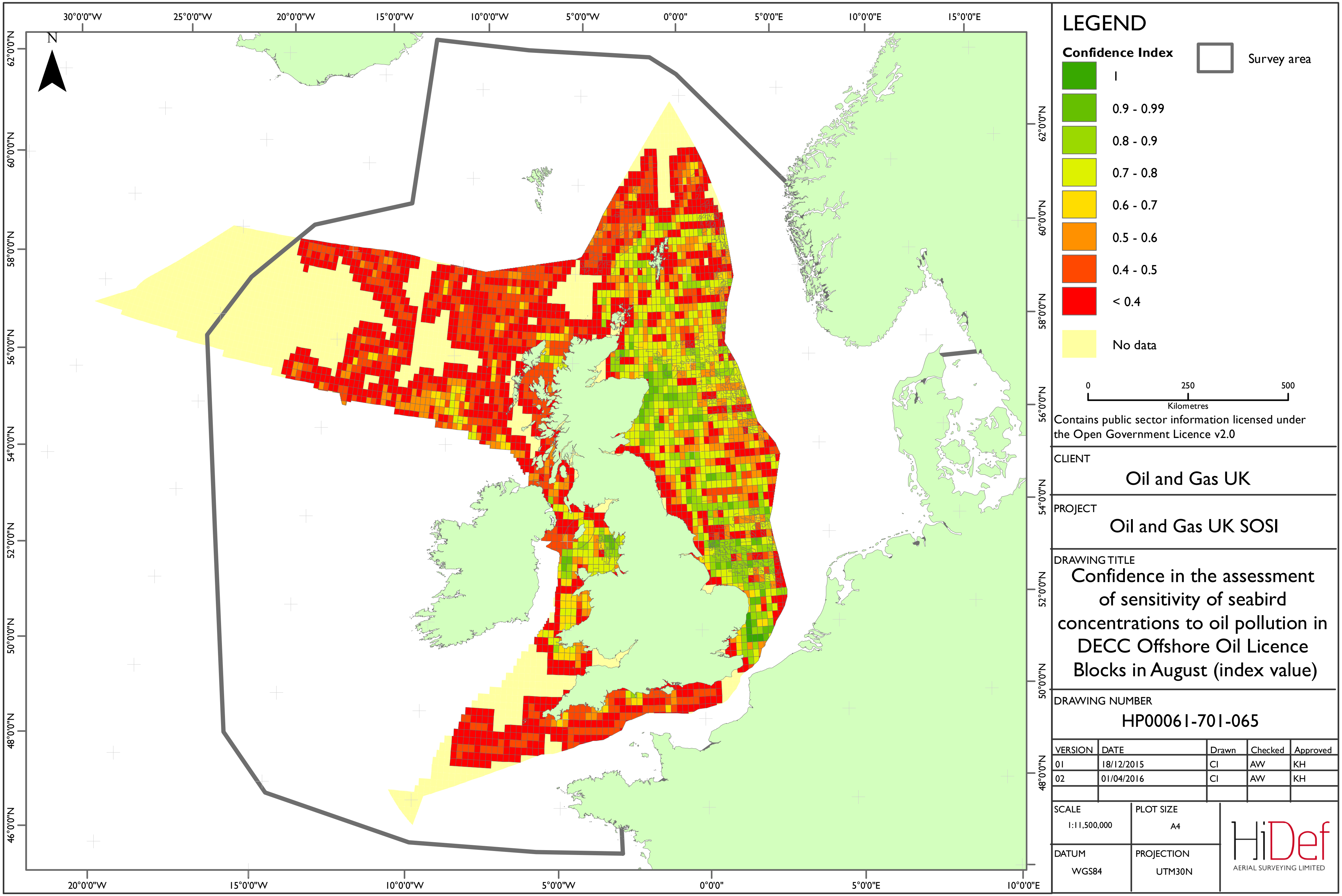
HP00061-701-064

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef AERIAL SURVEYING LIMITED

Figure 45 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in August (index value)



3.11 Seabird oil sensitivity in September

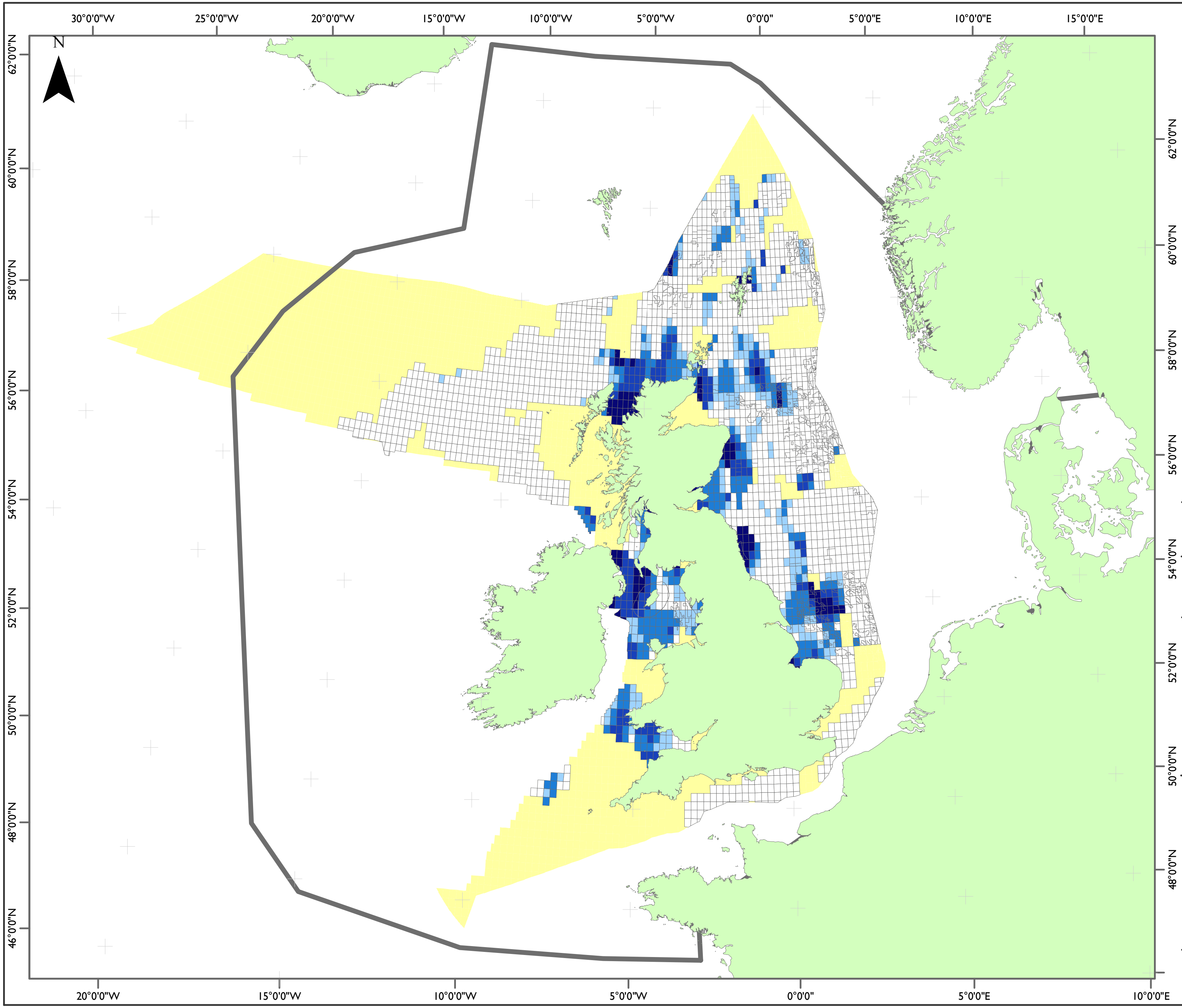
102 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 46, 47 and 48 respectively. The confidence index as a measure of the data quality is presented in Figure 49.

103 Inshore waterbirds continue to move from their breeding sites in the northern parts of the UK into sheltered waters of the Moray Firth (no surveys during the last 20 years), north-east Scotland, the Firths of Tay and Forth and even as far as The Wash. Red-throated divers undergo a full wing moult at this time of the year, which makes them particularly sensitive to oil pollution. European shags begin to disperse along the coast in September from their nesting sites, meaning that they are present along virtually the entire coastline of the northern UK. Great cormorants appear again at coastal sites again in the south of England. Black guillemots begin their moult during September and form dense concentrations of flightless birds near to their breeding sites in Orkney, Shetland and western Scotland.

104 Offshore seabirds continue to disperse at sea, with many species leaving the UKCS at this time of year (e.g. northern gannet, black-legged kittiwake and Atlantic puffin. Common guillemot and razorbill start the month in the same concentrations of mainly flightless and moulting birds, but become fully fledged during the month, which sees a break-up of these large concentrations. Sensitive concentrations of seabirds to oil pollution were patchy in their distribution within the UKCS, with highly sensitive aggregations to the west of Shetland around the median line, the outer Moray Firth, off north-eastern Scotland, north-eastern England and further offshore to the east of Orkney, south-east of Aberdeenshire, to the east of Flamborough Head, in the Minch, North Channel and off south-west Wales.

105 The survey coverage was high relative to some other months but significant small gaps remained in the Moray Firth, in the central North Sea to the south-east of Shetland, east of Aberdeenshire. Also to the north of the Western Isles, the Inner and Outer Hebrides, West Wales, south-west England and in the Outer Thames. The confidence index scores areas with coverage were also relatively good in the North Sea and the Irish Sea, although the areas with high were interspersed with areas of low confidence. Large blocks of low confidence data were found in the English Channel, to the north and west of Shetland and west of the Western Isles.

