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Regional baselines for marine mammal knowledge across the North Sea and Atlantic areas of Scottish waters: Appendix 3 - SCANS surveys

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Appendix 3: SCANS surveys

The SCANS surveys and their use in the characterisation of regional baselines of the Draft Plan Option sites within the Draft Sectoral Marine Plan for Offshore Wind Energy

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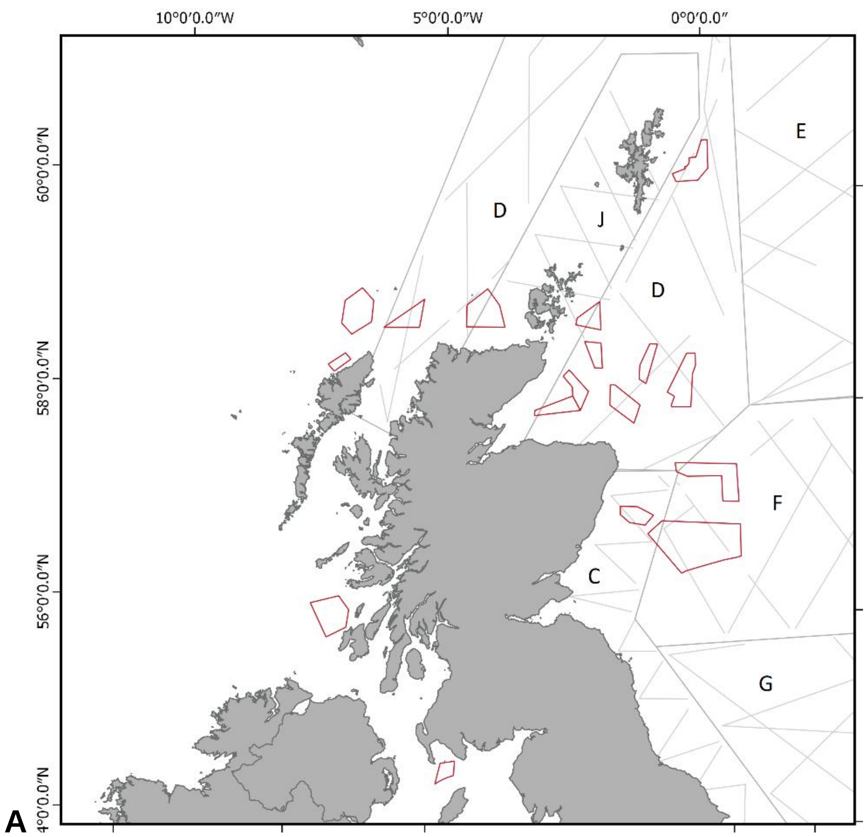
Introduction

The objective of this short note is to provide expert recommendations on the utility of SCANS survey data for baseline characterisation of Scottish waters, and to provide up-to-date information on plans for and associated costs of a future SCANS survey. The SCANS surveys are a series of large-scale cetacean surveys conducted in European Atlantic waters. They were initiated in 1994 in the North Sea and adjacent waters (SCANS 1995; Hammond et al., 2002) and continued in 2005, covering all shelf waters (SCANS-II 2008; Hammond et al., 2013) and 2007 in offshore waters (CODA 2009). Although the CODA survey did not include any Scottish Territorial waters, it did include part of the Scottish EEZ. In the mid-1990s, the primary need for such a large-scale survey was to obtain the first comprehensive estimates of abundance of harbour porpoise in the North Sea and adjacent waters so that estimates of bycatch could be placed in a population context. The motivation for subsequent surveys has been to provide information on distribution and abundance of cetaceans to facilitate reporting by Member States on Favourable Conservation Status under the Habitats Directive and, particularly, on Good Environmental Status (GES) under the Marine Strategy Framework Directive (MSFD). This was a primary aim of the SCANS-III survey. An additional aim was to provide information on summer distribution of cetaceans within the study area. Surveys are conducted primarily in July, although some survey effort was carried out in early August during the 2016 survey. The survey blocks containing each of the Draft Plan Option Areas are shown in Table 1 and Figure 1 A-C.

Table 1 Name of survey block from each of the SCANS surveys containing each of the Draft Plan Option Areas. If a Draft Plan Option Area is split between two survey blocks, both are shown.

Draft Plan Option Area	SCANS survey block	SCANS-II survey block	SCANS-III survey block
E1	F	V	R
E2	F	V	R
E3	C	V	R
N1	D/J	J/Q	K/S
N2	D	Q	K
N3	Not covered	Q	K
N4	Not covered	Q	K
NE1	D	J/T	T
NE2	D/J	J	S
NE3	D	T	S
NE4	D	J	S
NE5	D	J	S
NE6	D	V	T
NE7	D	V/T	T
NE8	D	V/T	T
SW1	Not covered	O	E
W1	Not covered	N	G



