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The use of harbour porpoise sightings data to inform the development of Special Areas of Conservation in UK waters.

Inter-Agency Marine Mammal Working Group

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Summary

This paper describes how harbour porpoise sightings data were used by UK's Statutory Nature Conservation Bodies (SNCBs) to identify possible Special Areas of Conservation (SACs). Two types of data have been analysed to investigate whether persistent high density areas for harbour porpoise exist in UK waters; these are effort-related sea-based data (collected from ships and aircraft) and effort-related land-based data (collected from coastal locations). Datasets were only used where permission had been granted by the data holders. The analysis of sea-based data was carried out by DHI Water and Environment Ltd. This analysis modelled the distribution of harbour porpoise density using a suite of environmental variables over an 18 year period (1994-2011) within 3 Management Units encompassing the range of harbour porpoises in UK waters. The land-based analyses, carried out by a consortium led by the SeaWatch Foundation, modelled the probability of occurrence of harbour porpoise around the UK coastline through time (1994-2014). Both analyses took into consideration, to differing degrees, the criteria of the EU Habitats Directive and its associated guidance. The primary outputs from the sea-based analysis were maps of areas, by season and Management Unit, that persistently contained densities of harbour porpoises that were relatively higher (within the top 10% of all densities) than elsewhere. From these, Areas of Search were identified taking into account the confidence in the underlying model predictions and associated survey data. These Areas of Search were refined further using a set of principles to define boundaries to develop a series of geographically spread sites that represents the distributional range of harbour porpoises in UK waters. The refinement of site boundaries also took into consideration land-based data where sites bordered the coast. The UK's proposed interpretation of 'sufficiency' of these sites as a UK network and the individual site grading is also considered.

The process resulted in a potential network of harbour porpoise sites within the UK portions of Management Units. The Welsh and Northern Ireland Governments, along with Defra on behalf of England and Secretary of State Offshore waters, gave approval for sites within their areas of jurisdiction to proceed to consultation.

Crynodeb

Mae'r papur hwn yn disgrifio sut y cafodd achosion o weld llamidyddion eu defnyddio gan Gyrff Gwarchod Natur Statudol y DU er mwyn pennu Ardaloedd Cadwraeth Arbennig posibl (ACAp). Mae dau fath o ddata wedi'u dadansoddi er mwyn canfod a oes ardaloedd dwysedd uchel parhaol ar gyfer llamidyddion i'w cael yn nyfroedd y DU. Data 'yn ôl ymdrech' oddi ar y môr yw hwn (a gasglwyd oddi ar longau ac awyrennau), ynghyd â data 'yn ôl ymdrech' oddi ar y tir (a gasglwyd oddi ar leoliadau arfordirol). Dim ond ar ôl cael caniatâd gan ddeiliaid y data y defnyddiwyd setiau data. Cafodd dadansoddiad o ddata'r môr ei gynnal gan *DHI Water and Environment Ltd*. Aeth y dadansoddiad hwn ati i fodelu dosbarthiad dwysedd llamidyddion trwy ddefnyddio cyfres o newidynnau amgylcheddol dros gyfnod o 18 mlynedd (1994-2011) o fewn 3 Uned Reoli a oedd yn cwmpasu dosbarthiad llamidyddion yn nyfroedd y DU. Aeth y dadansoddiadau o ddata'r tir, a wnaed gan gonsortiwm dan arweiniad y *Sea Watch Foundation*, ati i fodelu'r tebygolrwydd o weld llamidyddion o amgylch arfordir y DU dros amser (1994-2014). Yn ystod y ddau ddadansoddiad ystyriwyd i wahanol raddau feini prawf Cyfarwyddeb Cynefinoedd yr UE a'i chanllawiau cysylltiedig. Prif ganlyniadau dadansoddiad data'r môr oedd mapiau o ardaloedd, fesul tymor ac Uned Reoli, a oedd yn cynnwys yn barhaol ddwysedd o lamidyddion a oedd yn gymharol uwch (o fewn y 10% uchaf o ddwyseddau) nag mewn mannau eraill. Ar sail y rhain, pennwyd Ardaloedd Chwilio gan ystyried yr hyder yn rhagfynegiadau sylfaenol y model a data cysylltiedig yr arolwg. Cafodd yr Ardaloedd Chwilio hyn eu mireinio ymhellach trwy ddefnyddio cyfres o egwyddorion i ddiffinio ffiniau er mwyn datblygu cyfres o safleoedd wedi'u gwasgaru'n ddaearyddol sy'n cynrychioli dosbarthiad llamidyddion yn nyfroedd y DU. Wrth fireinio ffiniau'r safleoedd ystyriwyd hefyd ddata'r tir pan oedd y safleoedd yn ffinio ar yr arfordir. Ymhellach, ystyrir dehongliad arfaethedig y DU o 'ddigonolrwydd' y safleoedd hyn fel rhwydwaith ar gyfer y DU a graddau'r safleoedd unigol.

Arweiniodd y broses at rwydwaith posibl o safleoedd ar gyfer llamidyddion o fewn rhannau'r DU o'r Unedau Rheoli. Rhoddodd Llywodraethau Cymru a Gogledd Iwerddon, ynghyd â Defra ar ran Lloegr a'r Ysgrifennydd Gwladol Dyfroedd Alltraeth, ganiatâd i safleoedd o fewn ardaloedd eu hawdurdod symud ymlaen at gynnal ymgynghoriad.

Contents

1 Background

Article 4 of the EU Habitats Directive sets out the provisions for the selection of Special Areas of Conservation (SACs) for Annex I habitats and Annex II species. Key to the designation of SACs is Article 4(1), the relevant part of which states: '...*For aquatic species which range over wide areas, such sites will be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction*'.

Annex III of the Directive further sets out four criteria for selecting SACs for harbour porpoise (and other Annex II species). Of these, the Annex III criterion (a) is the most important in defining 'clearly identifiable' areas as: *Size and density of the population of the species present on the site in relation to the populations present within the national territory.* The size and density criterion is challenging to apply to the harbour porpoise because it is a wide-ranging mobile species, and further (non-binding) guidance on this has been provided by the European Commission (EC, 2007):

"*It is possible to identify areas representing crucial factors for the life cycle of this species [harbour porpoise]. These areas would be identifiable on the basis of:*
i) The continuous or regular presence of the species (although subject to seasonal variations);
ii) Good population density (in relation to neighbouring areas);
iii) High ratio of young to adults during certain periods of the year.
Additionally, other biological elements are characteristic of these areas, such as very developed social and sexual life."

2 Datasets used in analyses

Two visual survey data types exist for harbour porpoises that provide large-scale coverage in UK waters;

i) sea-based data collected from shipboard or aerial surveys; and
ii) land-based data collected from vantage points around the UK coastline.

Only effort-related survey data (i.e. where the sightings data can be related to the amount of surveying (effort) carried out) were used in the analyses of both data types to ensure bias in surveying patterns (spatially and temporally) could be accounted for. There is no single source of sea-based survey data, instead data have been compiled using the Joint Cetacean Protocol (JCP)[1] and comprise about 545 distinct effort-related surveys from ships and aircraft and spans 18 years of data collection (1994-2011). Not all of the data are public and therefore the majority remain under the control of the data owner. The total amount of survey effort collated amounted to approximately 1 million km of survey effort (distance over which surveying was carried out) and approximately 20,000 sightings of harbour porpoise. Previous analyses of the JCP (Paxton *et al,* 2011 & *in press*) developed a standardisation process that enabled the disparate datasets to be pooled. This included the statistical correction of the number of sightings of harbour porpoises due to differences in detection probabilities across the multitude of survey platforms, survey conditions and protocols.

Permission to use the datasets comprising the JCP for the purposes of an analysis investigating whether harbour porpoise SACs could be identified was expressly sought from each of the data owners/providers; only where permission was granted was the dataset used. The effort from the sea-based surveys was split into approximately 10km segments, each with its associated corrected number of harbour porpoise sightings. These segments were the starting point for an analysis undertaken by DHI Water Environments (UK) Ltd (DHI) with the aim of determining whether 'clearly identifiable' areas could be located for harbour porpoise (Heinänen and Skov, 2015a).

Land-based watches for cetaceans have been conducted at a large number of locations around the UK since 1965. It was not, however, until the 1980s that the watches began to follow protocols that required survey effort to be recorded (Evans *et al*, 2015). Dedicated effort-related land-based survey data were compiled from a wide range of UK sources with consent from data providers. This was part of a contract with a consortium led by the Sea Watch Foundation to analyse these data in the context of identifying coastal areas of persistent higher densities of harbour porpoises. Data for the analyses came from 678 locations and amounted to over 75,000 hours of survey effort and around 50,000 sightings from 1994 to 2014. The land-watch effort is reasonably well distributed around the UK, but certain areas (notably the west of Scotland, and to a lesser extent, south-east England) have relatively poor coverage, and a few areas (e.g. the Shetland Islands) have had little watch effort since the 1990s; the majority of effort has been in the last ten years (Evans *et al,* 2015).

[1] See http://jncc.defra.gov.uk/page-5657

3 The analyses

3.1 Sea-based data analysis (Heinänen and Skov, 2015a, b)

Harbour porpoises in most of the eastern North Atlantic are generally considered to behave as a 'continuous' biological population that extends from the French coasts of the Bay of Biscay northwards to the arctic waters of Norway and Iceland (Tolley and Rosel, 2006; Fontaine *et al,* 2007, 2010, 2014). Only the Iberian and Baltic populations are considered distinct (Fontaine *et al,* 2007 and 2010). For conservation and management purposes, however, it is practical to divide the population into smaller units, termed Management Units (MUs). These smaller MUs reflect differences, to some extent, in the spatial preferences of individuals and also the spatial variation in human activities. In the UK, three MUs have been defined for harbour porpoise: West of Scotland, Celtic and Irish Seas, and North Sea (Figure 1) (IAMMWG, 2015). These areas have also been used by ICES (2014) to define Assessment Units (ICES, 2014) for this species in wider European waters.