Figure 46 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September



LEGEND

Median Sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September

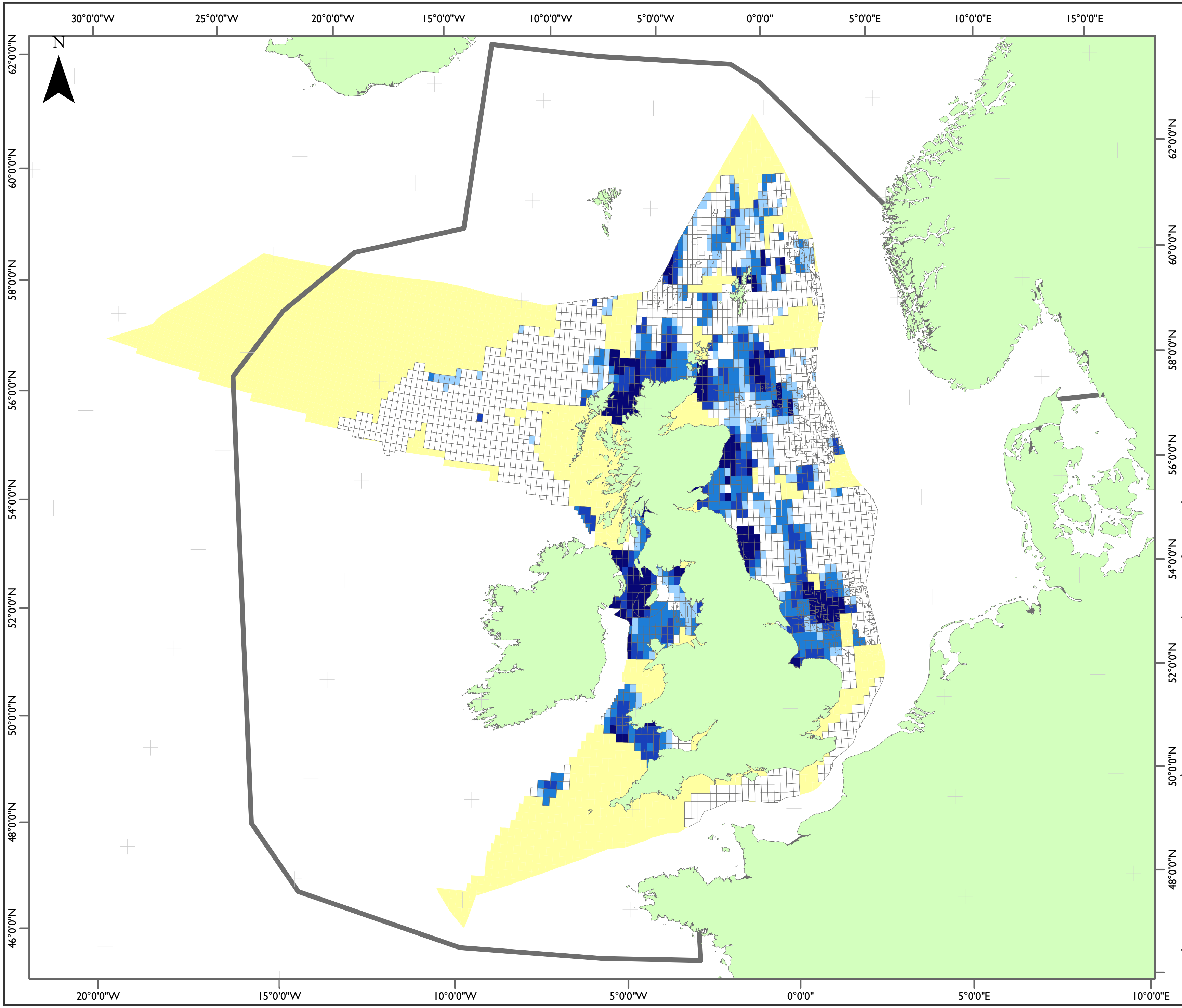
DRAWING NUMBER
HP00061-701-067

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 47 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September



LEGEND

Maximum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September

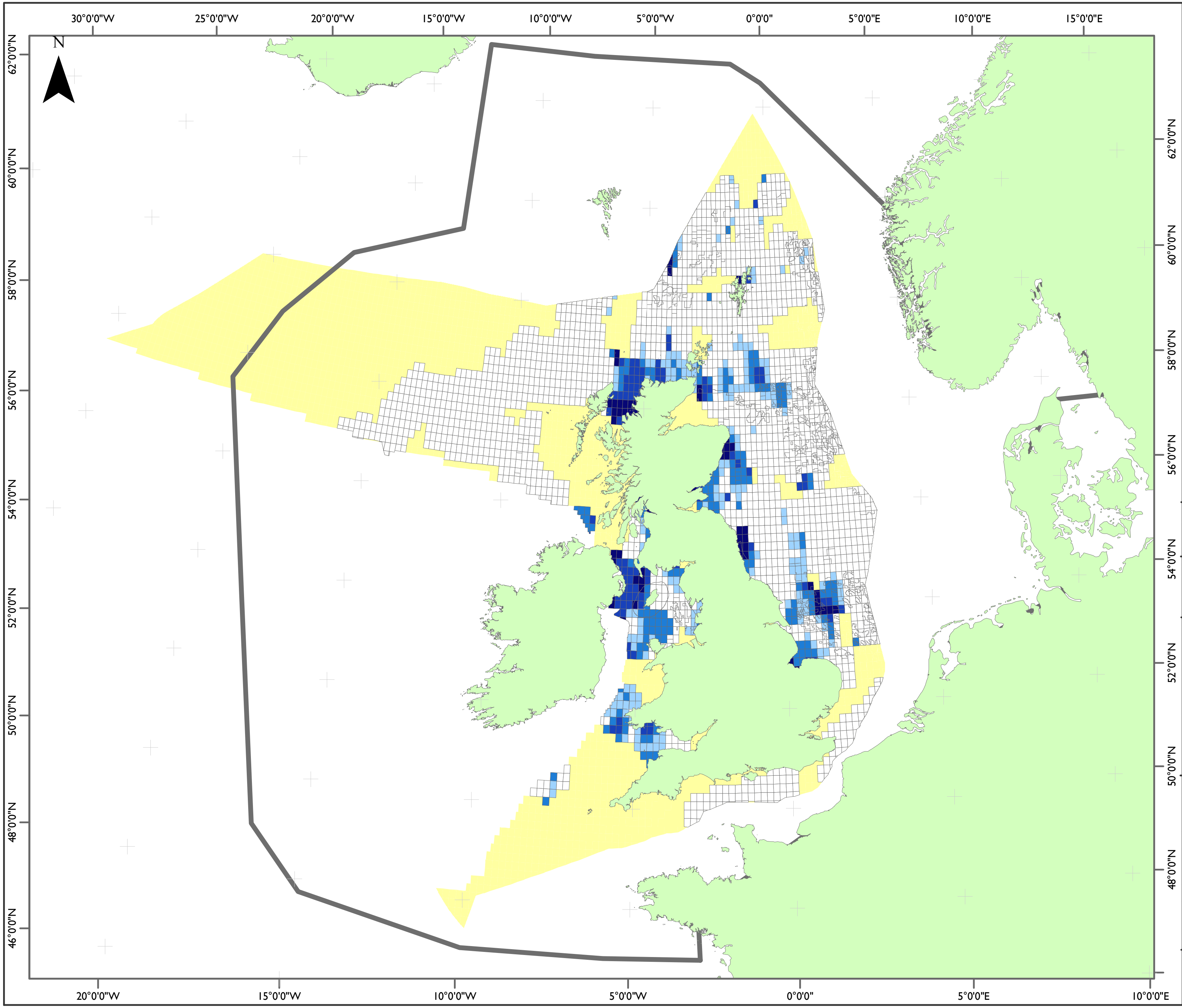
DRAWING NUMBER
HP00061-701-068

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 48 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September



LEGEND

Minimum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September

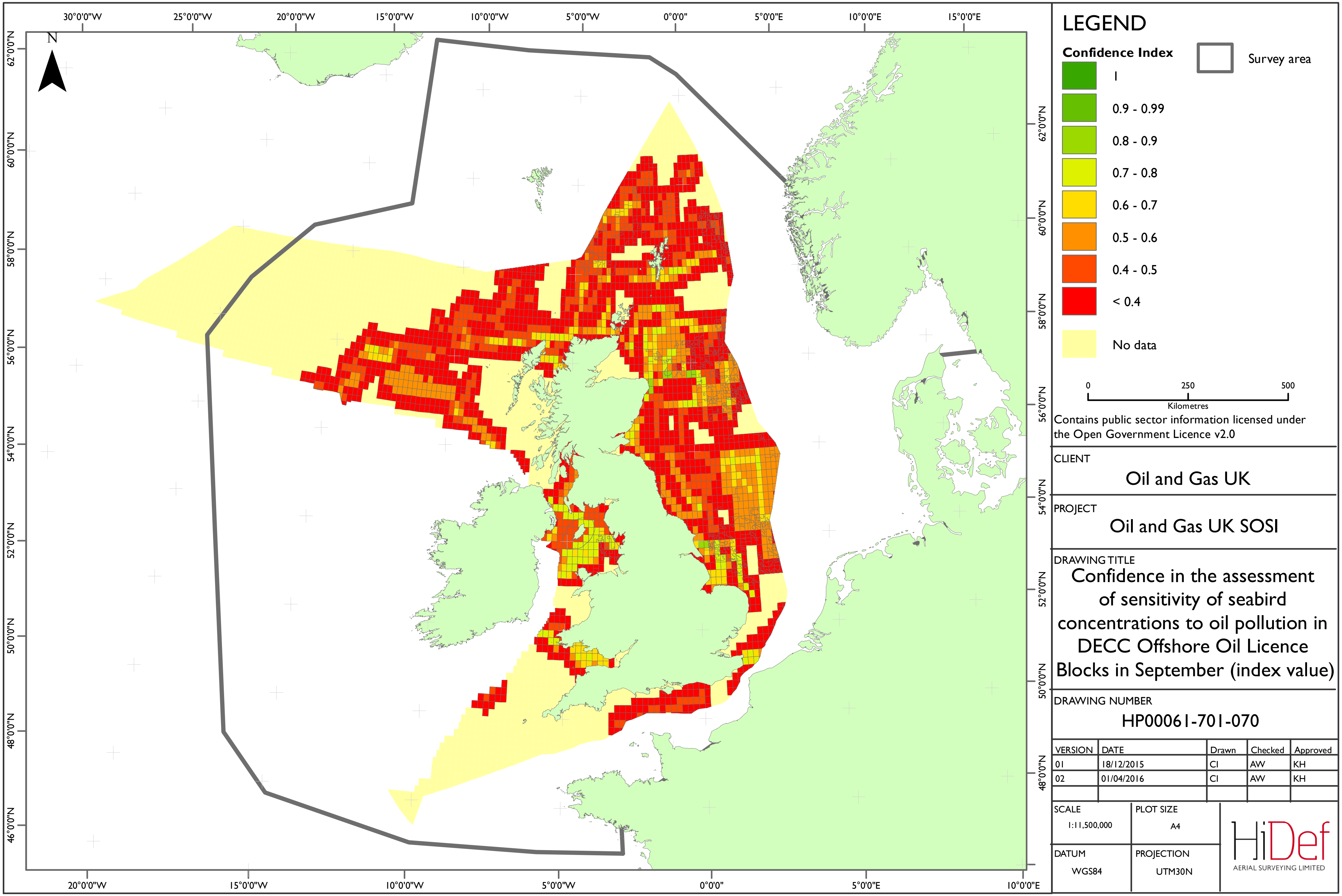
DRAWING NUMBER
HP00061-701-069

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 49 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in September (index value)