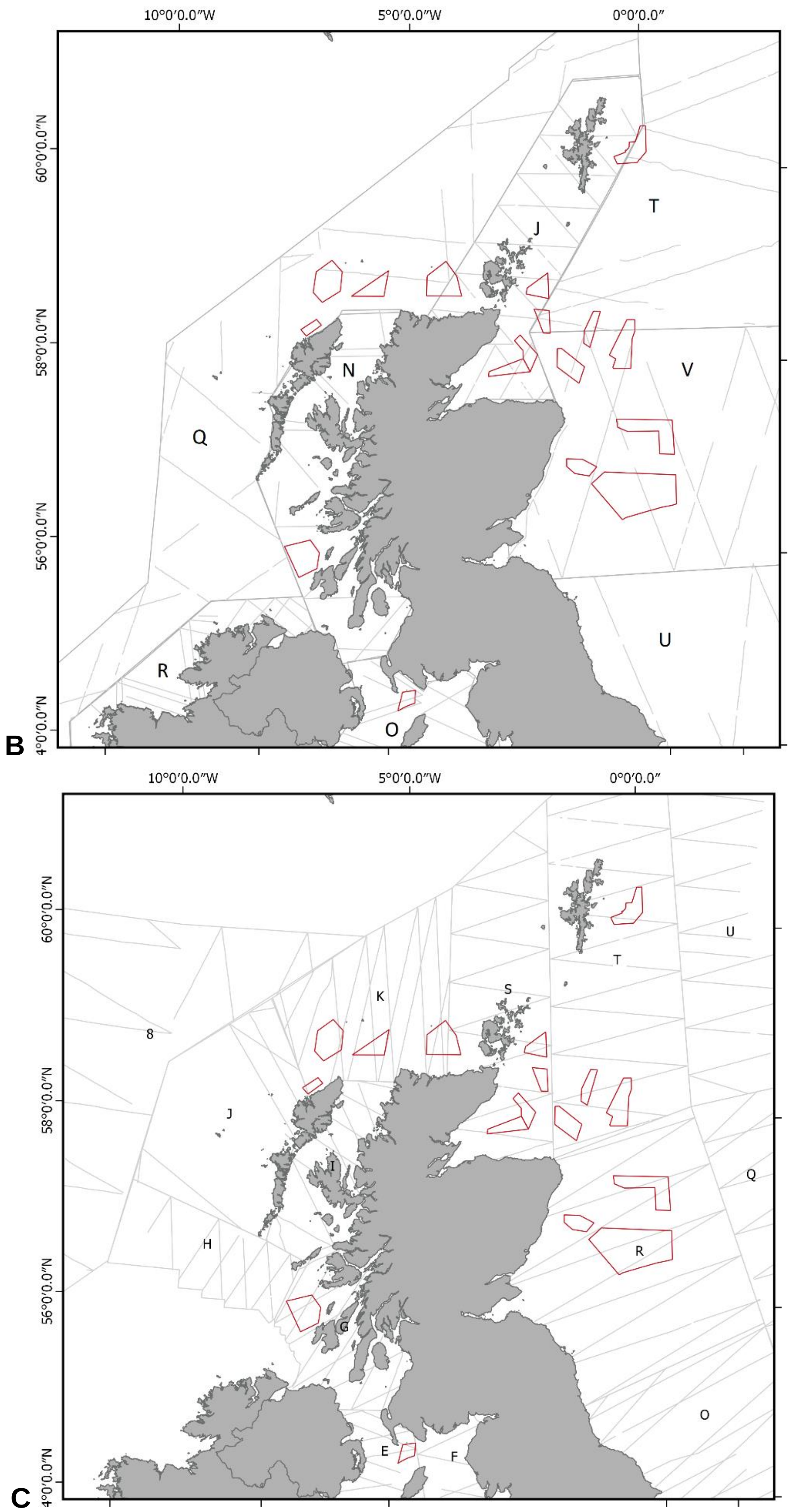


Figure 1 The location of the Draft Plan Option Areas with reference to the survey blocks from SCANS (A), SCANS-II (B) and SCANS-III (C).

SCANS Survey Methods

Survey methods are outlined in detail in Hammond et al., (2002, 2013, 2017). In all surveys, pre-defined survey transects were covered using a combination of ships and aircraft, except for the CODA survey, for which only ships were used. Both ship and aircraft methodology incorporated methods to allow for estimates to be corrected for animals missed on the transect line. Aerial surveys utilised the circle-back method of Hiby (1990), and ship surveys were conducted using a double platform line transect survey with two independent teams of observers.

Relevant results

Species list

In combination, the SCANS surveys have recorded 14 species of cetacean. Table 2 shows which species have been seen in survey blocks which include the Draft Plan Option Areas. Please refer to the species accounts within the main report and Appendix 5 Supplementary Material – Density Estimates for details of species seen in each Draft Plan Option site, including associated abundance and/or density estimates, during each SCANS survey. In all three surveys, harbour porpoise was recorded in every survey block including a Draft Plan Option Area (Table 2).

Table 2: Cetacean species seen in each of the SCANS surveys in survey blocks containing Draft Plan Option Areas. Names of the relevant survey blocks are indicated by letters. Figure number indicates the map (below) on which the locations of the SCANS-III sightings can be seen.

Species	SCANS (Hammond et al., 2002)	SCANS-II (Hammond et al., 2013)	SCANS-III (Hammond et al., 2017)	Figure number
Beaked whales			K,T,	Figure 2
Bottlenose dolphin	D	J,N,Q,T,V	E,G, R,S	Figure 3
Common dolphin	D	N,Q	K	Figure 3
Fin whale		Q,T	K	Figure 4
Harbour porpoise	All blocks containing Draft Plan Option Areas	All blocks containing Draft Plan Option Areas	All blocks containing Draft Plan Option Areas	Figure 5
Humpback whale			T	Not shown
Killer whale	D	T,V	T	Figure 4
Minke whale	All blocks containing Draft Plan Option Areas	J,O,Q,T,U,V	E,G, K,R,S,T	Figure 6
Pilot whale		Q	K	Figure 4

Risso's dolphin		Q	E,K,T	Figure 3
Sperm whale			S	Figure 4
Striped dolphin			K	Figure 3
White-beaked dolphin	C,D,F,G	J, N,Q,U,V	K,R,S,T	Figure 7
White sided dolphin		Q,T,V	T	Figure 3