The 10km effort segments and their associated corrected counts of harbour porpoise sightings (abundance) (1994-2011) were assigned to the relevant MU and season (summer April-September; and winter October-March) in which they were collected. Environmental variables relating to the harbour porpoise's 'habitat', including one anthropogenic pressure - the intensity of shipping traffic - were spatially and temporally linked to the corresponding effort segment. The abundance per effort segment was then modelled against the identified suite of environmental variables, such as water depth, seabed sediment type and currents. The survey data included a significant number of zero entries, due to a large number of segments with no porpoise sightings. This was dealt with by using a 'hurdle model' (Stefánsson, 1996; Heinänen *et al,* 2008), which is a two-step Generalized Additive Model[2] (GAM; Hastie and Tibshirani, 1990). The final model for each MU was a GAM with an interaction term between latitude and longitude, time period and the significant environmental variables. The latitude-longitude interaction term was added to explain some of the spatial differences not accounted for by the environmental variables alone. The inclusion of a time-period term (1994-1999, 2000-2005 and 2006-2011) captured any changes in the distribution of porpoises over time. The data used in the models extended beyond the UK portion of the MUs so as to minimise 'edge effects' at the boundaries of the MU where model fit is generally poor. These models were then used to predict seasonal average density surfaces (the surface is comprised of a grid of cells, each 5km x 5km, and within each is an estimate porpoise density) for each MU and each year. The associated standard error (a measure of confidence in the density estimate) was calculated by using the formula developed for estimating the statistical variances of the product of two or more random variables; in this instance, the random variables are the predicted outputs from the two stages of the model in each grid cell (Goodman, 1960).

[2] A GAM is simply a statistical technique that is used to explore the relationship between a response variable (such as harbour porpoise density or presence) and a suite of environmental variables (such as water depth). Each of the environmental variables is modelled in turn and in combination with each other ('interactions'). The most significant variables will be identified as the best 'predictors' of the response variable i.e. there is a relationship between them. These variables and their relationship to the response are expressed as the 'Final Model'.

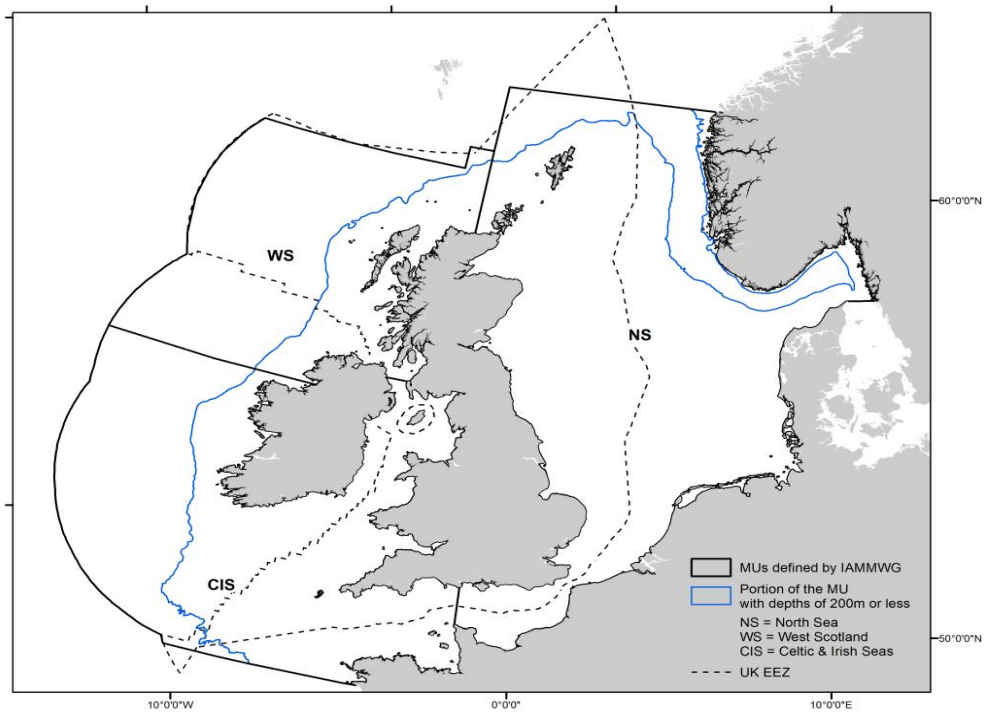

Figure 1: Management Units for harbour porpoise defined by the UK Inter-Agency Marine Mammal Working Group (IAMMWG, 2015). These areas were used by ICES (2014) to define Assessment Units in wider European waters.

Relatively higher density areas within each seasonal-annual density surface were identified based on the 90th percentile i.e. grid cells with a value of density ranked within the highest 10% of the gridded density estimates for the entire MU were selected. The decision to use the 'top 10%' was based on the work of Embling *et al*. (2010) which used a perimeter length to area ratio approach to identify areas for harbour porpoise protection off the west coast of Scotland. By comparing areas with the top 1%, 5% and 10% of densities, the perimeter–area ratio was lowest (desirable) and its confidence interval was narrowest for areas defined by the 10% threshold. This was therefore adopted for this work.

The most *persistent* high-density areas within the top 10% layer were then identified by scoring both the number of years when 'high densities' were predicted (a scale from 0 to 1) and a measure of how recent these 'high densities' were (a scale from 0 to 1). As the number of years and degree of recent high densities may trade off each other (e.g. in cases with recent high densities over few years or historical high densities over a larger range of years), the scores were averaged to provide a final persistency index (Robertson *et al*, 2004); areas with a score of over 0.5 were selected. To reduce 'noise' in the resulting maps of persistent high-density areas, continuous areas smaller than 100km^2 were removed. The persistency analyses ultimately represent the final step in the identification of areas that have persistent higher densities of harbour porpoises, and should be 'clearly identifiable' from surrounding areas. The analysis process is shown in Figure 2.

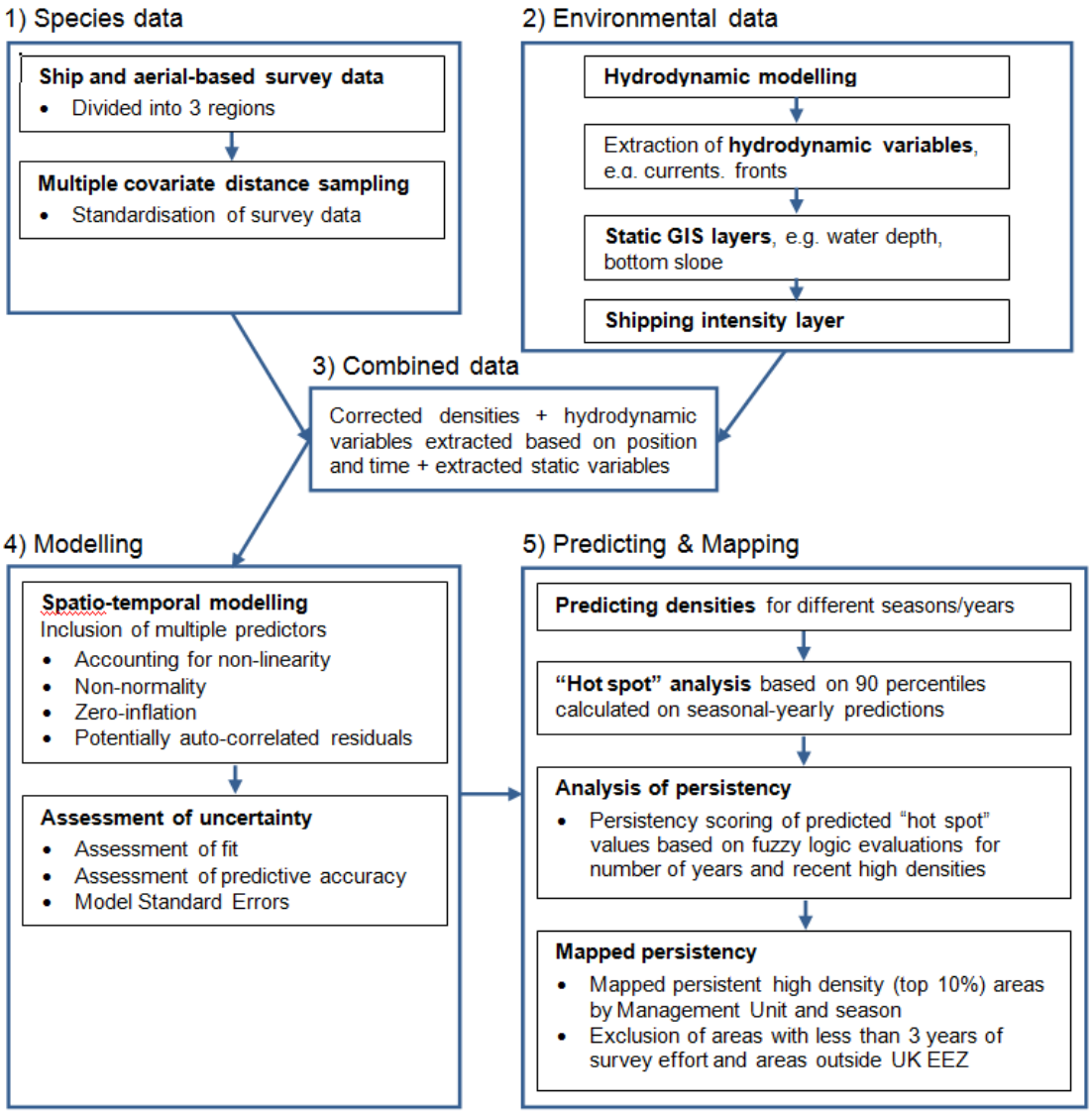

Figure 2: The steps used in analysing the Joint Cetacean Protocol data (Heinänen and Skov, 2015a).