3.12 Seabird oil sensitivity in October

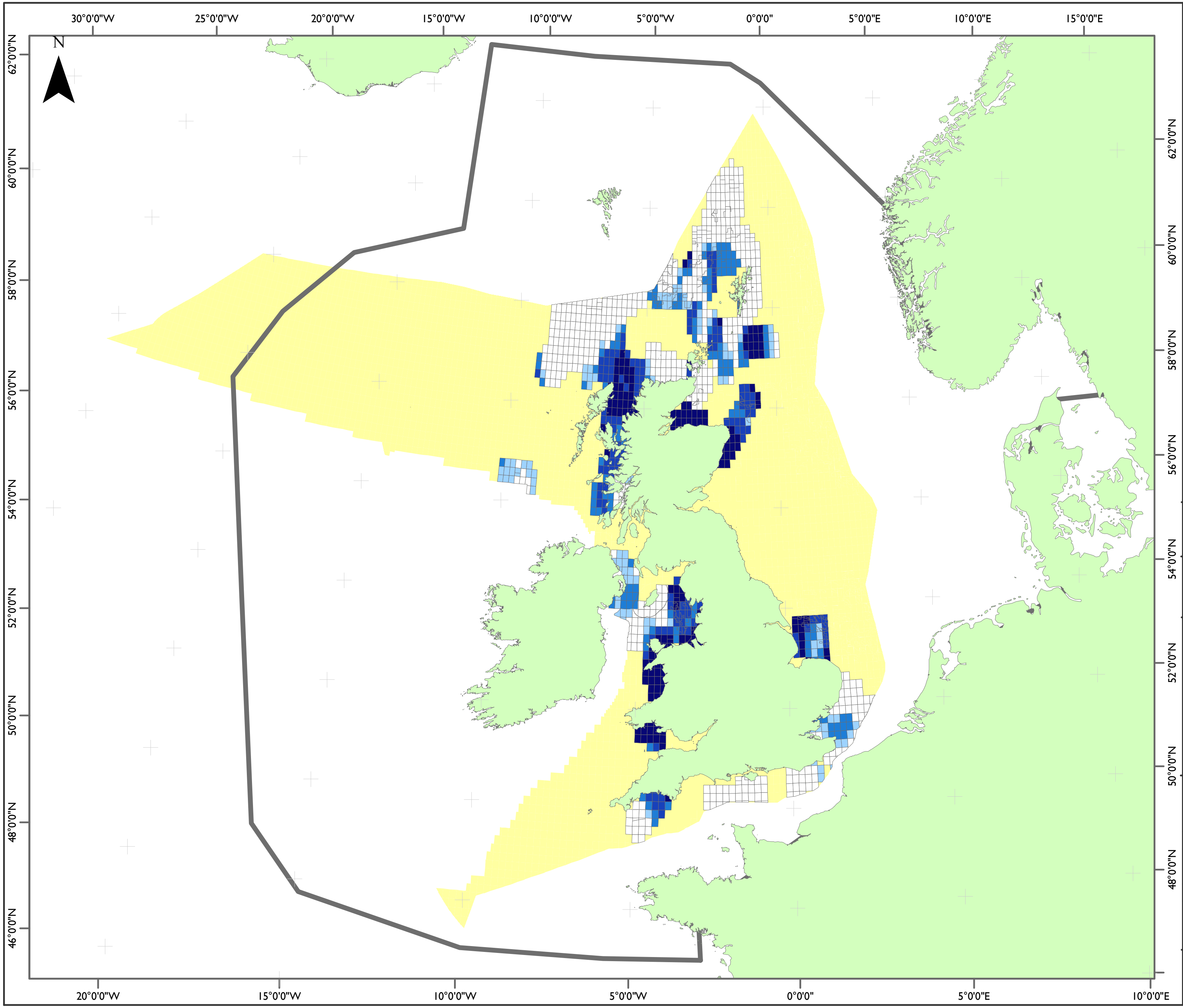
106 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 50, 51 and 52 respectively. The confidence index as a measure of the data quality is presented in Figure 53.

107 In October, inshore waterbirds continue to move into their wintering areas, with large numbers appearing in the Irish Sea, Moray Firth, the Firths of Tay and Forth (no survey data), Carmarthen and Cardigan Bays and in the Outer Wash. These are mainly common scoter, common eiders, red-throated divers and the first returning great northern divers, with the last species confined to northern and western Scotland. Red-throated divers and black guillemots continue to undergo their moult, although most finish this phase during the month.

108 Offshore seabirds continue to disperse out of the UKCS, and the abundance of many species is greatly diminished, especially Manx shearwaters, northern gannets, black-legged kittiwakes and Atlantic puffins. Gulls such as herring and great black-backed gulls spend more time at sea during October. The more sensitive species, common guillemots and razorbills are fully fledged and many disperse from around the UK. Some adult common guillemots make intermittent returns to their breeding sites in October, so may be present around their colonies at this time. Sensitive concentrations of seabirds to oil pollution were recorded in offshore areas west of Shetland, to the east of the Fair Isle Channel, off north-eastern Scotland, in the Minch and the Sea of Hebrides and in the eastern Irish Sea.

109 Coverage at sea was almost universally poor with very large gaps in the oil exploration and production areas of the North Sea, around the Western Isles and in south-west England. Where there was coverage, confidence indices for the data was almost universally low apart from in the Irish Sea and off south-eastern England.

Figure 50 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October



LEGEND

Median Sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October

DRAWING NUMBER
HP00061-701-072

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE
1:11,500,000

PLOT SIZE
A4

DATUM
WGS84

PROJECTION
UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 51 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October

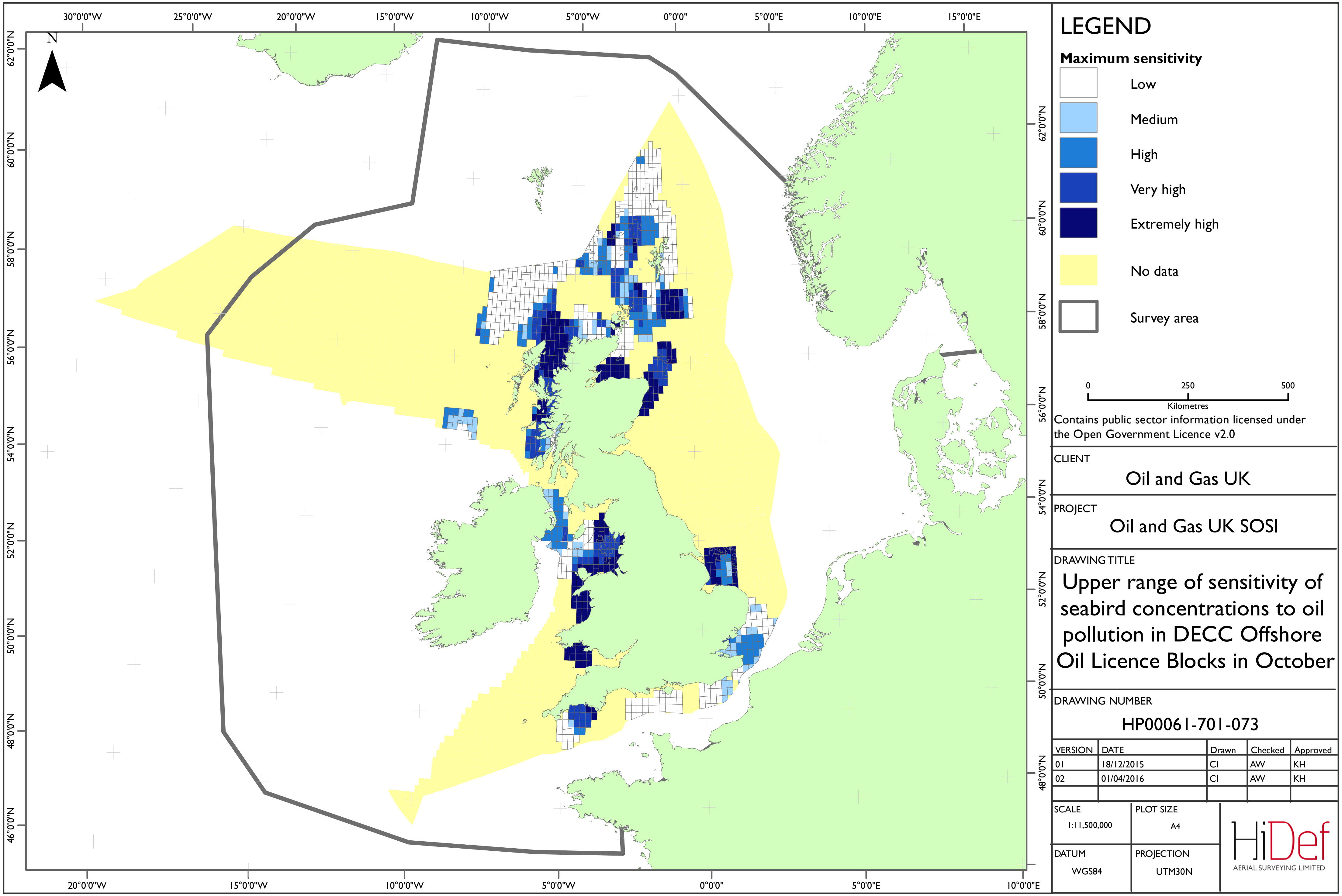
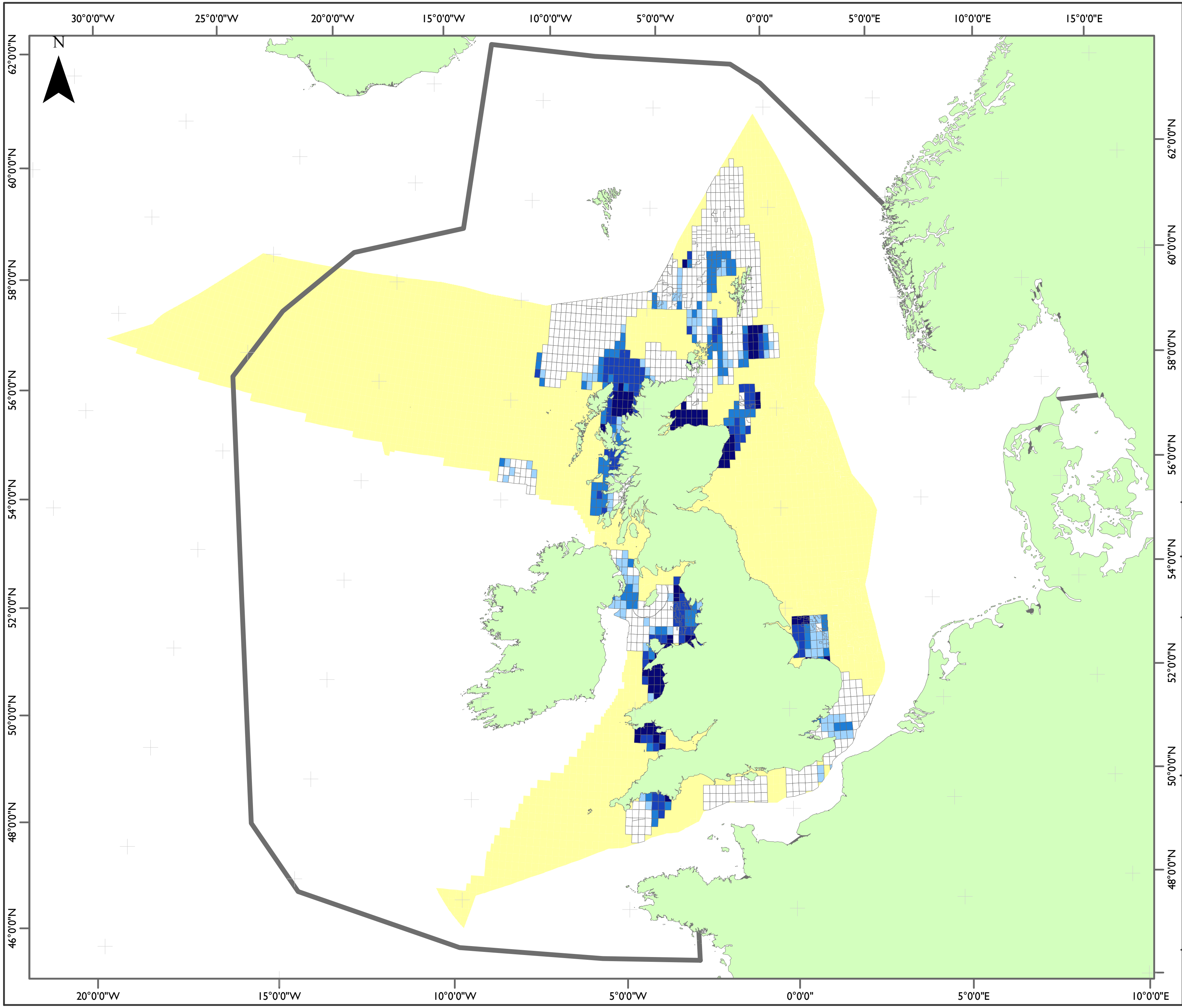