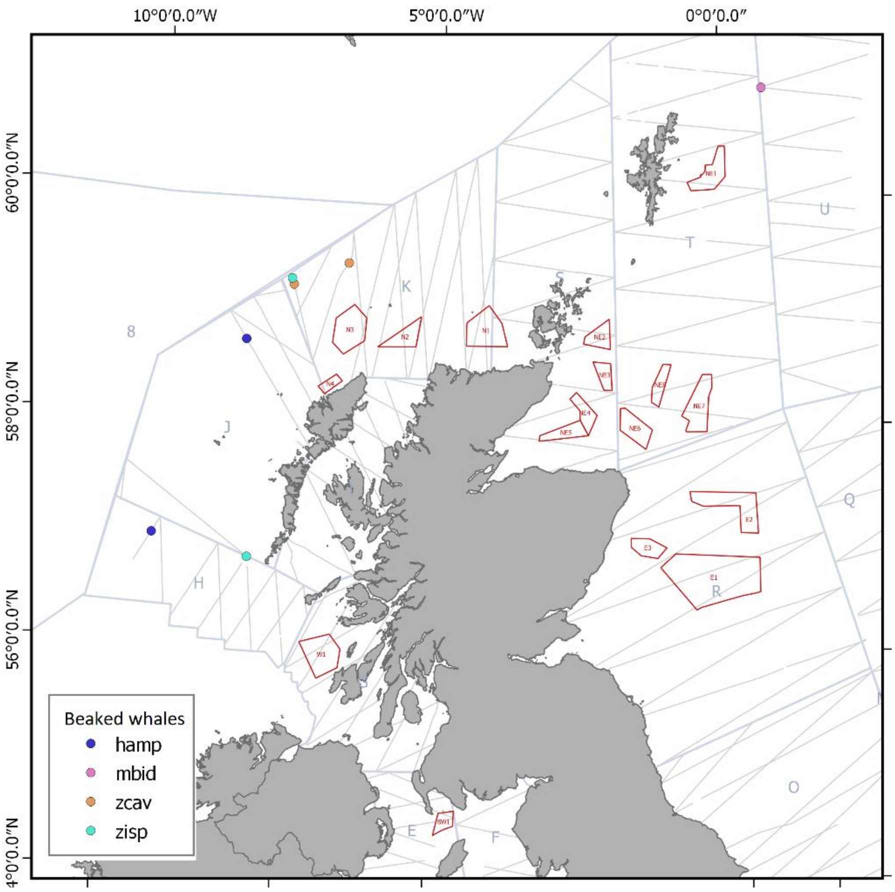


Figure 2: Sightings of beaked whale species seen during the SCANS-III surveys, within survey blocks containing Draft Plan Option Areas. hamp = Northern bottlenose whale (Hyperoodon ampullatus), mbid = Sowerby's beaked whale (Mesoplodon bidens), zcav = Cuvier's beaked whale (Ziphius cavirostris) and zisp= beaked whales unidentified to species.

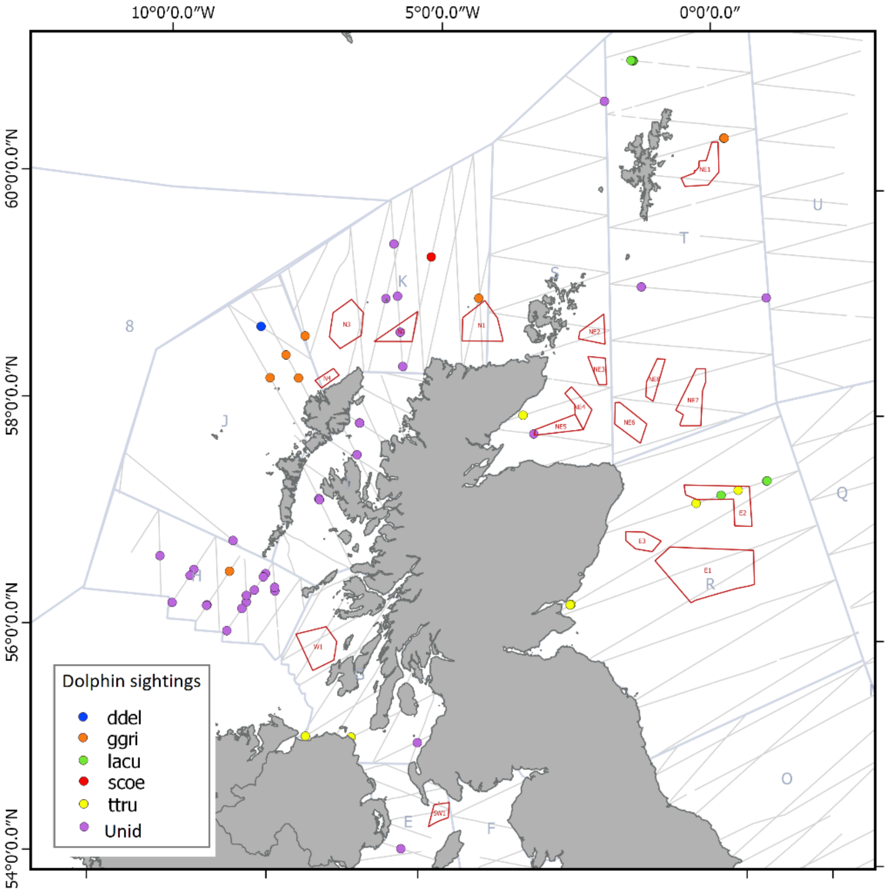


Figure 3: Sightings of dolphin species seen during the SCANS-III surveys, within blocks containing Draft Plan Option Areas. Ddel = Common dolphin (Delphinus delphis), ggri= Risso's dolphin (Grampus griseus), lacu= white-sided dolphin (Lagenorhynchus acutus), scoe = striped dolphin (Stenella coreualba), ttru= bottlenose dolphin (Tursops truncatus). Unid= dolphins not identified to species. White-beaked dolphins are shown in Figure 7.