The draft report of Heinänen and Skov (2015a) was peer reviewed by three external reviewers in addition to review by the IAMMWG. The comments received were considered and addressed by DHI in the final report.

An additional analysis (Heinänen and Skov, 2015b) was carried out by DHI in late 2014 to provide outputs that represented a general picture of the predicted density and associated confidence for the entire time period (1994-2011) by MU and, where appropriate, by season. The outputs of this analysis were used towards the end of the process of identifying draft SACs to validate the areas chosen.

3.2 Land-based data analysis (Evans *et al,* 2015)

The nature of the land-based survey dataset required a different modelling approach to be taken to that of Heinänen and Skov (2015a). It was not possible to include environmental variables in the modelling to describe the habitat of the harbour porpoise (given there was no

measurement of the effectively surveyed area from the coast), or to undertake a seasonal analysis, as the vast majority of land-based sighting surveys are limited to the summer months between May and September. For the analysis, sighting and count rates (animals per hour) for each year between 1994 and 2014 were initially calculated for each of the 678 locations. GAMs were then used to predict the likelihood of occurrence by time periods so that changes over time could be assessed (middle six months of the year for the period 1994-2014, and for the whole year during time periods 1994-2003, 2004-2014, and 1965-1993), accounting for explanatory variables that affect observer's ability to observe harbour porpoise, e.g. sea state, elevation and use of optical instruments. Two fundamental models were used, including latitude and longitude (Model A), or site number as a proxy for position along the coastline (Model B). Locations at which there were at least three years of survey effort, with a minimum of 100 minutes of effort per year (i.e. five hours minimum of watch effort overall) were selected for plotting the GAM predictions. The GAMs were run separately for each MU. Locations with values of counts per unit effort and predicted likelihood of occurrence (from the GAMs) within the top 10% of all values in the MU were identified; this was for consistency with the 'threshold' chosen for the sea-based density estimates.

The draft report of Evans *et al*, (2015) was peer reviewed by three external reviewers in addition to review by the IAMMWG. The comments received were considered in production of the final report.

4 Modelled outputs as the basis of area selection

Due to the widespread distribution of harbour porpoises, the sea-based survey data were considered more appropriate for identifying draft SACs since the land-based survey data has limited relevance beyond 1-2km of the shore. With reference to the Directive (Criterion IIIa) and associated guidance for site identification, it was not possible to evaluate the land-based survey data outputs (predicted likelihood of harbour porpoise occurrence) in terms of locations having '*good population density (in relation to neighbouring areas)'* and being '*clearly identifiable*'. However, it was recognised that land-based data may provide contextual information on the sea areas selected from the DHI models.

The modelling approach of Heinänen and Skov (2015a) effectively included site-selection criterion IIIa of the Directive and associated sub-criteria in the guidance (EC, 2007) (**Error! Reference source not found.**). The approach predicted densities throughout the UK shelf (by MUs) to identify areas of persistent (sub-criterion i) and higher density relative to other areas (sub-criterion ii). The modelling also identified the environmental variables that supported higher densities of porpoise, thereby providing information on *physical and biological factors essential to their life and reproduction*. The data were insufficient to allow the proportion of calves to adults (sub-criterion iii) to be assessed because survey protocols have not consistently required the presence of calves to be recorded, and on many occasions it is not possible to distinguish calves from older porpoises.

The key outputs from the DHI analyses included annual and seasonal maps (comprising 5km x 5km grid cells) of predicted porpoise density and an associated measure of confidence in the model (coefficient of variation (CV) = Standard Error (SE)/density). Figure 3 shows some examples of predicted density and confidence maps for summer 2009 for each MU. These seasonal-annual maps were not the basis of site identification; these density layers were then further analysed (see Section 3, 'The Analyses') to produce overall maps of areas in which the density estimates of harbour porpoise were persistently (over the 18 year time span) within the top 10% of density estimates for the entire MU. The persistent areas with the top 10% of predicted harbour porpoise density were identified by MU and season (except for the West Scotland MU, where winter data were not available) (Figure 4).

Table 4.1: Summary of the use of the criteria and sub-criteria to identify possible harbour porpoise SACs. MU = Management Unit. Source refers to the sea-based (S) and land-based (L) analyses. AoS = Areas of Search; Y = Yes; N = No.

Criterion/ sub-criterion	Source	Can Criterion be assessed	Approach	Scale
Article 4.1 ...*'For aquatic species which range over wide areas, such sites will be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction*'.	S	Y	Density mapping at MU scale and areas delineated the top 10% of density estimates	MU
	L	Y	Presence mapping at MU scale, with locations identified by the top 10% of relative presence	
a) Size and density of the population of the species present on the site in relation to the populations present within the national territory	S	Y	Density surfaces generated per annum and season	MU & site
	L	N	Relative presence (occupancy) provides proxy for abundance Published literature to support link between presence and abundance	
b) Degree of conservation of the features of the habitat which are important for the species concerned and restoration possibilities	S	Y	Features of the habitat identified as important for the species through distribution models. Generally not able to judge restoration possibilities	MU & site
	L	N		
c) Degree of isolation of the population present on the site in relation to the natural range of the species	S	N		MU
	L	N		
d) Global (overall) assessment of the value of the site for the conservation of the species concerned	S	Y	Provides site-specific abundance information & habitat which can be placed in context of information on population status	MU & pop.[3]
	L	N		
Guidance sub-criteria: Continuous or regular presence of the species (subject to seasonal variations)	S	Y	Persistency index derived over space and time (annually and seasonally)	MU & site
	L	Y	Presence at individual location over time and seasons	Site
Guidance sub-criteria: Good population density (in relation to neighbouring areas)	S	Y	Large scale density mapping allows comparisons between areas	MU MU
	L	Y	Large scale mapping of probability of presence allows comparisons between areas of coast	
Guidance sub-criteria: High ratio of young to adults during certain times of the year	S	N		Site
	L	N		
Additional element in Guidance: Other biological elements that are characteristic, such as very developed social and sexual life	S	Y	Environmental variables used as proxies for prey distribution to model density. Represents 'biological elements'. Unable to judge social and sexual life.	MU & site
	L	N		

[3] Population

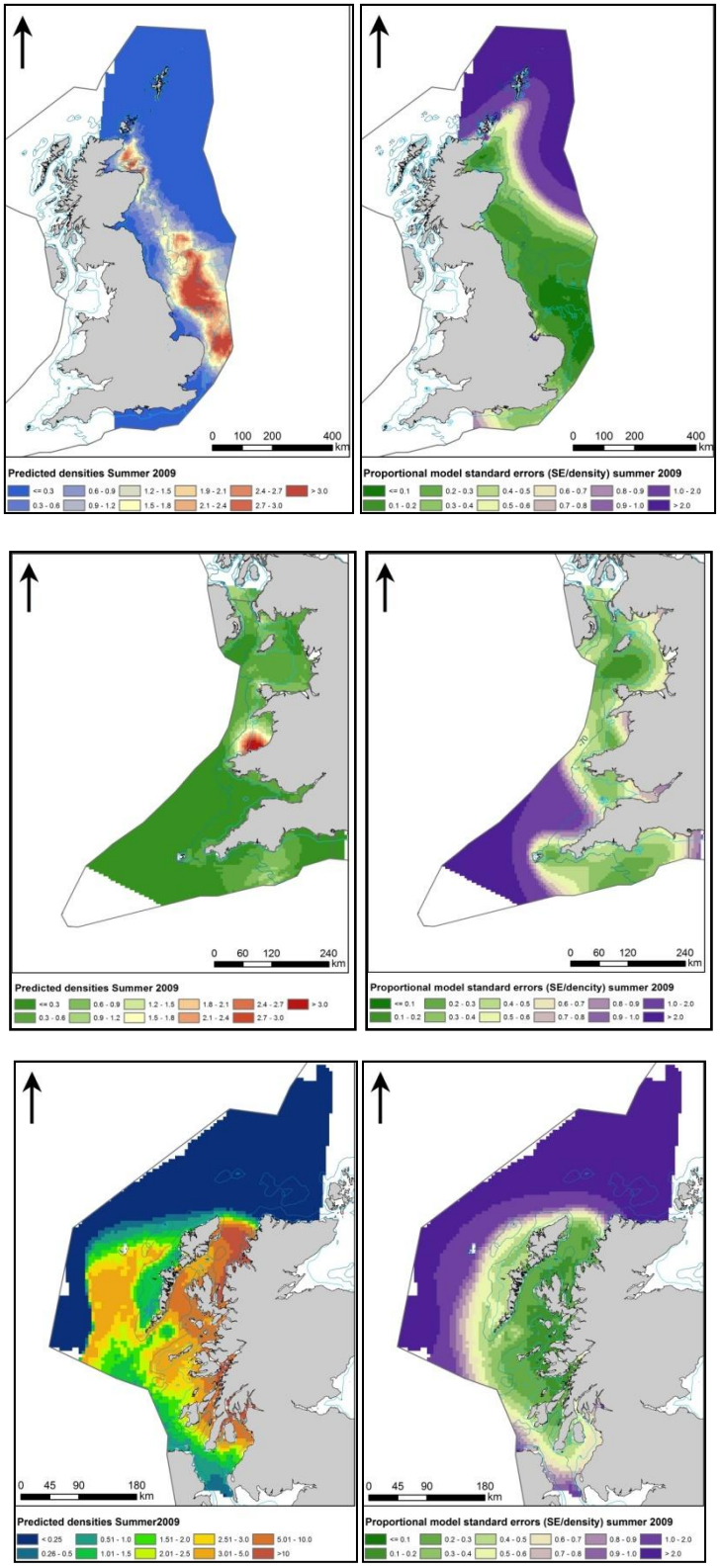

Figure 3: Examples of mapped outputs of harbour porpoise density (left) (increasing density from either blue to red (top), green to red (middle), or blue to orange (bottom) and model confidence (SE/density = coefficient of variation [CV]) (right) (decreasing confidence from green to purple) for the North Sea MU (top); Celtic and Irish Seas MU (middle) and West Scotland MU (bottom) during summer 2009.