Figure 52 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October



LEGEND

Minimum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October

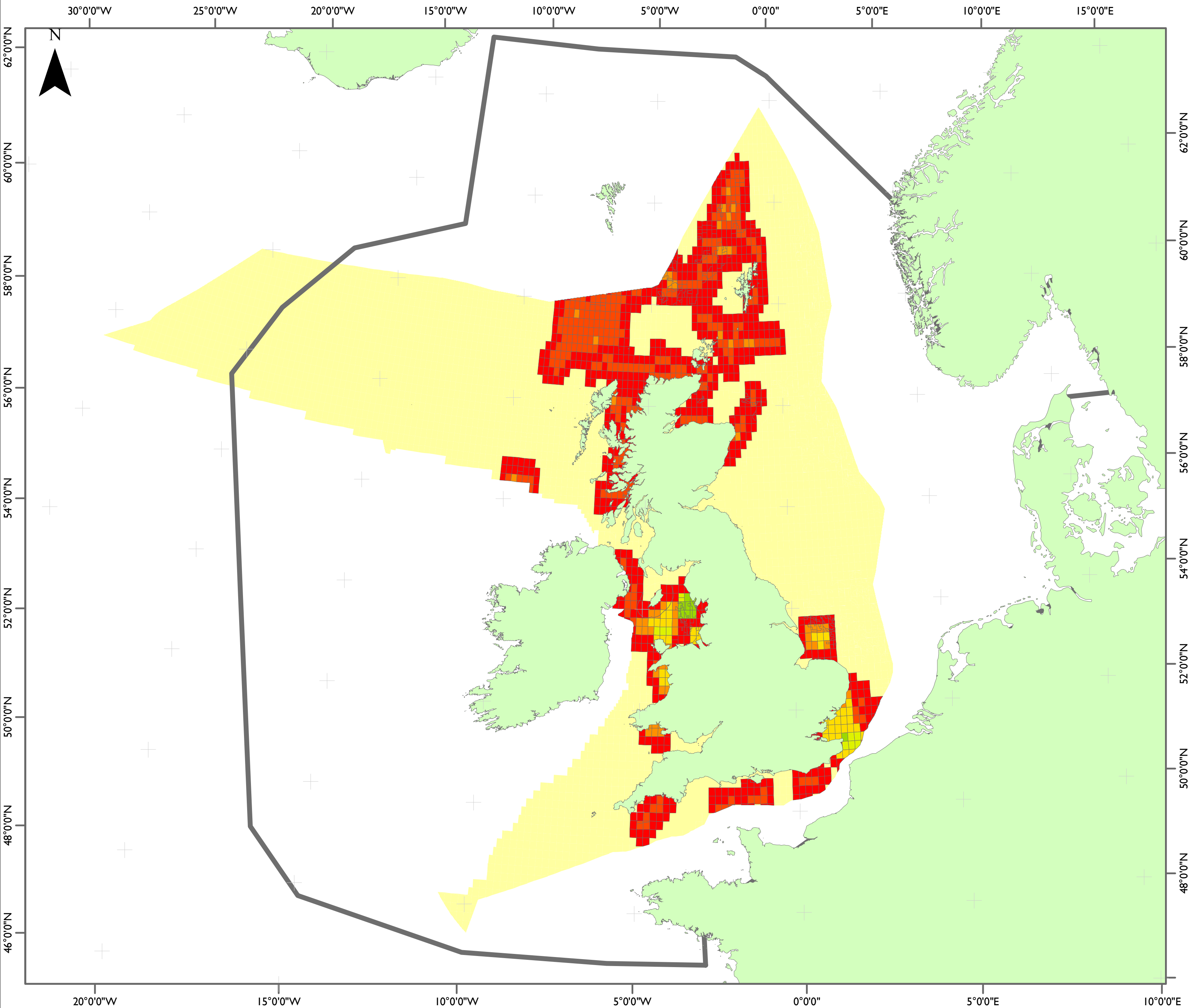
DRAWING NUMBER
HP00061-701-074

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 53 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October (index value)



LEGEND

Confidence Index

- 1
- 0.9 - 0.99
- 0.8 - 0.9
- 0.7 - 0.8
- 0.6 - 0.7
- 0.5 - 0.6
- 0.4 - 0.5
- < 0.4
- No data

Survey area

0 250 500
Kilometres

CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in October (index value)

DRAWING NUMBER
HP00061-701-075

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE 1:11,500,000
PLOT SIZE A4
DATUM WGS84
PROJECTION UTM30N

HiDef
AERIAL SURVEYING LIMITED

3.13 Seabird oil sensitivity in November

110 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 54, 55 and 56 respectively. The confidence index as a measure of the data quality is presented in Figure 57.

111 Inshore waterbirds appear in greater numbers at traditional wintering sites with all species having completed wing moult and periods of flightlessness. Important locations for these species are sheltered waters of Orkney and Shetland, the Moray Firth, Firth of Tay and Forth, the outer Wash, the outer Thames, the Western Isles the Irish Sea, Cardigan and Carmarthen Bays. Some of these sites (mainly those further south) are occupied by large numbers of sea-duck, especially common scoter, and also by red-throated divers. Great northern divers occur mainly in sheltered waters in Orkney and Shetland, around the Western Isles and in sea-lochs of the western mainland of Scotland. European shags are dispersed widely around the coast of the UK, while black guillemots also disperse more widely in inshore waters around northern and western UK. Many of these sites were not surveyed during November.

112 Offshore seabirds are relatively unconstrained by the location of their colonies, and the suite of species present is typified by fulmars, gulls, common guillemot and razorbills, although the latter species tends to occur closer inshore during the winter and to the south and west of the UK. High densities of sensitive concentrations of seabirds to oil pollution were found to the west of Shetland including an area close to the median line, in the outer Moray Firth, off north-eastern England and eastern England, in the outer Bristol Channel, the north-east Irish Sea and to the north of the Western Isles.

113 As was the case in October, coverage was poor in November, with extensive gaps around the oil producing areas of the North Sea. Closer inshore there were significant gaps in the Fair Isle Channel, around the coast of western Scotland and in parts of south-west England and the English Channel. The only regions in which there were high confidence indices for survey coverage were in the Irish Sea, the Bristol Channel, the outer Wash and the outer Thames.