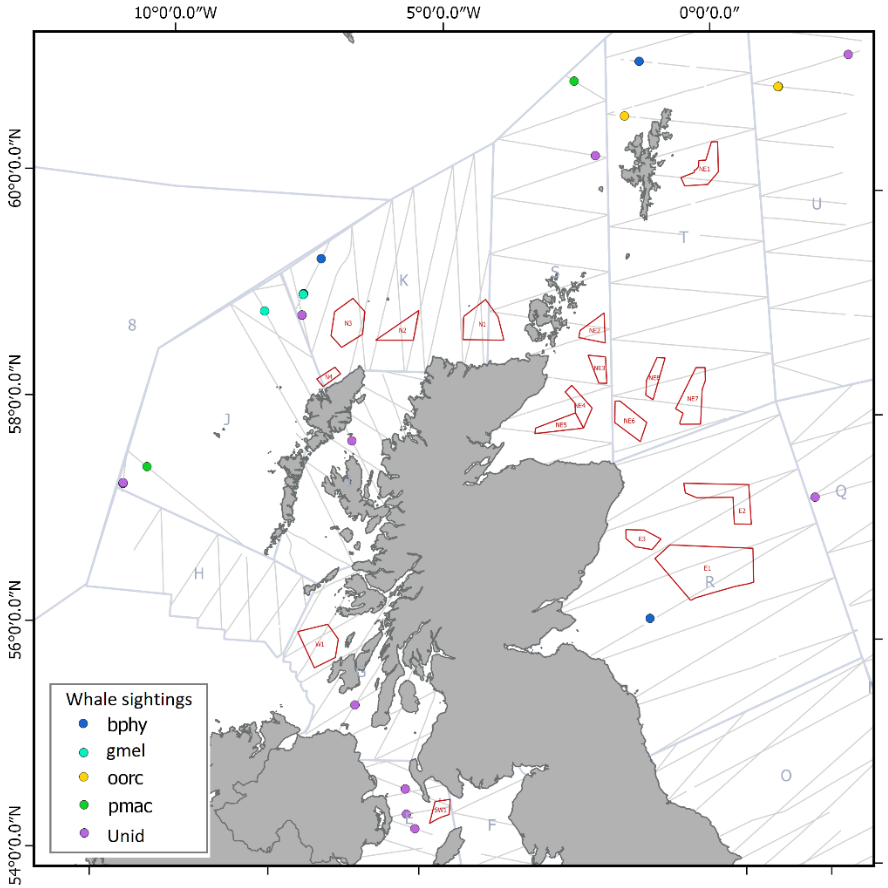


Figure 4: Sightings of whale species seen during the SCANS-III surveys, within blocks containing Draft Plan Option Areas. bphy = fin whale (Balaenoptera physalis), gmel= pilot whale (Globicephala melas), oorc= killer whale (Orcinus orca), pmac= sperm whale (Physeter macrocephalus) and Unid= whales not identified to species. A single humpback whale was sighted at the far north of block T, out of the area covered by this map. Minke whales are shown in Figure 6.

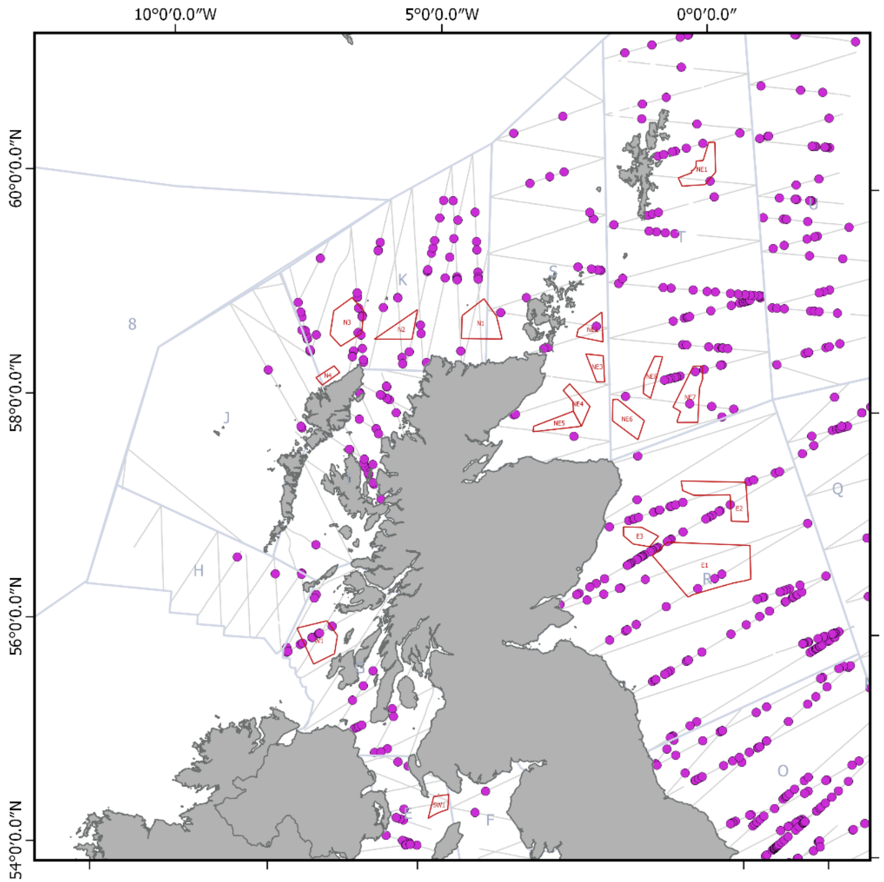


Figure 5: Sightings of harbour porpoise seen during the SCANS-III surveys, in blocks containing Draft Plan Option Areas.