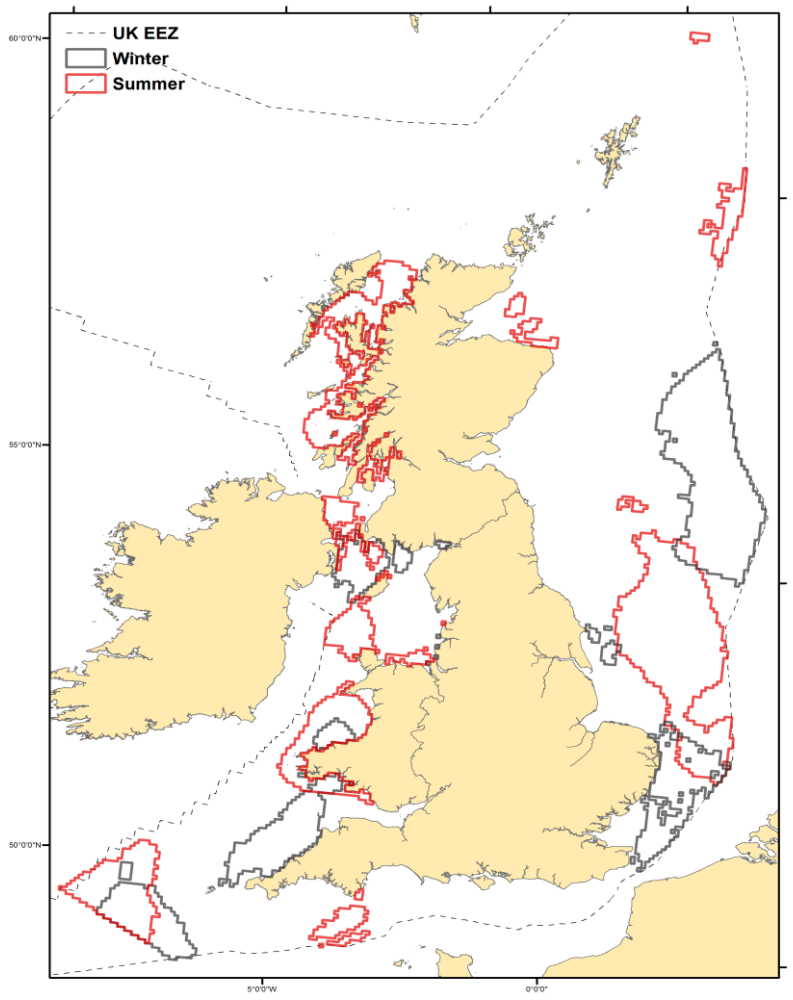

Figure 4: Areas persistently containing the top 10% of harbour porpoise predicted density by season identified from the at-sea dataset. There were no winter data for West Scotland (after Heinänen and Skov, 2015a).

For the land-based survey data, locations with the highest (top 10%) predicted likelihood of occurrence of harbour porpoise were identified. Counts per unit effort were not used due to potential bias in these estimates. Note that density could not be estimated from the land-based data. These locations were then filtered to choose only those with 100+ minutes per year of survey effort for at least three years. The modelled outputs of these locations were then assessed against persistence – for how many blocks of time was the predicted likelihood of occurrence at each location in the top 10% of values within the MU. For consistency with the assessment of the sea-based outputs, data only for locations were retained that had likelihood of occurrence in the top10% for summer months using either model (A or B) for the entire period (1994-2014). Figure 5 maps these locations. How well the modelling approach of Evans *et al.* (2015) considered the site-selection criteria and associated sub-criteria is summarised in Table 4.1.

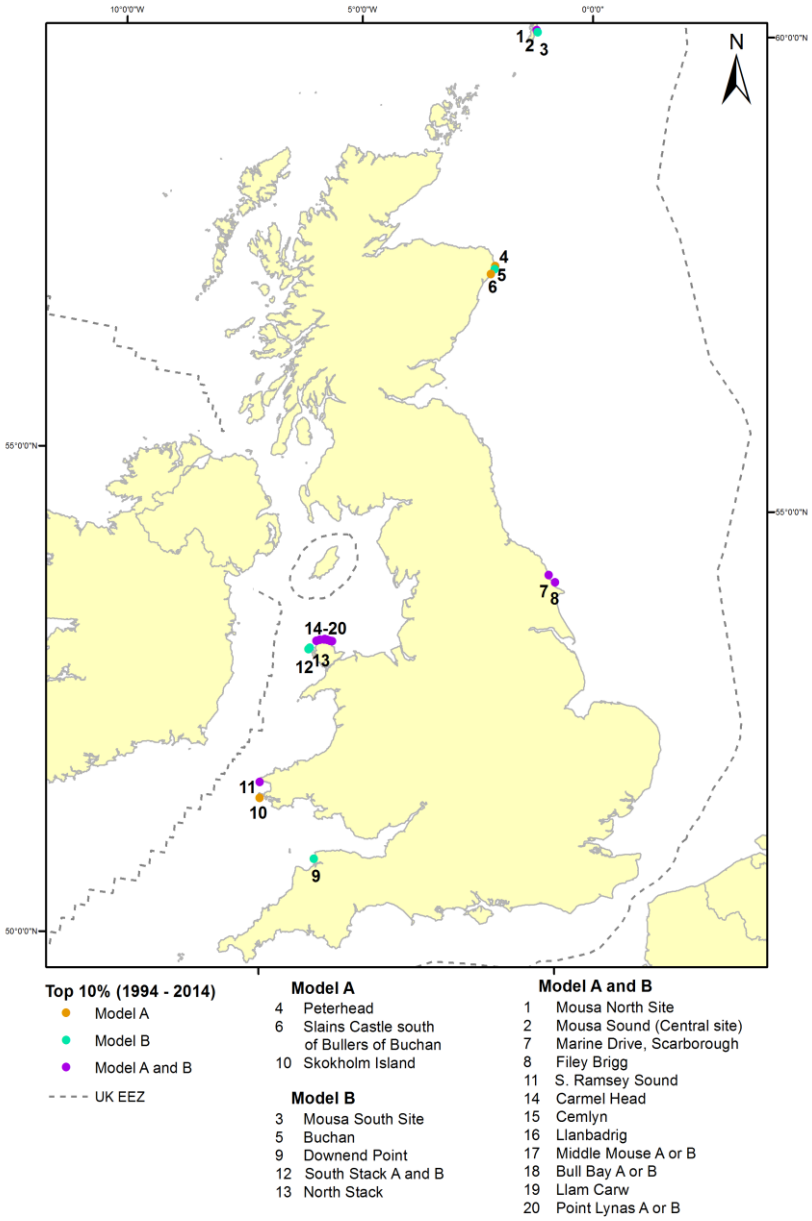

Figure 5: Land-based observation locations with values of predicted likelihood of occurrence of harbour porpoise within the top 10% throughout the time period 1994-2014 based on both models A (latitude x longitude) and B (site location) (see Evans *et al*, 2015).

5 Developing Areas of Search

In the context of this work, the term 'Area of Search' (AoS) is an area from within which SACs may be identified.

The starting maps for deriving AoS were those showing the areas of persistent top 10% of density for each season by MU (Figure 4). DHI also produced the same maps but filtered to show those areas with 3 years or more of survey data. However, these effort- filtered data were not used; the areas were relatively small and it was logical that AoS should be large and then refined to ultimately identify SACs. Instead, the persistent top10% areas were refined based primarily on the confidence in the underlying data (amount of survey effort and sightings) *and* in the model itself; taking all these factors into account (through criteria outlined below) was a more robust method than filtering by survey effort alone.

The level of confidence in the DHI model predictions and consequently within the areas identified as persistently containing the top 10% of porpoise density, varied spatially and through time (annually and seasonally); this variability was the basis of the criteria to identify a set of recommended AoS. To understand this variation, data behind the annual confidence layers from DHI were processed to show the number of years in each 5km x 5km grid cell that the model confidence (coefficient of variation, CV)[4] was <0.3 (see footnote [5]) (Figure 6).