Figure 54 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November

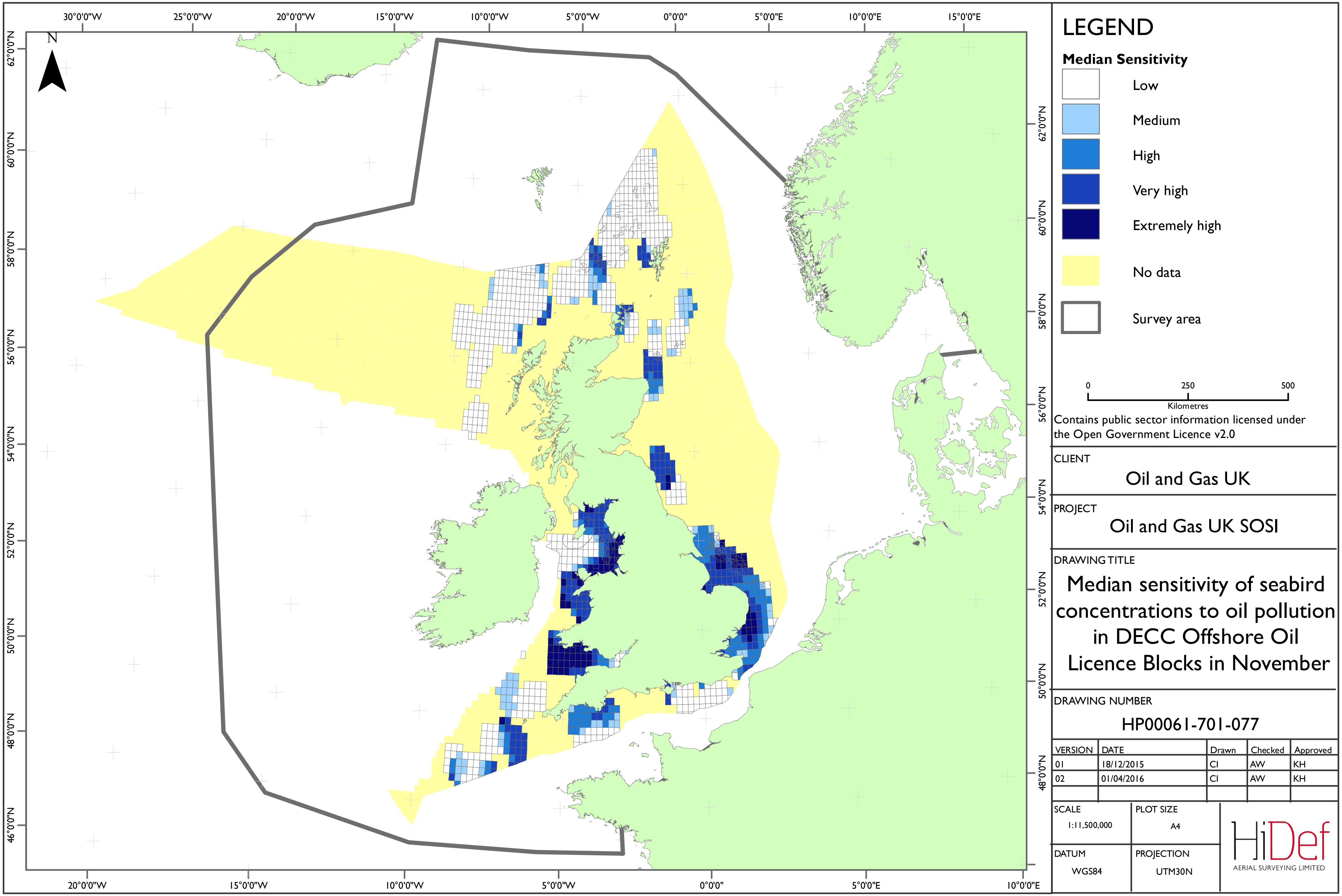
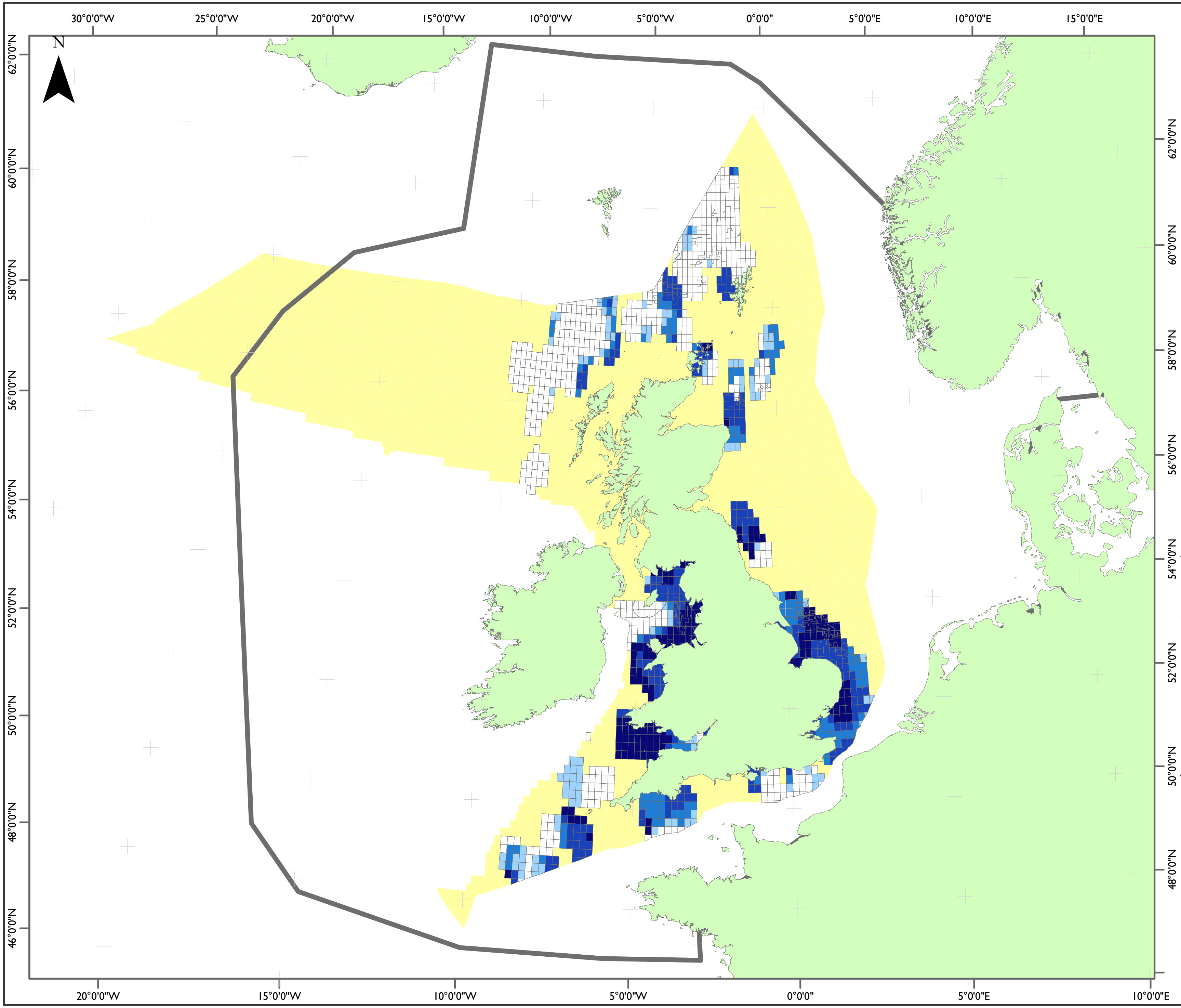


Figure 55 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November



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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November

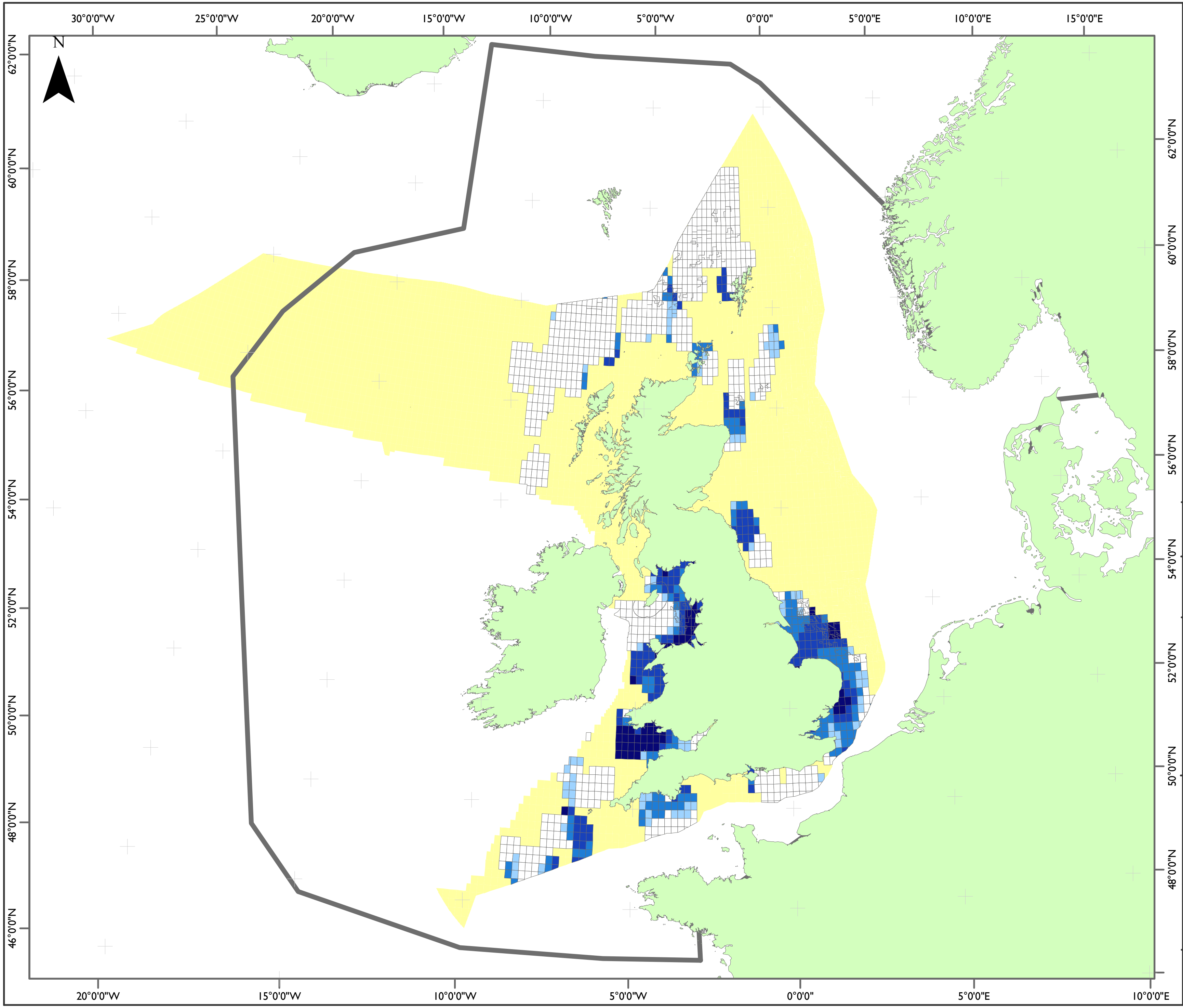
DRAWING NUMBER
HP00061-701-078

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 56 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November