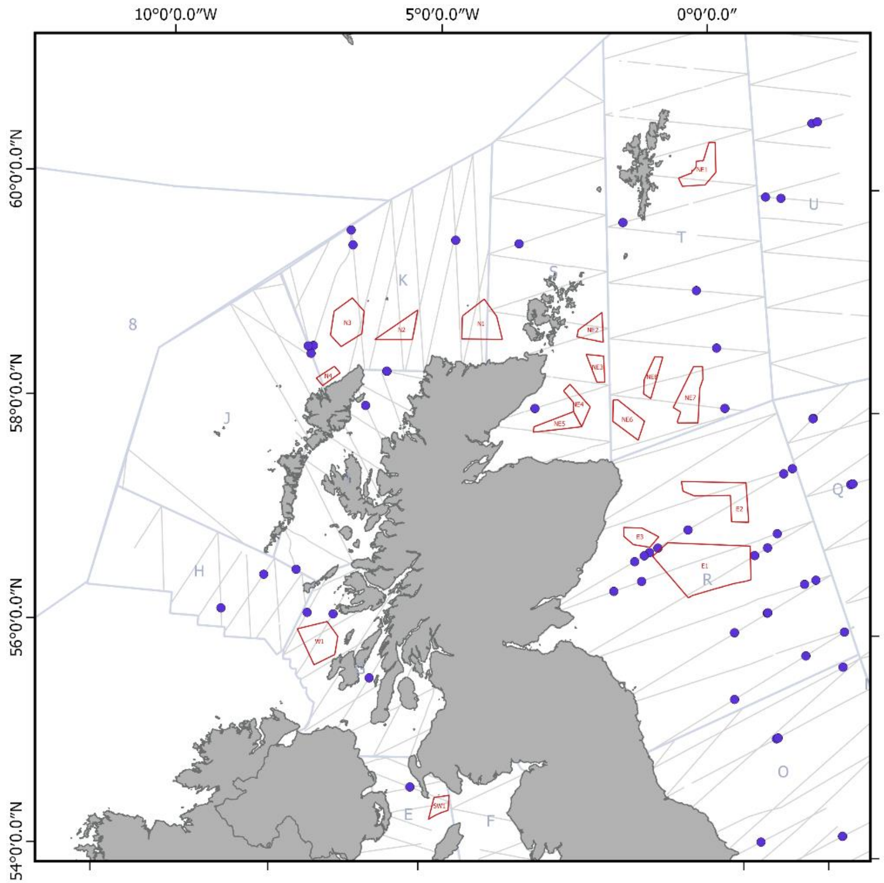


Figure 6: Sightings of minke whale seen during the SCANS-III surveys, within blocks containing Draft Plan Option Areas.

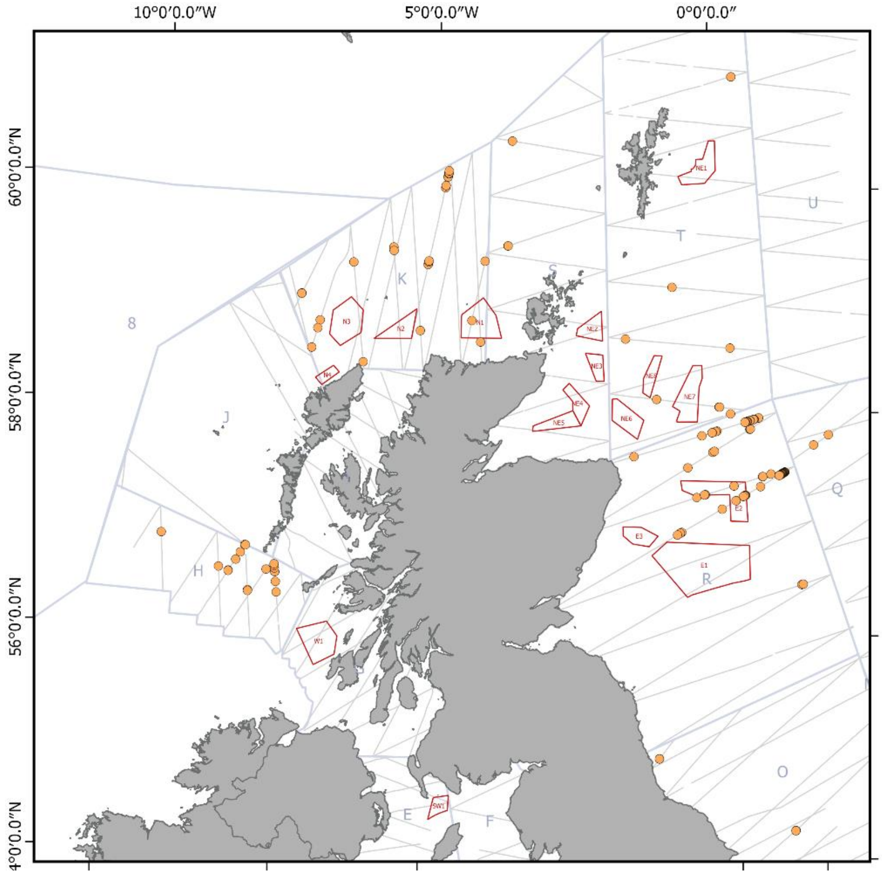


Figure 7: Sightings of white-beaked dolphin during the SCANS-III survey, within blocks containing Draft Plan Option Areas.

Abundance and distribution from SCANS-III survey

Abundance estimates were calculated for each SCANS-III block for which there were sufficient sightings. Tables 3-8 show estimates for the survey blocks containing Draft Plan Option Areas. Blocks and species with no estimate had insufficient data to calculate one. Full methodology is presented in Hammond et al., 2017.

Table 3 Harbour porpoise abundance and density (animals/km^2) estimates from SCANS-III for the survey blocks containing one of the Draft Plan Option Areas. CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance (Hammond et al., 2017).

Block	Abundance	Density	Mean group size	CV	CL low	CL high
E	8,320	0.239	1.31	0.28	4,643	14,354
G	5,087	0.336	1.52	0.43	1,701	10,386
K	9,999	0.308	1.44	0.27	5,643	16,306
R	38,646	0.599	1.38	0.29	20,584	66,524
S	6,147	0.152	1.35	0.28	3,401	10,065
T	26,309	0.402	1.33	0.29	14.219	45,280

Table 4 Bottlenose dolphin abundance and density (animals/km^2) estimates from SCANS-III for the survey blocks containing one of the Draft Plan Option Areas. CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance (Hammond et al., 2017).