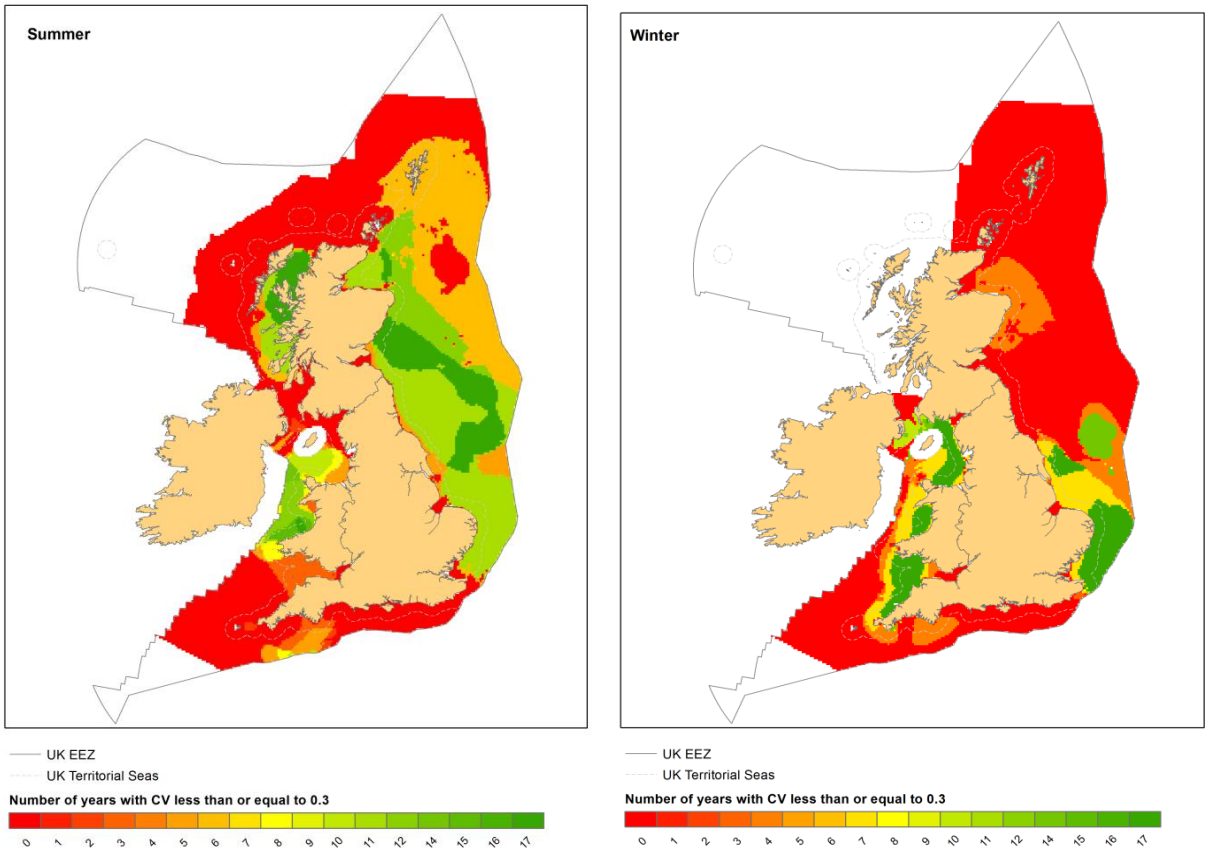

Figure 6: Gridded distribution of the number of years with model confidence <0.3 for summer (left) and winter (right).

[4] The Proportional standard Error = standard error/density used in Heinänen and Skov (2015a) is referred to here as the CV.
[5] This is the variation around the density estimate for each pixel. The threshold CV of 0.3 is generally considered to be reasonable (Taylor and Gerrodette, 1993; Taylor *et al,* 2007). It is also the threshold used in relation to bycatch monitoring by EU Regulation 812/2004.

The confidence over each of the large contiguous persistent top 10% areas was then assessed based on three grades of confidence in the majority (>50%) of each area defined as:

High = the CV was less than 0.3 for 10 or more years;
Moderate = the CV <0.3 for 5 to 9 years; and
Low = where CV <0.3 for less than 5 years

Additionally, consideration was given to whether the predicted areas of persistent top 10% density were supported by actual observations of harbour porpoise (verifying the model outputs) and the geographical spread of those observations over the area (Figure 7). These combinations of considerations lead to a decision matrix (Table 5.1) and this was initially applied to the summer and winter areas of persistent top 10% of density to identify the first draft of AoS within each MU.

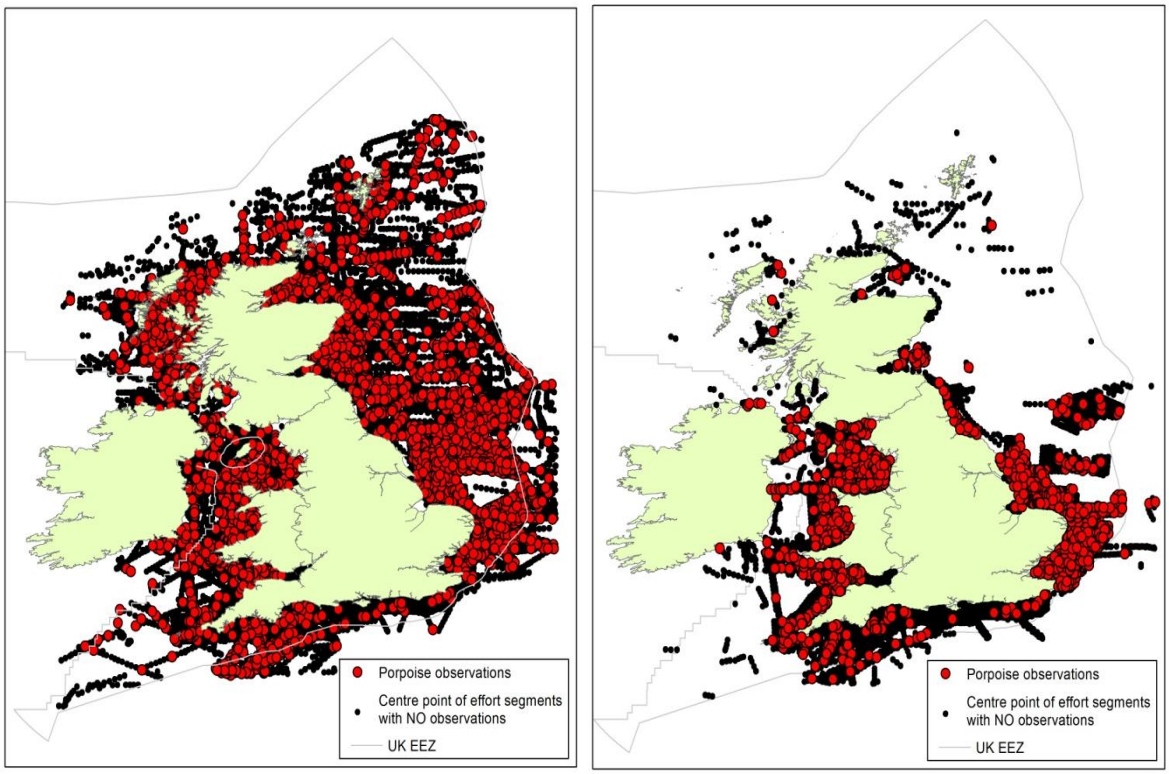

Figure 7: Distribution of harbour porpoise 'sightings' (effort segments with harbour porpoise density >0) and central location of effort segments with no sightings for summer (left) and winter (right). Some datasets extended beyond the UK Exclusive Economic Zone (EEZ) and were used in the model so as to limit edge effects at the EEZ boundary during predictions.

Table 5.1: Decision matrix applied to the areas with the persistent top 10% of harbour porpoise density for initial classification of first draft Areas of Search. Confidence is measured as the number of years (within the 1994-2011 period) during which the Coefficient of Variation (CV) in the area was below the desired threshold of 0.3.

Confidence within the majority (>50%) of the persistent top 10% density area		**Spread of sightings within the persistent top 10% density area**			
		Low	Moderate	High	High
		<10% (by area)	25% or more[6] (by area)	50 % or more (by area)	100% (by area)
Confidence in modelled density (i.e. number of years where the CV of the prediction for the area is<0.3)	High (≥10 years)	AoS	AoS	AoS	AoS
	Moderate (5-9 yrs)	Not AoS	AoS	AoS	AoS
	Low (<5 yrs)	Not AoS	Not AoS	AoS	AoS

The spread of sightings within these first draft AoS is driven by the distribution and to some extent the amount of survey effort. The first draft AoS were therefore further filtered based on the number of years for which there had been survey effort in the majority of the AoS (Figure 8). Those first draft AoS with a majority low model confidence were discarded at this stage. Within the remaining moderate/high model confidence areas, those with sufficient survey years (defined as three or more years) throughout the majority (>50%) but with a low spread of observations were discarded on the basis that despite considerable survey effort few sightings were made (the data did not convincingly support the model predictions). However, some of the remaining first draft AoS that had high model confidence, but low survey years (<3 years), were retained. The latter decision was based on the fact that the model predicted, with high confidence, high densities of porpoise but the low survey effort is likely the cause of the low observations.

A filter based on size was then applied and areas less than 500km^2 were removed because such small areas are likely to be ineffective for porpoise conservation relative to the much larger areas identified. The result of the above combined stages was a second draft of AoS.

At this stage, only the remainder of the draft AoS with high confidence over the majority of the area were retained in the recommended AoS (Figure 9). The process for defining the recommended AoS is set out in Figure 10.

[6] No areas had a spread of sightings that covered between 10-25%; hence there is no category.

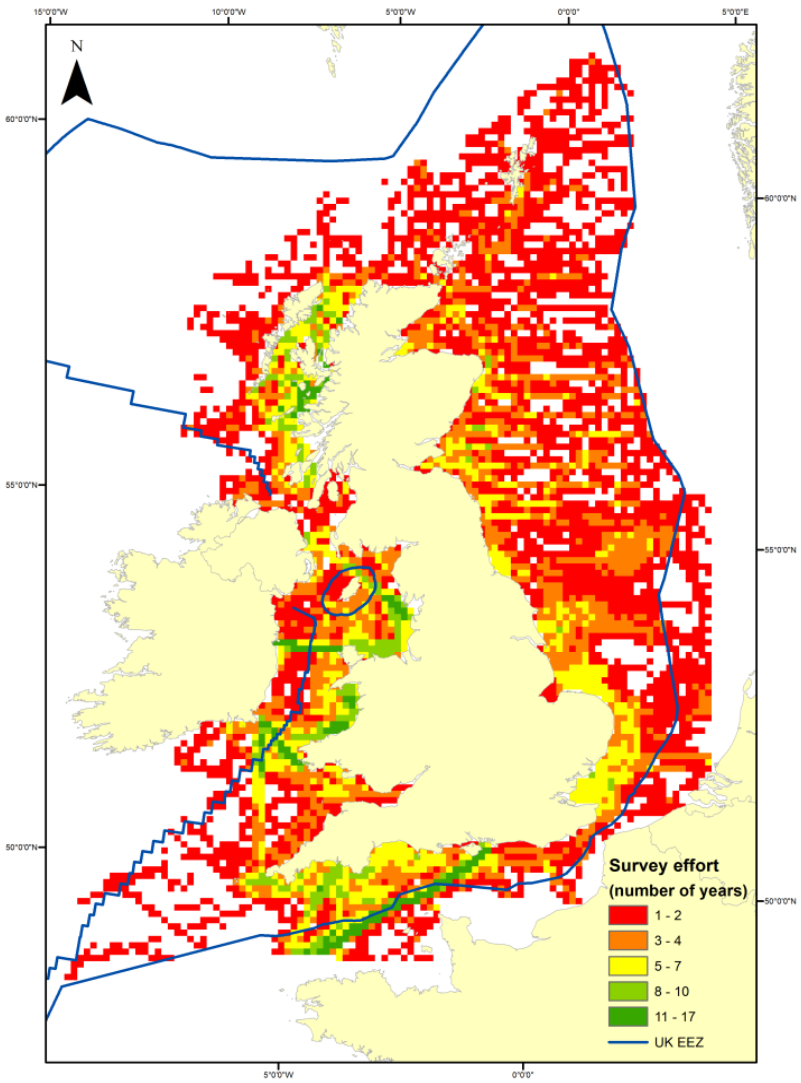

Figure 8: Number of years with survey coverage in each 5km x 5km grid cell within UK EEZ. Red pixels indicate those areas that have only one or two years in which surveys occurred, whilst orange, yellow and green pixels indicate areas when surveys occurred in three or more years.