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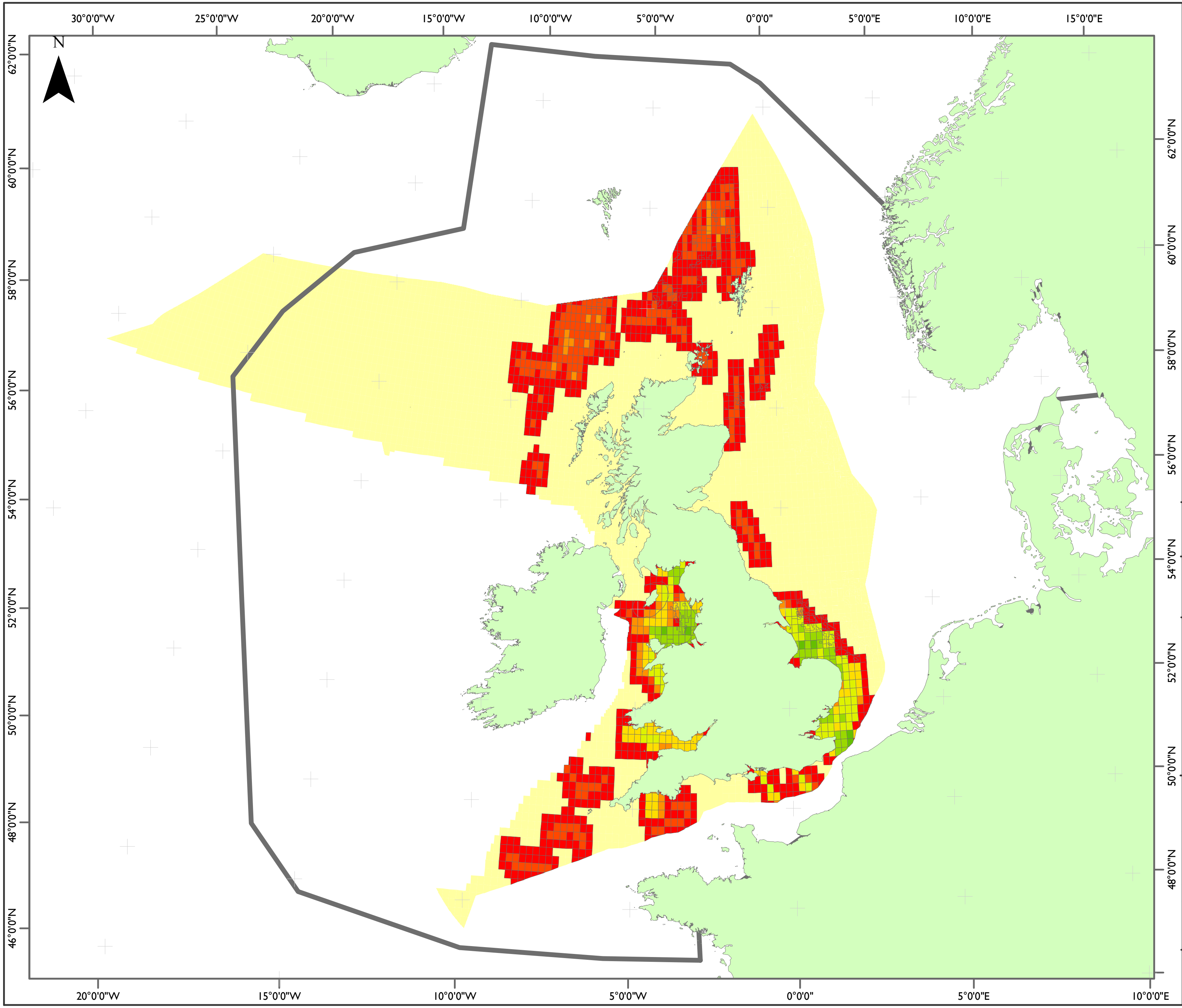
CLIENT
Oil and Gas UK
PROJECT
Oil and Gas UK SOSI
DRAWING TITLE
Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November
DRAWING NUMBER
HP00061-701-079

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef AERIAL SURVEYING LIMITED

Figure 57 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November (index value)



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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in November (index value)

DRAWING NUMBER
HP00061-701-080

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE
1:11,500,000

PLOT SIZE
A4

DATUM
WGS84

PROJECTION
UTM30N

HiDef AERIAL SURVEYING LIMITED

3.14 Seabird oil sensitivity in December

114 The median, minimum and maximum SOSI scores for each licence block are shown in Figures 58, 59 and 60 respectively. The confidence index as a measure of the data quality is presented in Figure 61.

115 Inshore waterbirds are approaching peak numbers at traditional wintering sites. Important locations for these species are sheltered waters of Orkney and Shetland, the Moray Firth, Firth of Tay and Forth, the outer Wash, the outer Thames, the Western Isles the Irish Sea, Cardigan and Carmarthen Bays. These sites are occupied by large numbers of sea-duck, especially common scoter and red-throated divers. Great northern divers occur mainly in sheltered waters in Orkney and Shetland, around the Western Isles and in sea-lochs of the western mainland of Scotland. European shags are dispersed widely around the coast of the UK, while black guillemots also disperse more widely in inshore waters around northern and western UK. Some of these sites were not surveyed during December.

116 Offshore seabirds are relatively unconstrained by the location of their colonies, and the suite of species present is typified by fulmars, gulls, common guillemot and razorbills, although the latter species tends to occur closer inshore during the winter and to the south and west of the UK. These surveys found highly sensitive concentrations of offshore seabirds to oil pollution in an area to the east of the Fair Isle Channel, in the outer Moray Firth, east of the Firth of Tay, off north-eastern England, to the south of the Dogger Bank and to the north of the Western Isles.

117 As was the case in October and November, there were significant gaps in survey coverage in the central North Sea, to the north and to the west of Shetland and north-west of Orkney, around western Scotland and off south-west England. The confidence indices for these survey data were low in all areas apart from in the Irish Sea, West Wales and off south-eastern England.

Figure 58 Median sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in December

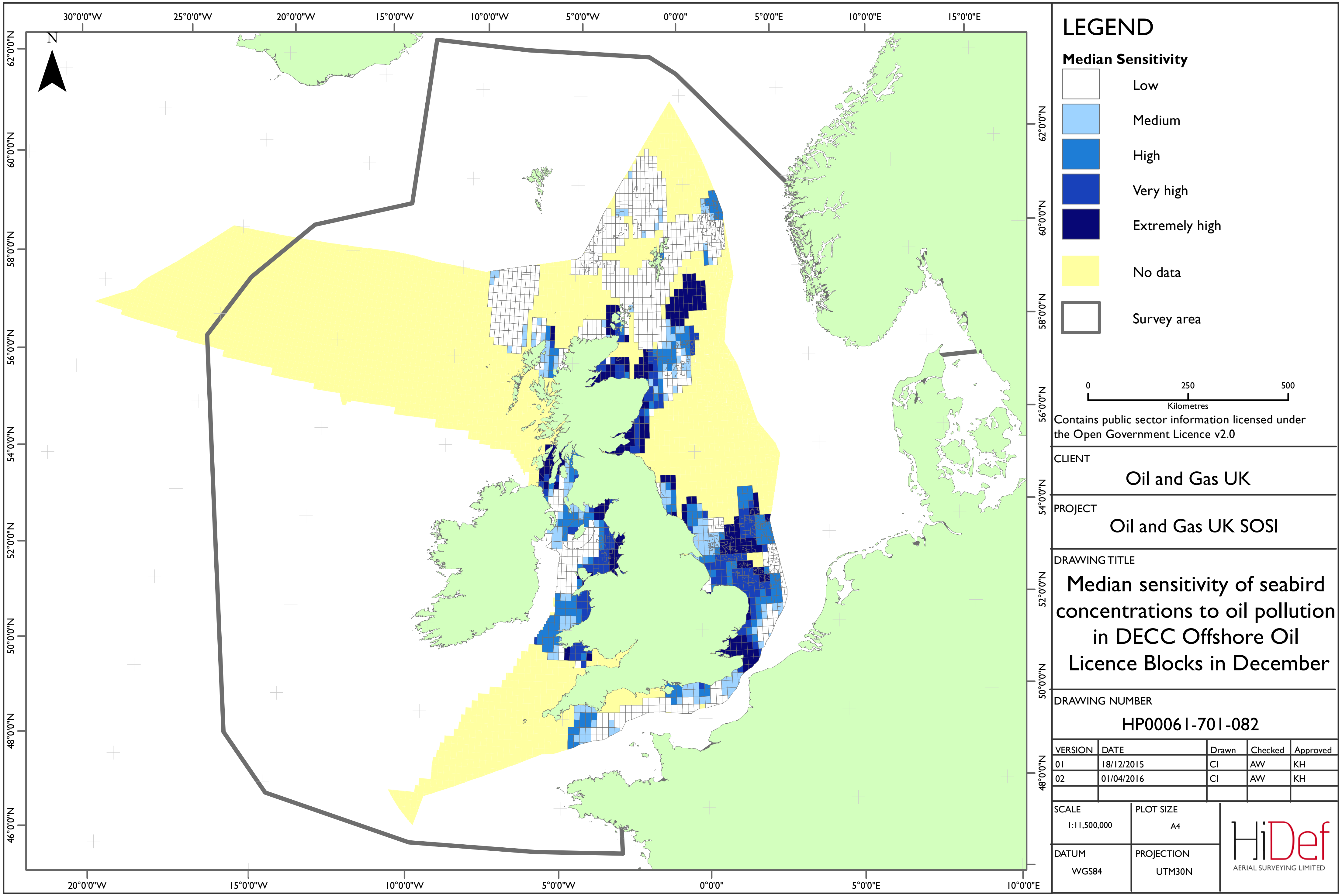
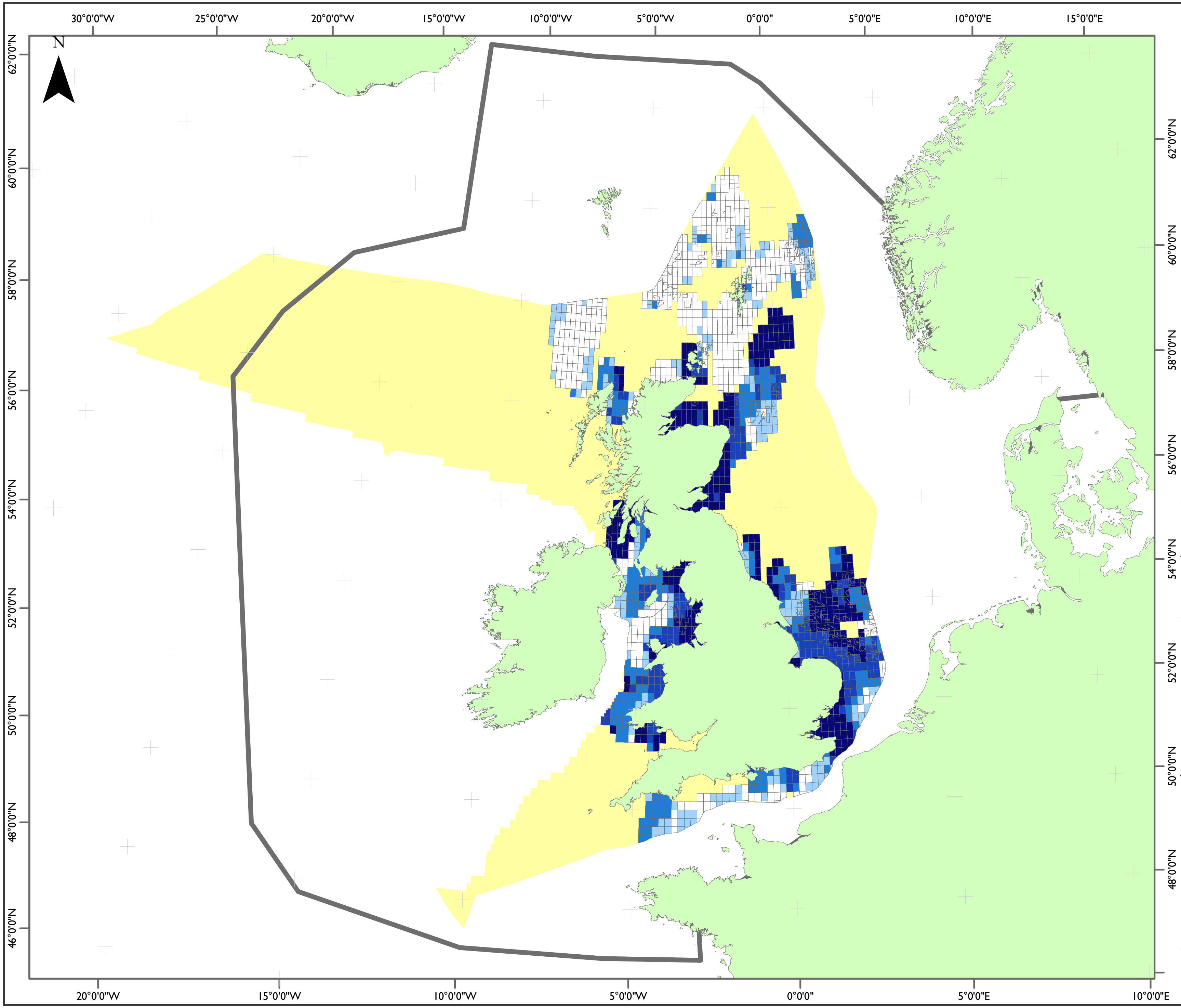