Block	**Abundance**	**Density**	**Mean group size**	**CV**	**CL low**	**CL high**
E	288	0.008	1.50	0.57	0	664
G	1,824	0.121	9.67	0.68	0	4,474
K	No estimate available					
R	1,924	0.030	5.25	0.86	0	5,048
S	151	0.004	2.00	1.01	0	527
T	No estimate available					

Table 5 Risso's dolphin abundance and density (animals/km^2) estimates from SCANS-III for the survey blocks containing one of the Draft Plan Option Areas. CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance (Hammond et al., 2017).

Block	Abundance	Density	Mean group size	CV	CL low	CL high
E	288	0.008	1.50	0.57	0	664
G	No estimate available					
K	No estimate available					
R	No estimate available					
S	No estimate available					
T	No estimate available					

Table 6 White-beaked dolphin abundance and density (animals/km^2) estimates from SCANS-III for the survey blocks containing one of the Draft Plan Option Areas. CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance (Hammond et al., 2017).

Block	Abundance	Density	Mean group size	CV	CL low	CL high
E	No estimate available					
G	No estimate available					
K	No estimate available					
R	15,694	0.243	3.70	0.48	3,022	33,340
S	868,	0.021	3.00	0.69	0	2,258
T	2,417	0.037	3.43	0.46	593	5,091

Table 7 White-sided dolphin abundance and density (animals/km^2) estimates from SCANS-III for the survey blocks containing one of the Draft Plan Option Areas. CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance (Hammond et al., 2017).

Block	Abundance	Density	Mean group size	CV	CL low	CL high
E	No estimate available					
G	No estimate available					

K	No estimate available					
R	644	0.010	3.00	0.99	0	2.069
S	No estimate available					
T	1,366	0.021	3.25	0.98	0	5,031

Table 8 Minke whale abundance and density (animals/km^2) estimates from SCANS-III for the survey blocks containing one of the Draft Plan Option Areas. CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance (Hammond et al., 2017).

Block	Abundance	Density	Mean group size	CV	CL low	CL high
E	603	0.017	1.00	0.62	134	1,753
G	410	0.027	1.33	0.70	0	1,259
K	295	0.009	1.00	0.81	0	994
R	2.498	0.039	1.18	0.61	604	6,791
S	383	0.010	1.00	0.75	0	1.364
T	2,068	0.032	1.10	0.81	290	6,960

In addition to abundance and density estimates, preliminary predicted density surfaces for SCANS-III species have been created using the Generalised Additive Model (GAM) framework previously used in analysis of SCANS and SCANS-II data (Hammond et al. 2013). In brief, GAMs were developed to model density as a function of a variety of environmental covariates. The best model (as selected based on AIC) was then used to create a predicted density surface, generated from the modelled relationships between animal presence (sightings locations) and the environmental covariates retained in the GAM. Maps of predicted density may differ from maps of sighting locations for a number of reasons including: some areas receiving more effort than others; sightings being dependent on weather conditions, which were corrected for by the modelling; predictions in a particular area being a result of modelled density-environment relationships fitted to data from the wider area.

Predicted density surfaces for summer 2016 are provided for harbour porpoise, minke whales and white-beaked dolphins (Figures 8-10). Predicted density surfaces for fin whale, long-finned pilot whale, beaked whale and common dolphin have been developed but are not presented in this report as the vast majority of sightings are to the west of Ireland or in the Bay of Biscay (depending on species), with few sightings in Scottish waters. Predicted density surfaces could not be developed for killer whale, humpback whale or white-sided dolphins as there were not enough sightings. It should be noted that this work is continuing (Hammond et al., In Prep), and although preliminary results have been presented to the ICES Working Group on Marine Mammal Ecology, these are not yet publicly available (publication expected late in 2020).