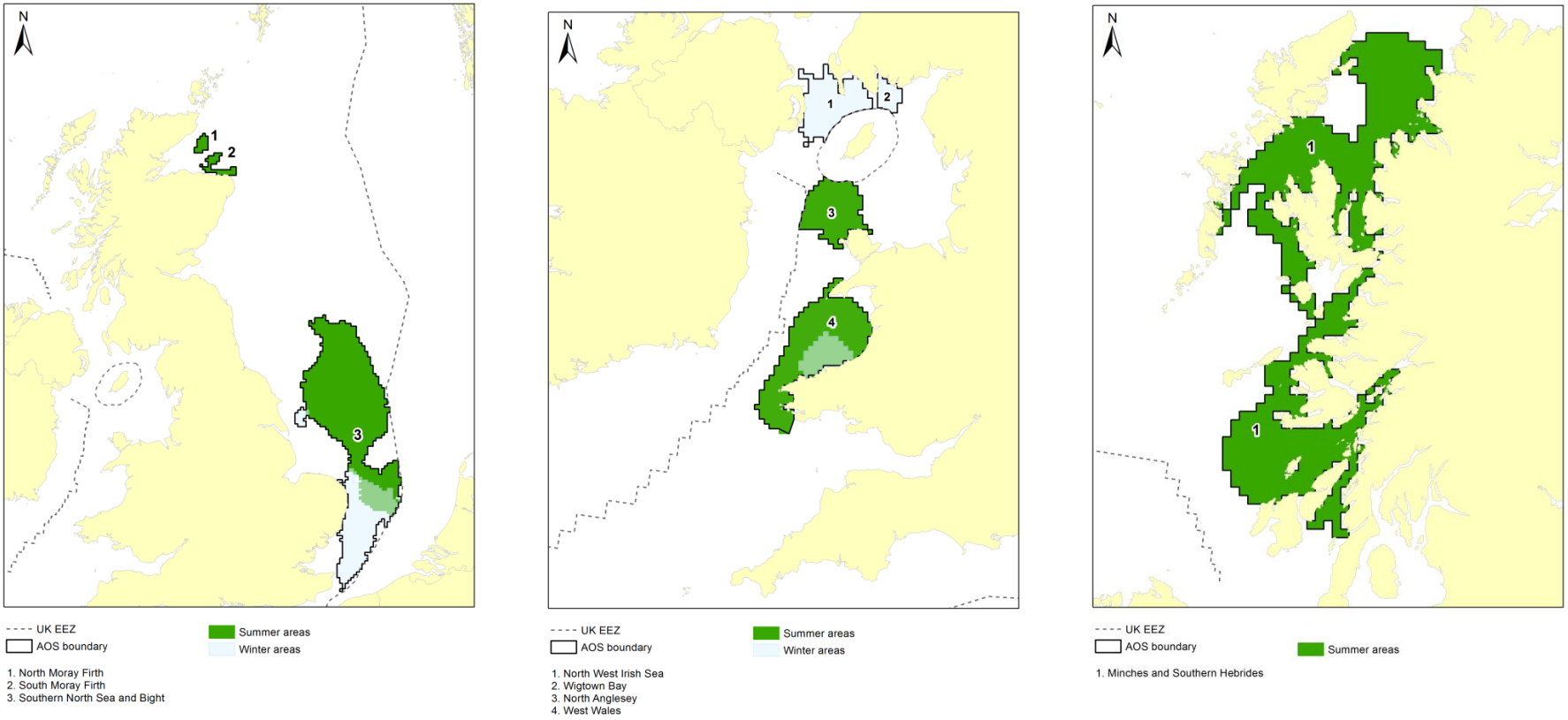

Figure 9: Recommended Areas of Search by season identified for harbour porpoise for the North Sea MU (left), Celtic and Irish Sea MU (centre) and West Scotland MU (right). Note that there were insufficient data for a winter analysis for the West Scotland MU.

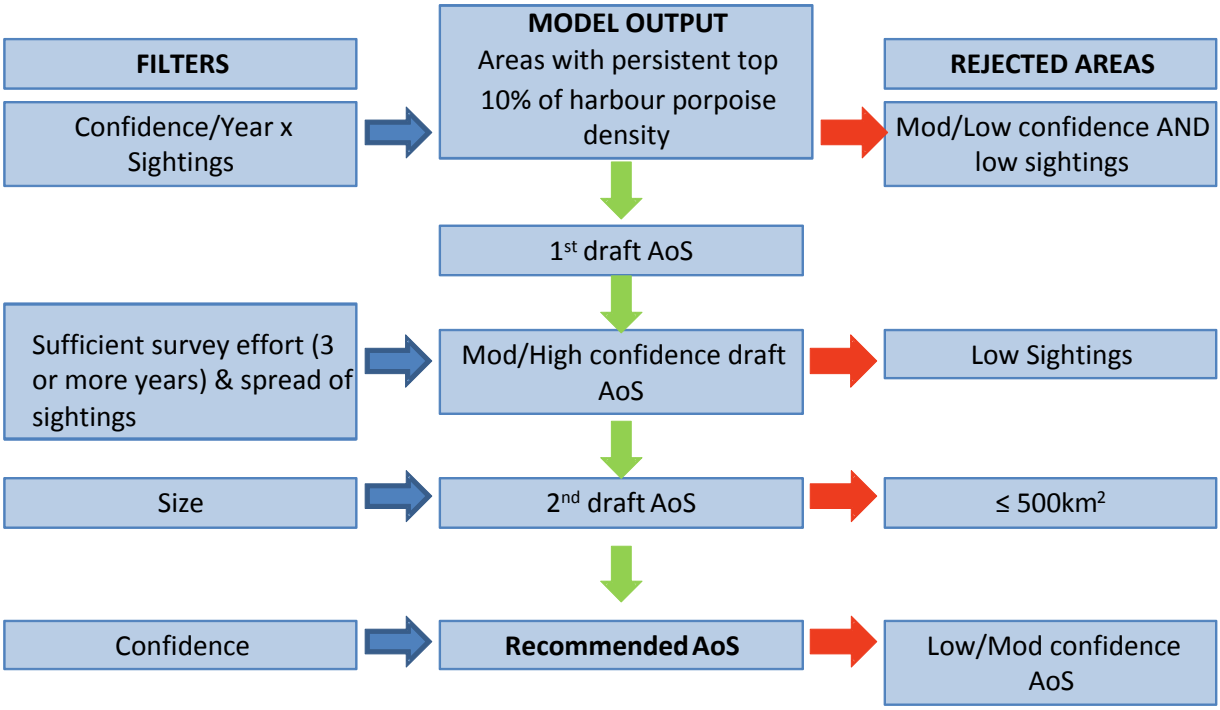

Figure 10: Process of defining Areas of Search for harbour porpoise undertaken by the IAMMWG.

6 Sufficiency

The Habitats Directive requires that sites that are designated for a species (or habitat) by each Member State must take account of the principles of:

a) Natural range (Article 3.1);
b) Sufficiency (Article 3.1); and
c) Proportionality (Article 3.2).

'Natural range' in UK waters has been partly considered through the selection of AoS for each of the MUs. The related assessments of sufficiency and proportionality of the sites for Annex II species is unclear. Assessments of sufficiency are conducted by the European Topic Centre at Biogeographical Seminars[7] but also annually on the basis of Member States Natura 2000 database. The proportion of the qualifying feature within the sites compared with the national population plays a role in determining sufficiency. For UK harbour porpoise SACs, an assessment of sufficiency of the recommended AoS was undertaken for UK waters within each MU. This helps further ensure natural range is taken into account (and the sum of the UK parts of the MUs adds up to the national population). The national (UK) parts of the MUs were truncated to the area where water depths are 200m or less, since this represents the area where harbour porpoise are principally distributed.

The process to propose and assess SACs against the national part of the MU takes into account the other principles of sufficiency expressed at the Marine Natura 2000 Seminar for the Atlantic Sea Region (held in Galway on 24-25 March, 2009); this includes an assessment based on whether;

i) the amount of national resource is adequately covered;
ii) the geographic spread of the resource is reflected in the site network; and
iii) that any variation in biological communities is covered.

Ensuring that sites are chosen within each MU satisfies the need for geographical spread, recognises any variation in population structure between regions and acknowledges the response of harbour porpoises to differing features in the marine environment around the UK (e.g. there are not extensive sandbanks to the north-west of Scotland, and there are no sea lochs in south-east England, so the habitats used in each area will, naturally, be different).

Two approaches are considered in regard to the amount of 'national resource' that is covered by the site network: either 'population' (abundance) or the 'habitat' (area) of the site within the network or both. Habitat has been identified through the work of Heinänen and Skov (2015a). The nature of the physical 'habitat' available to harbour porpoise differs around the UK; for example, the hydrography is most complex around the convoluted coasts west of Scotland, whereas the wide, relatively shallow shelf of the North Sea presents a different stratification regime than other regions. Ultimately, the distribution and availability of prey in the MUs is likely to be the driving factor of porpoise distribution but the prey, in turn, are likely to be influenced by habitat, so habitat features can be used as a proxy for the distribution of prey. In all three MUs the presence of harbour porpoises was positively related to the coarseness of the surface of the seabed sediments (Heinänen and Skov, 2015a) which suggests it is a strong predictor of their distribution. There are well documented links between sediment type and certain fish, such as sandeel (Wright *et al*, 2000), which are a component of the porpoise diet.