Figure 59 Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in December



LEGEND

Maximum sensitivity

- Low
- Medium
- High
- Very high
- Extremely high
- No data
- Survey area

0 250 500
Kilometres

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CLIENT
Oil and Gas UK

PROJECT
Oil and Gas UK SOSI

DRAWING TITLE
Upper range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in December

DRAWING NUMBER
HP00061-701-083

VERSION	DATE	Drawn	Checked	Approved
01	18/12/2015	CI	AW	KH
02	01/04/2016	CI	AW	KH

SCALE	PLOT SIZE
1:11,500,000	A4
DATUM	PROJECTION
WGS84	UTM30N

HiDef
AERIAL SURVEYING LIMITED

Figure 60 Lower range of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in December

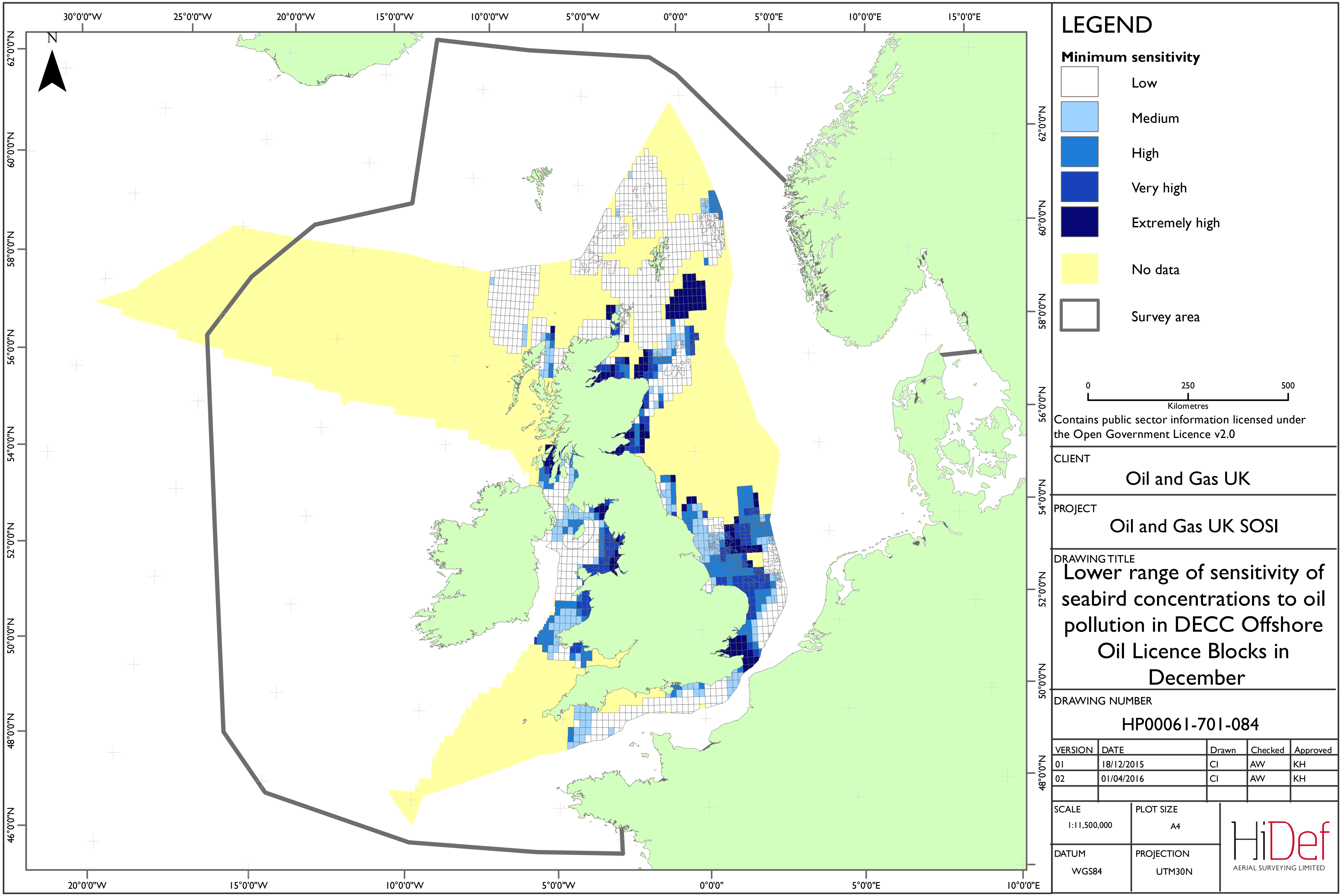
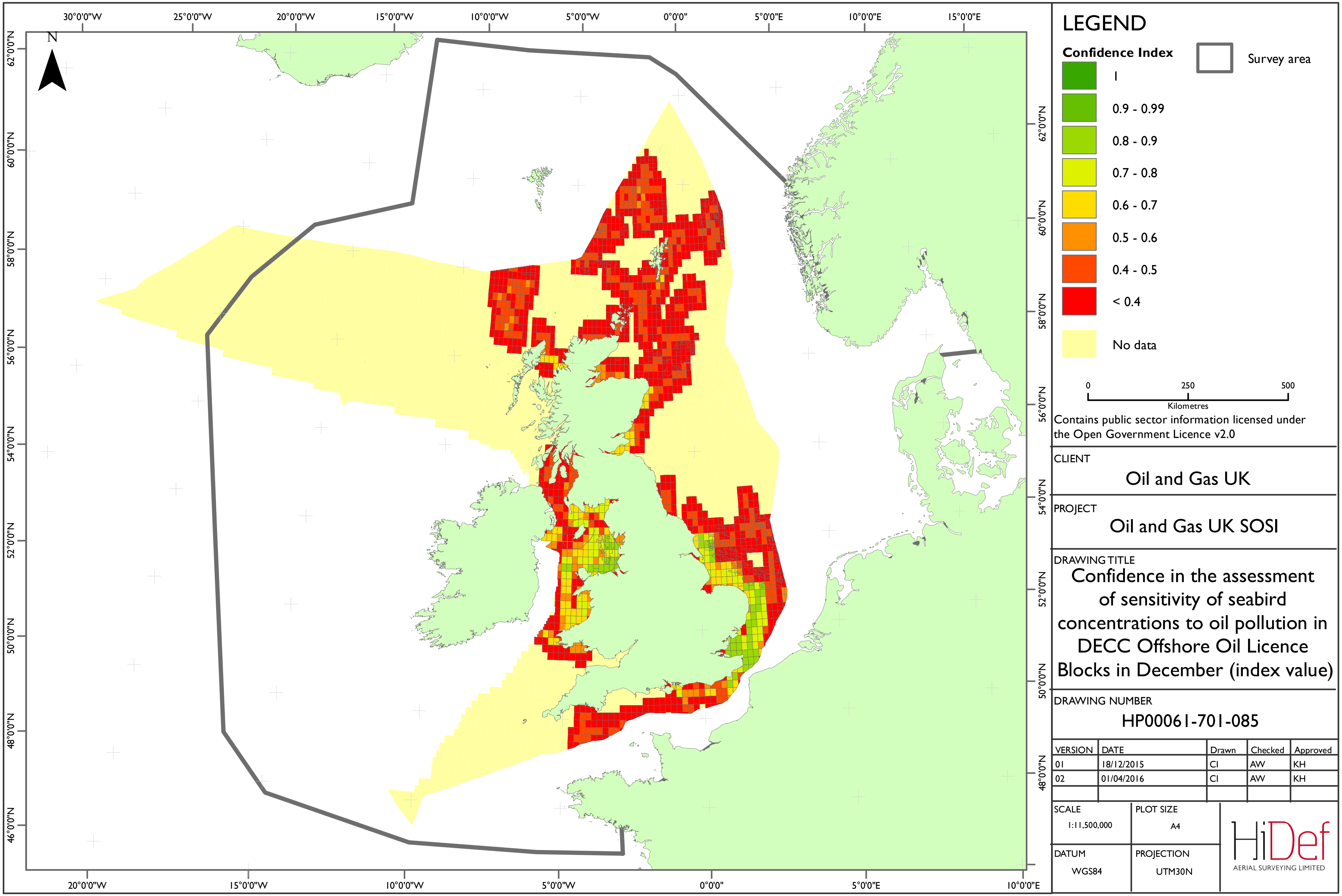


Figure 61 Confidence in the assessment of sensitivity of seabird concentrations to oil pollution in DECC Offshore Oil Licence Blocks in December (index value)



4 Discussion

4.1 Biases in data sources

118 Three types of survey data were identified for use in this analysis and were merged using correction factors to account for known biases of each survey method. It was necessary to make some assumptions about the biases present in each of these which were likely to lead to underestimates in overall abundance in some cases.