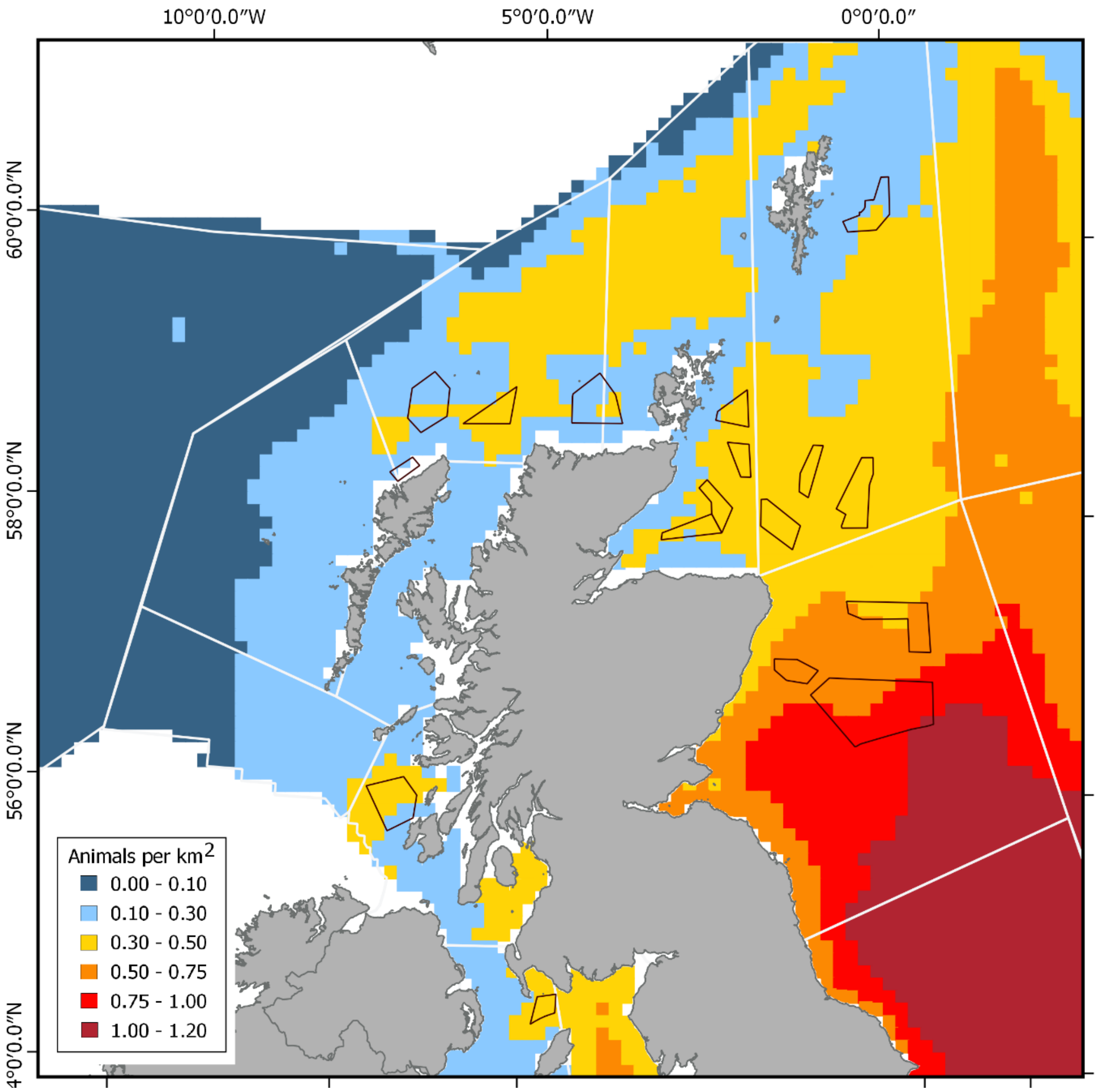


Figure 8 Predicted density surface for harbour porpoise in 2016. The colour scale is in units of animals per km². Draft Plan Option Areas are outlined in black for reference. SCANS-III survey blocks are marked in white.

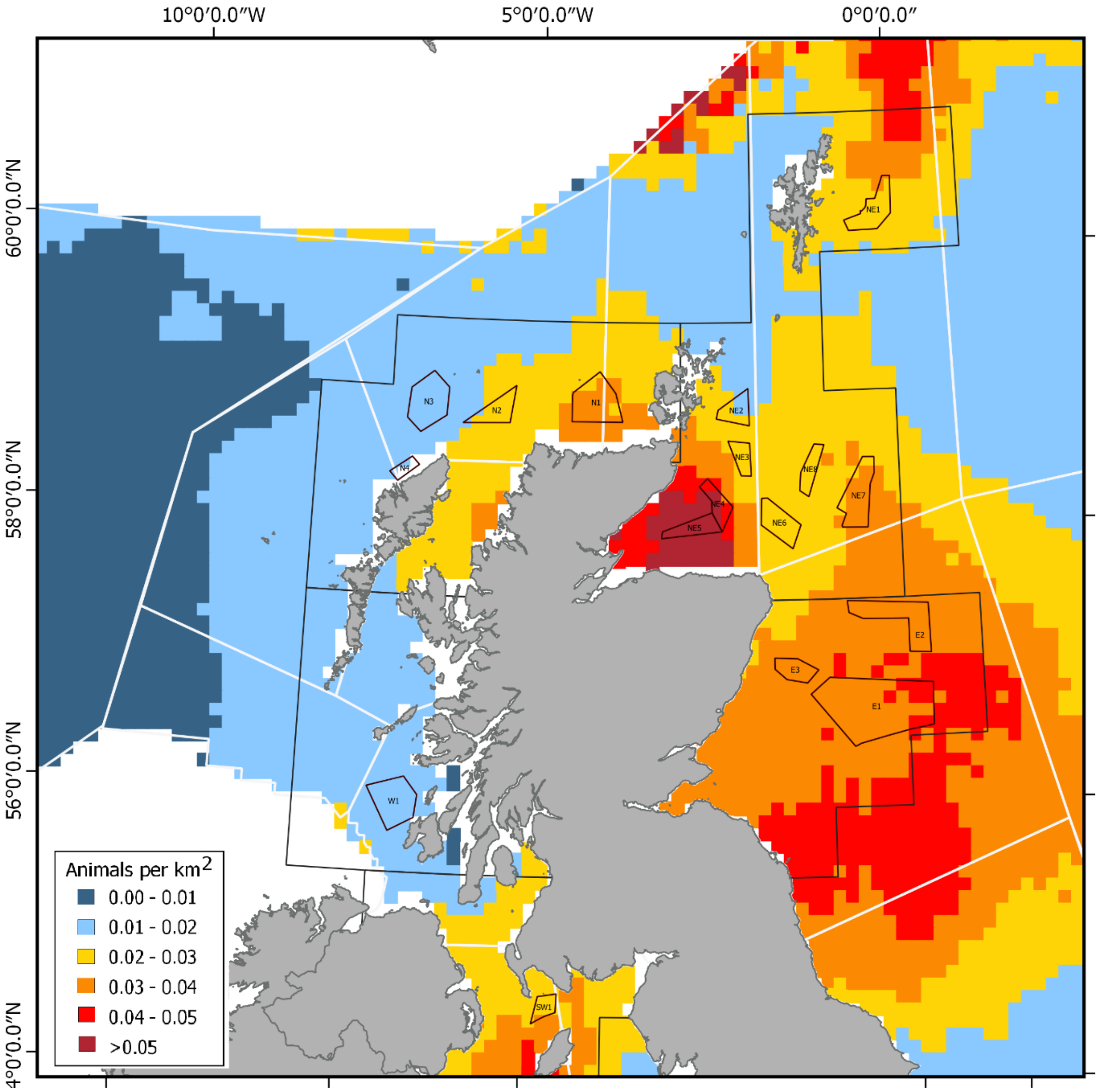


Figure 9 Predicted density surface for minke whales in 2016. The colour scale is in units of animals per km² Draft Plan Option Areas are outlined in black for reference. SCANS-III survey blocks are marked in white.