[7] The First Biogeographical Seminar for the Marine Atlantic was held in Galway, 2009. This is the only Marine seminar for this region to date.

The UK's approach for harbour porpoise has been to use both 'habitat' (area) and 'population' (abundance) to assess the resource covered (a measure of sufficiency) by the resulting SAC network. Abundance estimates for each recommended AoS were based on the most-robust estimates available to date from the SCANS-II survey (Hammond *et al,* 2013). These estimates are derived from a single survey of the European continental shelf in July 2005. There are no winter estimates of abundance available. The abundance is simply the number of animals estimated to be within the site at that point in time. The mobility of the species means that actual numbers within sites varies (sometimes greatly) and the concept of a 'site population' for harbour porpoise does not exist.

Based on the available information outlined above as to what factors are important to 'sufficiency' together with what the European Topic Centre have deemed 'sufficient' for harbour porpoises in other Member States, the UK proposed that sites derived from AoS should aim to cover 10-14% of the habitat and 20% of the population within the national[8] part of each MU. The sufficiency of the recommended AoS (combined for both summer and winter) was estimated to determine whether there was enough coverage by area and abundance within each MU from which sites could be refined (Table 6.1). At the UK scale, the recommended AoS included enough habitat area and harbour porpoise abundance to meet the proposed threshold of sufficiency (Table 6.1).

Table 6.1: Sufficiency of the recommended Areas of Search for harbour porpoise.

Management Unit	**Combined seasonal option by habitat area as % of the national MU area**	**Combined seasonal abundance as % of the national MU population**
North Sea MU	14	25
Celtic and Irish Sea MU	11	18
West Scotland MU	13	81
UK overall	13	29

However, the sufficiency within the Celtic and Irish Sea MU was below the proposed threshold for abundance and on the low-side of the habitat threshold (Table 6.1). However, it was particularly noted that the geographic and seasonal representivity within the Celtic and Irish Sea MU was lacking in the southern part (middle map Figure 9); therefore, the winter persistent top 10% area in the region of the Outer Bristol Channel (see Figure 4) was reintroduced. The Outer Bristol Channel had previously been taken out of the recommended AoS because the majority of the area was perceived to be moderate/low confidence, especially further offshore, with only moderate observations. However, on review, it was concluded that an area could be defined from the persistent top 10% winter area for which the majority had high confidence in the model output (see Section 7). Inclusion of the Outer Bristol Channel increased the sufficiency of the recommended AoS to 31% abundance and 18% of area in the Celtic and Irish Sea MU and improved geographical and seasonal representivity.

[8] Water depths of 200m or less.

7 Recommended Draft SACs

The recommended AoS were then re-assessed to form recommended draft SACs. The principles for the recommended draft SAC network were that the sites should capture mainly the high confidence portions of the AoS only, but without impacting connectivity within the AoS, and meet the proposed sufficiency thresholds. At the MU scale, the sites should provide seasonal and geographic representation. Where seasonal recommended AoS overlapped, they were joined together to create a single AoS[9].

Within each of the recommended AoS, confidence in the model predictions remained variable despite the majority of the area being of high confidence. As a result, some AoS were 'trimmed' so that only areas with high confidence were retained and formed recommended draft SACs namely; Bristol Channel Approaches and the Southern North Sea. The lower confidence areas were often underpinned by few survey data.

A suite of eight recommended draft SACs were submitted as initial advice to Governments in December 2014. The five recommended draft SACs within England, Wales, Northern Ireland and Secretary of State offshore waters are shown in Figure 11. The Scottish government later (June 2015) decided not to proceed with consultation on sites in their waters at that time and as a consequence these recommended draft SACs are not shown in the figure below.

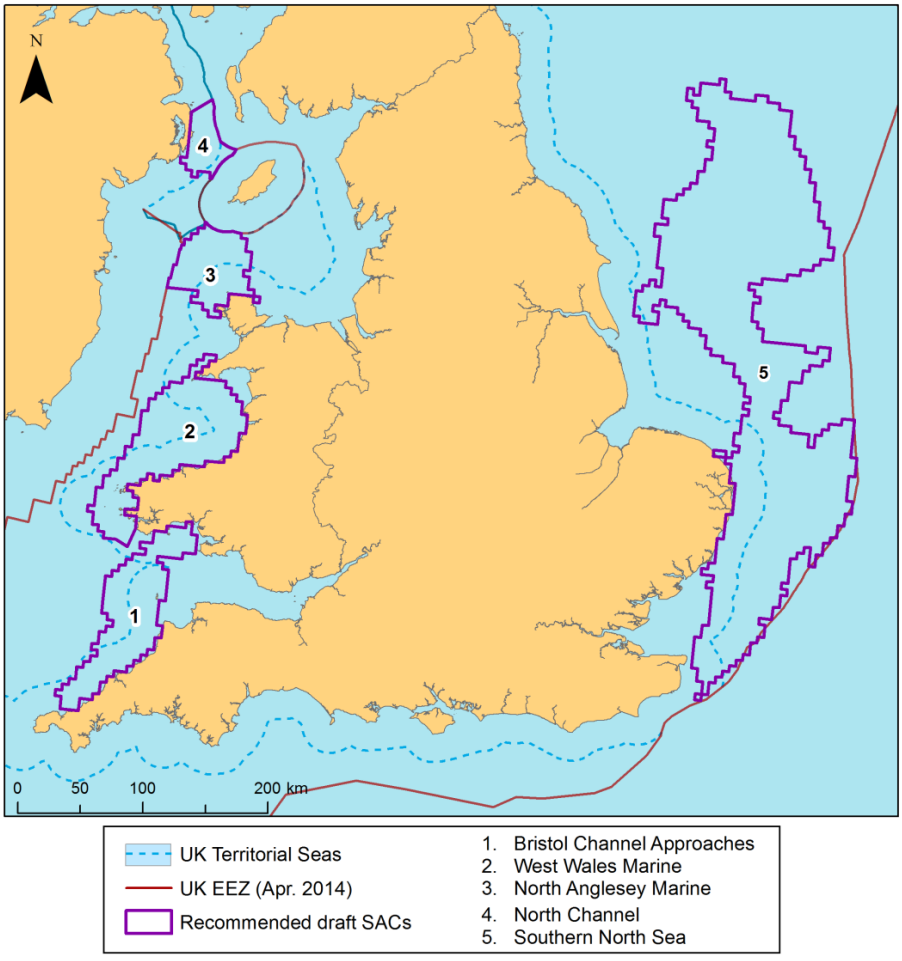

Figure 11: Recommended draft SACs for the harbour porpoise in England, Wales, Northern Ireland and Secretary of State offshore waters.

[9] Seasonality within the AoS may be an important consideration for management of the site.

The sufficiency of the original eight recommended draft SACs at the UK level was 13% by area and 22% by population which met the proposed thresholds of 10-14% coverage of the UK habitat and 20% coverage of the UK population. These thresholds of the eight original draft SACs were also met at the MU level for all three MUs. For the five draft SACs that were progressed towards consultation, in England, Wales, Northern Ireland and offshore waters, the sufficiency within the UKs national waters was 10% by area and 18% by population (**Error! Reference source not found.**).

Table 7.1: Summary of recommended draft SAC by habitat and population within the national portion (water depths of 200m or less) of each Management Unit based on the 5 draft SACs.

Management Unit	**Habitat area as % of the national MU area**	**Abundance as % of the national MU population**
North Sea	12	18
Celtic and Irish Sea	13	23
UK total	10	18

8 Refining boundaries for draft SACs

The boundaries of the recommended draft SACs were refined in the development of the draft SACs to be submitted to Government in summer 2015. Available guidance developed for defining SAC boundaries for marine sites away from the coast has focused on habitat features, largely from modelled data (McLeod *et al*, 2005; JNCC, 2012). The harbour porpoise sites are also based on modelled data and the outputs from this approach and that used for habitat features are consequently similar. Therefore, the guidelines have largely been transferred to consideration of boundaries for porpoise sites:

1. As a general principle, site boundaries should be drawn closely around the qualifying feature for which the sites have been selected, taking into account the need to ensure that the site operates as a functional whole for the conservation of the feature (McLeod *et al,* 2005).
2. Where possible, the seaward boundaries of the sites should be drawn using straight lines to ensure ease of identification on charts and at sea (McLeod *et al,* 2005) (and thereby, minimising the number of nodes in the boundary where feasible).
3. However, a balance is needed between more-complex site shapes drawn more tightly around the feature, and simple square/rectangular boundaries, so that the area of 'non-interest-feature' included within the site boundary is reduced, but this should not be to the detriment of the structural and functional integrity of the interest feature (JNCC, 2012).
4. Site boundary coordinates be provided in degrees, minutes, seconds (JNCC, 2012).

The nature of the boundaries for the recommended draft SAC were 'blocky' due to their emergence from the 25km^2 gridded model output of the DHI analysis (5km x 5km grid squares). Additional principles for creating boundaries for the harbour porpoise sites were therefore needed:

5. Diagonal runs of pixels (the DHI grid squares) should be straightened by a line that approximates the centre of the diagonal;
6. Vertical and horizontal lengths >2 pixels were maintained whenever possible to preserve overall shape;
7. Modifications of the boundary of each recommended draft SACs should not alter the total area of the site by more than approximately 5%;
8. Draft SACs will not extend into rivers;
9. Estuaries are excluded where the width of the entrance is ≤2km and the model did not indicate the area was included;
10. The 'coastal' edge of sites is defined by the Mean Low Water (MLW) tide line;
11. In England small ports and harbours which have enclosed inner harbour areas have been excluded.
12. Site boundaries were aligned with the EEZ boundary where they were closely aligned.