119 For boat-based surveys, it was necessary to assume that all birds were being detected in the closest two bands to the transect line. Given so many surveys by a very wide variety of observers in the ESAS database, this is unlikely to be true and would lead to an underestimate of abundance overall. Variation in the amount of this bias is likely to be small in comparison to overall changes in abundance exhibited by seabirds. There was an assumption that six species were exhibiting responsive movement towards the ship, based upon comparison between predicted numbers at sea from population models, and observed population estimates by Kober *et al.* (2010). This assumption is likely to be good, but it is also likely that more species might show responsive movement toward the ship that could not be corrected for (e.g. lesser black-backed and herring gulls). Again, these effects are likely to be small in the overall picture, and given the amalgamation of data for several species, are likely to get lost among other variation and biases in the data.

120 A similar assumption was made for visual aerial survey methods that all birds were detected in the closest distance band to the transect line, but variable observer efficiency and responsive movement are likely to mean that this is not true. Comparison with digital video aerial surveys suggest that this bias may lead to estimates from visual aerial survey methods for divers and auks as low as 40% of those from digital methods, (Webb and Garthe 2013). No correction for availability bias was possible for pursuit diving species, and this is likely to lead to a further under-estimate for divers and alcids. The results of surveys from inshore areas in the south of England where most of the visual aerial surveys were carried out are likely to give underestimates of the sensitivity of seabird concentrations to oil pollution in these areas. Oil licence blocks in which surveys were carried out using visual aerial techniques can be identified using maps in Appendix D.

121 We included both visual boat-based and visual aerial survey data in which not all species could be recorded. These surveys will result in underestimates of the sensitivity of seabird concentrations to oil pollution, because the total SOSI scores are dependent upon using abundance estimates of all species that were present, and not just a subset. The survey blocks in which such surveys were carried out are also mapped in Appendix D.

122 Digital video aerial surveys are known to be affected by availability bias. We made efforts to account for this bias, but often these adjustments were based upon inadequate data. For example, the adjustments made for common guillemot were based upon diving frequency for adults during the chick-rearing period (Thaxter *et al.* 2009). However, but there is no reason to believe that diving rates in the chick-rearing period are typical of any other time of the year, when different time constraints will apply. While the corrections made for these species were sometimes large, the scale of the errors are likely to be small in comparison to the scale of natural variation in seabird abundance.

4.2 Survey coverage

123 Overall coverage was moderately good in some months, particularly in July and August. However, coverage in other months was poor; in April, October and November, because the availability of survey data for this analysis was particularly poor.

124 The amount of survey data for previous studies of this type have never been absolutely complete (e.g. Tasker and Pienkowski 1987; Webb *et al.* 1995; Bradbury *et al.* 2014), but none of these had to deal with gaps in survey effort of the magnitude of the current report. Furthermore, the confidence in the data, where survey data were available, was mostly very low. This was caused by there being low quantity of data, over only one year, sometimes with missing species, and because the data were relatively old.

125 A potential solution to dealing with these gaps in coverage might have been to use density surface modelling to predict the abundance of seabirds in the gaps (e.g. Mackenzie *et al.* 2013). This approach models the abundance of seabirds at each location with covariates which includes at least the north-south and the east-west location but where possible with habitat variables. This method also uses the variance in the data to estimate the errors at specific locations too. This can be a very powerful tool, and if good models can be created, can give reasonably robust estimates at locations and times of year when there are no survey data. The main disadvantages are that good co-variate data for the entire region is unlikely to be available for anything other than sea depth which is likely only to explain only a small amount of the variation in abundance in the data; it is time-consuming and therefore expensive; and the number of encounters of any month may be too low for all but the most abundant species. By not including species in the final calculations, this will lead to under-estimates in the sensitivity scores.

126 Another solution might have been to combine months in the analysis. This might be possible for some of the winter months (e.g. December, January and February), when there are relatively few changes in seabird activity. But planning for and responding to oil pollution is very different to other human pressures, such as fishing or offshore wind farms, where the pressure is continuous throughout the year; to remove the ability to respond differently to changes in seabird sensitivity at different times of the year would have impacted on the quality of the product.

127 It is unlikely that it will be possible to improve data coverage and data analysis in the short term. Users of seabird oil sensitivity information should consider using information from adjacent months to those in which there is a serious gap for their particular project or application. It is possible also to refer to JNCC (1999), but the accuracy of those data, given their age, is likely to be poor.

4.3 Data smoothing

128 We used KDE to smooth raw data for the final analysis. The resulting distribution maps are more difficult to interpret than the summaries provided at the scale of the Oil Licence Block. This is mainly because of an effect of the smoothing algorithm which, at greater ranges from the sample location when survey data are sparse, produced improbable results. The outputs from this analysis were used to create the sensitivity maps using the Oil Licence Block, and many of those effects from the KDE analysis are averaged out in that process. We have presented the outputs of these maps in Appendix E, but not provided interpretation of them. These outputs and the underlying seabird density data are also available in the GIS outputs from this project.

4.4 Use of the Certain method for assessing sensitivity to oil pollution

129 The method proposed by Certain *et al.* (2015) is a detailed analysis of the types of information available for describing the different sensitivity factors that build to give the overall sensitivity of a seabird species to a human pressure. It is arguable that the method is over-elaborate, and a simpler method, as originated by Williams *et al.* (1995), could serve the same purpose.

130 In an ideal world, we would ground-truth different approaches for the accuracy of their predictions, but it would not be viable to all components of the index, which would require the ability to monitor population

effects, when the populations of origin of individual birds at any location are not known, and would also require a degree of experimental manipulation, which would be ethically unacceptable. The purpose of indices of this type are to provide a tool to allow expert judgement of the likely effects or impacts of a human pressure. While expert judgement is good at estimating the relative effect of different factors on a species, the relationship and weighting of these factors is much more difficult, and the method proposed by Certain *et al.* (2015) is a more objective way of doing this.

131 Certain *et al.* (2015) recommended that the sensitivity scores for each species are not multiplied by the respective density estimates, but suggests instead that the proportion of each species within the 'seabird community' at each location is divided by $1 - r$, and then overlaid by a density map of all seabird species combined. The overlap zone represents the region where seabird abundance is highest and the community sensitivity is highest. This method is best suited to binary 'Go / No Go' decisions, such as for determining where wind farms should or should not be located. Oil spill planning and reaction is more complex and more suited to a graded response based on a single continuous variable that combines abundance with sensitivity as we have done. It might be possible to generate multiple overlap zones of different scale by using different percentage cut-off points (see next paragraph), and thus provide something closer to a continuous scale as required for oil pollution response. However, this adds a high degree of complexity to the assessment method which might not add any real value.

132 Ultimately, one of the biggest judgements made is in the final process: the assessment of the cut-off points for presenting the SOSI maps. There are few data to support ours, Garthe and Hüppop (2004) and Certain *et al.*'s (2015) assessment that the threshold between low and moderate sensitivity should lie at 60th quantile of the Oil Licence Blocks. However, our judgement to use the 60 percentile threshold was based upon precedence, observations of the frequency distribution of the oil sensitivity values and seemed to make a degree of sense.

4.5 Comparison with previous assessments of sensitivity

133 The assessment of sensitivity of seabird concentrations to oil pollution in this report uses a different approach to that used in previous assessments around the UK. In particular, there is no temporal overlap in the data used in the two analyses, and because there is a difference in the overall proportion of oil licence blocks assigned to each of the sensitivity categories (e.g. 25% of blocks assigned to the low sensitivity category in JNCC (1999) and 60% of observations assigned to this category in the present study). Furthermore, there are five current SOSI categories (with the addition of extremely high sensitivity) compared to the four used in JNCC (1999).

134 In general, visual inspection of the location of areas of highest sensitivity matched expectations reasonably well, when compared with publications such as JNCC (1999). However, comparing is difficult, not just because of a change in methods, but also given the considerable reduction in the amount of data underlying the new analysis, where there are considerable coverage gaps.

135 One significant exception was noted: in spite of survey coverage having a high confidence rating in this publication during the month of August, the sensitivity of seabird concentrations in an area to the east of Aberdeenshire was only moderate to high, whereas this same region was one of the most important regions of high sensitivity in previous publications (JNCC 1999, Carter *et al.* 1993). On checking of the raw contributing data, this change appears to be real and represents a genuine change in the abundance of the most sensitive seabird concentrations between the two periods, and not because, for example, of differences in the method for calculating and defining the most sensitive areas between the this and the older assessments.

5 Conclusions and recommendations

136 The analysis of new data and the revision to methods have been successful in providing a new assessment of the sensitivity of seabird concentrations to oil pollution. In particular, this new analysis uses better methods for combining different sensitivity factors together and for combining these with abundance data for each species. This analysis also uses more recent data than its predecessors which better reflect the current abundance and distribution patterns around the UK (Webb *et al.* 2014).

137 This report adopted most parts of a method for analysing and compiling data for assessment of sensitivity to human pressures developed by Certain *et al.* (2015). While there is no way to ground-truth this approach, it appears to be based upon sound principles, and represents the best way to assemble seabird data with an assessment of individual species' sensitivity to oil pollution. Their recommendation of dividing the proportion of each species present at each location instead of the seabird density is best suited to 'Go / No Go' decisions, such as where best to build wind farms. We recommend that such an analysis should be tailored to the requirements of the end users, and for presenting an analysis of the sensitivity of seabird concentrations to oil pollution where interpretation by non-specialists is required, that seabird density and sensitivity are not separated, but merged into a single continuous measure of sensitivity, as we have done here.

138 This report used a large amount of visual aerial survey data, collected mainly around the English coast in areas earmarked for renewable energy developments. It was difficult to control for likely biases in these data, and seabird density estimates derived from these data were almost certainly biased downwards. Not to have used these data would have exacerbated a considerable problem with data gaps. A number of comparison studies have taken place between digital video aerial surveys and visual aerial surveys, and when fully analysed, these should be used to control the biases from visual aerial data in future compilations of different data types.

139 The amount of data used in this analysis represents a considerable decrease compared to the assessment presented in Stone *et al.* (1995), which were collected over a shorter time period and used in analysis for JNCC (1999). This large decrease in data collection is acute in the region of the oil exploration and production areas in the North Sea and west of Shetland where this report highlights considerable data gaps in all but two months of the year. If this analysis were to be renewed, for example, in five years then large amounts of older data would drop out of the analysis and would exacerbate an already serious shortfall in the data available (see Appendix D, Figures D37 to D48 where all red shaded areas would disappear).

140 The problem is acute because some of the gaps may hide important changes in the location of sensitive concentrations that have taken place since JNCC (1999) was produced.

141 We recommend strongly that steps are taken to begin addressing the most important of these data gaps, and to strengthening the quality of the data in with existing coverage. The GIS layers provided with this report can easily be used to generate a plan to prioritise how much and where new survey should take place.

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