The recommended draft SACs were further refined to reflect some SNCB assessments of the appropriateness of using land-based data. DoE (Northern Ireland) have extended the boundary of the North Channel draft SAC to include waters off their coastline to the north-west (Figure 13); they have regional systematic land-based observation data to support this. The extension comprises a 2 - 8km wide coastal strip running from 2km off Island Magee, broadening to form an 8km wide corridor across the entrance to Belfast Lough and continues to 2km offshore from Mew Island (Copelands). The land-based sightings data to support this are held by the Irish Whale and Dolphin Group from various watch locations along the Northern Ireland coast. Analysis by DoE showed that the waters within the extension held the highest numbers of porpoises recorded along the Northern Ireland coastline and encloses known important local areas. The extension recognises the potential for movement

of individuals between Portmuck near the northern end of Island Magee, Black Head at the northern extent of Belfast Lough and the Copeland Islands to the south, and also provides a pragmatic operational boundary.

The results from Evans *et al.* (2015) were also considered by Wales. A number of land-based locations persistently (1994-2014) with the highest (top 10%) predicted probability of occurrence of harbour porpoise, were contained within the boundaries of the North Anglesey recommended draft SAC (Figure 5, locations 12-20) and the West Wales Marine recommended draft SAC (Figure 5, locations 11-10). There were no further land-based locations in Wales with persistent (1994-2014) high probability of occurrence.

The final boundaries for the draft SACs in England, Wales, Northern Ireland and Secretary of State offshore waters are given in Figure 12. At the time of writing this report, Scottish Government had decided not to proceed to consultation on sites in their waters at that time. As a consequence, Northern Ireland DoE and JNCC provided advice to Governments that included a new site, the North Channel, based on the original rdSAC advice but entirely outwith Scottish waters (see site 4, Figure 12). These five sites went to consultation in January 2016.

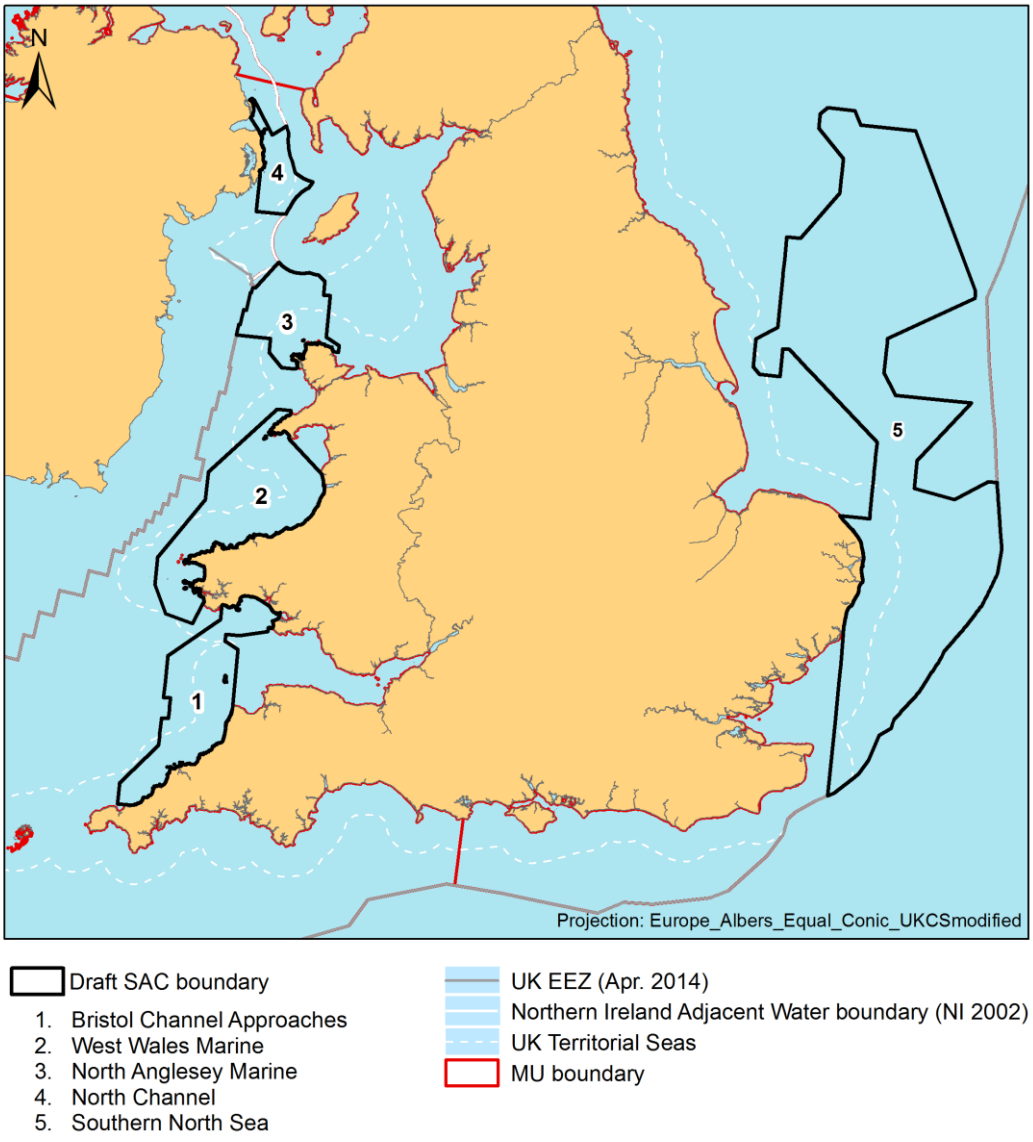

Figure 12: Final boundaries of the draft SACs in England, Wales, Northern Ireland and Secretary of State offshore waters and proposed for public consultation as possible SACs (pSACs).

9 Grading

The relative importance of proposed SACs is assessed through stage 1 of Annex III of the Habitats Directive and is based on the assessment at national level of:

(a) size and density of the population of the species present on the site in relation to the populations present within national territory;
(b) degree of conservation of the features of the habitat which are important for the species concerned and restoration possibilities;
(c) degree of isolation of the population present on the site in relation to the natural range of the species; and
(d) global assessment of the value of the site for conservation of the species concerned.

The assessment of the harbour porpoise draft SACs was carried out in relation to the relevant MUs rather than at the national level, so as to align with the site identification process. In relation to the Annex III criterion (a), abundance estimates calculated for each site were used directly to grade, adapting the explanatory notes of the Natura 2000 standard data form for assessment within MUs:

Grade A: >15% to 100% of the relevant UK management unit population
Grade B: >2% to 15% of the relevant UK management unit population
Grade C: >0% to 2% of the relevant UK management unit population

With regard to the Annex III criterion (b), there are two sub-criteria:

(i) degree of conservation of the features of the habitat important for the species:

I. elements in excellent condition;

II. elements well conserved;

III. elements in average or partially degraded condition; and

(ii) restoration possibilities.

Sub-criterion (i) requires a global evaluation of the features of the habitat regarding the biological requirements of a given species, and (ii) only needs to be taken into account when the elements are in an average or partially degraded condition. Applying the classification of the two sub-criteria to grades:

A. conservation excellent (elements in an excellent condition, independent of the grading of the possibility of restoration)
B. good conservation (elements well conserved independent of the grading of the possibility of restoration OR elements in average or partially degraded condition and easy to restore)
C. average or reduced conservation (all other combinations).

The network of draft SACs, relative to the rest of the shelf, includes the best habitat for porpoises and the areas have been used persistently between 1994 and 2010. It is assumed that the preference for these habitats is associated with good feeding opportunities and prey aggregations. The available evidence indicates that the conservation status of the UK harbour porpoise population is currently 'Favourable[10]'. Therefore, it is considered that the conservation of features of the habitats (Annex III criterion (b)) across the network is graded as sub-criterion (i) II: elements are well conserved, and restoration possibilities do not have

[10] As reported in the Article 17 Habitats Directive report. See the supporting information for harbour porpoise here: http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/S1351_UK.pdf

to be considered. Therefore, the overall grade for all sites against this criterion is at least grade B given that the habitat within sites is supporting higher densities of porpoises compared to anywhere else. We do not know which features of the habitat are the most important drivers of the association with prey; nor are the main prey species of porpoise within the sites known. Until this is known, it cannot be further defined whether the quality of the habitat in each of the sites is good or excellent, while noting that it must be considered to be at least good. Therefore a grade of A/B has been awarded for all sites.

With regard to the Annex III criterion (c)**,** as a wide ranging species, harbour porpoises within SACs cannot be considered isolated in relation to the rest of the population. Animals within the SACs are part of the wider MU population. Therefore, with respect to isolation, any harbour porpoise site would be graded C: population not isolated within extended distribution range.

The global assessment of a site is weighted towards the grade awarded to the site for its size and density, given that the conservation of features of the habitat is not clearly understood and the sites are all equal in quality with regard their 'degree of isolation'. The proposed gradings for the draft SACs are shown in Table 9.1.

Table 9.1: Proposed grades for the harbour porpoise draft SACs.

Site	Abundance of porpoise (CV)	% of the UKs MU population	Annex III Criteria			
			(a)	(b)	(c)	(d)
			Size and Density Grade	Degree of conservation of the features of the habitat	Degree of isolation	Global assessment
Southern North Sea	18524 (0.23)	19	A	A/B	C	A
North Channel	537 (0.35)	2.02	B	A/B	C	B
North Anglesey Marine / Gogledd Môn Forol	1084 (0.557)	4	B	A/B	C	B
West Wales Marine / Gorllewin Cymru Forol	2506 (0.30)	9	B	A/B	C	B
Bristol Channel Approaches / Dynesfeydd Môr Hafren	2135 (0.53)	8	B	A/B	C	B

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