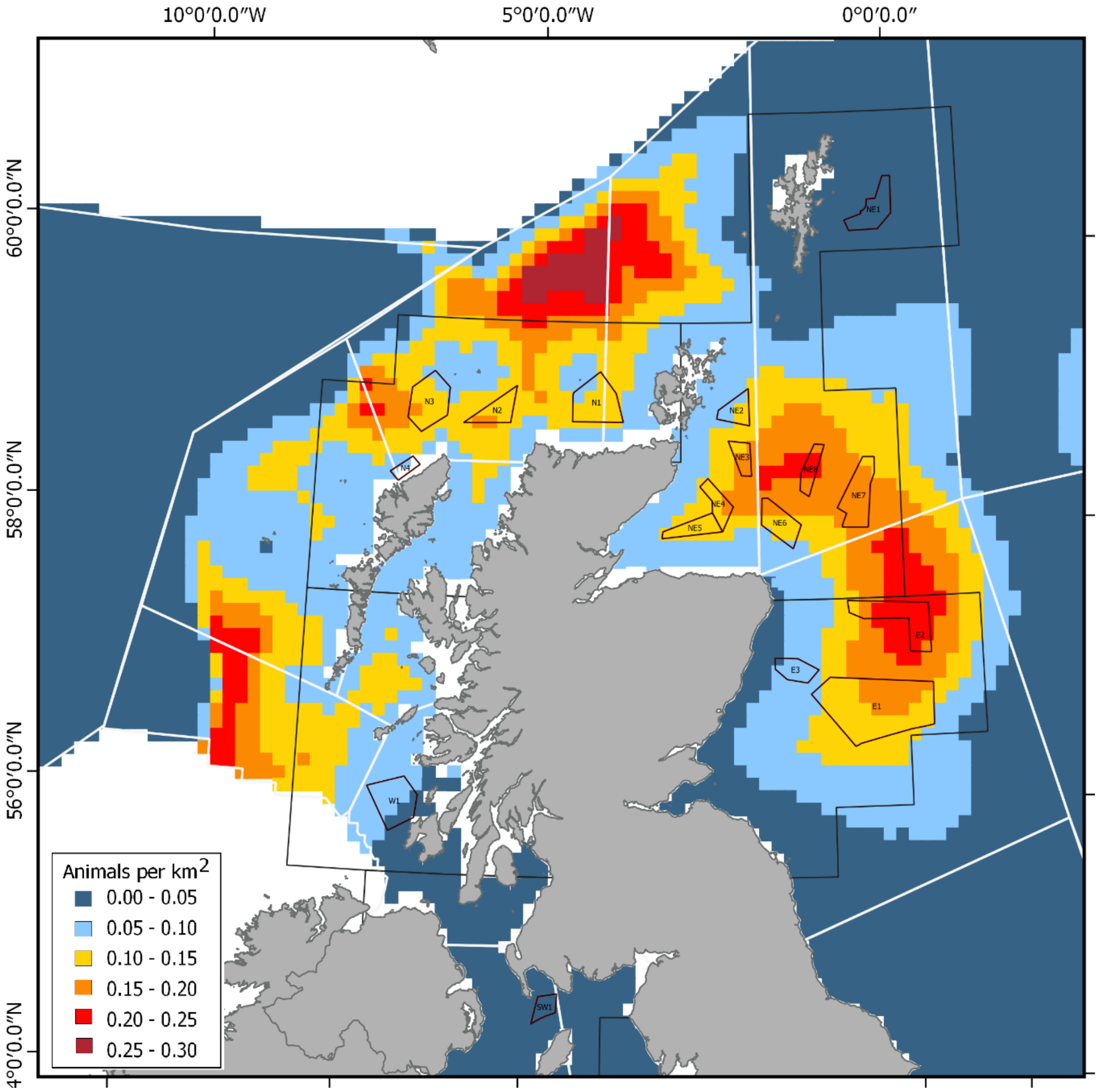


Figure 10 Predicted density surface for white-beaked dolphin in 2016. The colour scale is in units of animals per km^2 *Draft Plan Option Areas are outlined in black for reference. SCANS-III survey blocks are marked in white.*

The SCANS surveys as a data source for baseline characterisation

Utility of the SCANS dataset

The SCANS surveys are large scale surveys, designed to provide robust information which can be used to fulfil international reporting obligations. Having data for such a large geographical area covering a 22-year span is an invaluable resource. In addition, the coverage of a wide area simultaneously is a major advantage for highly mobile species; in particular, inter-annual variation in distribution and abundance does not need to be accounted for as it would in a patchwork of smaller scale surveys. The area is surveyed according to an equal coverage probability design so that sample density can readily be extrapolated to the survey blocks.

The estimates of abundance are robust, and are corrected for animals missed on the transect line, which is important to minimise bias, particularly for cryptic species and for aerial surveys. The fairly intensive effort (particularly in shelf waters in 2016) leads to relatively good precision compared to many other surveys.

Simple power analyses have shown that, in the North Sea, the three surveys combined have 80% power to determine annual rates of decline of 1.8% for harbour porpoises and 5% for white-beaked dolphins. For minke whales, an annual rate of decline of 0.5% would be detectable due to the availability of additional data for this species (Hammond et al., 2017). Note, however, that these calculated rates of decline would be greater if there were inter-annual variability in the number of animals in the North Sea. Such variability may be low for harbour porpoises and white-beaked dolphins but is likely to be higher for minke whales (see below).

Limitations - Spatial considerations

The SCANS data were not collected with the purposes of characterising small discrete areas, such as the Draft Plan Option Areas. The entire SCANS-III survey area covers a region of 1,816,137 km^2, and despite achieving a total of 61,392.5 km of effort in good survey conditions, this is still a large scale survey. The size of the Draft Plan Option Areas is such that each area may include only a fraction of a single SCANS-III survey line, if any direct survey effort at all. It is important to recognise that information from SCANS surveys about density and abundance in the Draft Plan Option Areas is extrapolated from the sample data over a wider area; this is appropriate for highly mobile species. It is important to emphasise that the information from SCANS surveys does not characterise variation in density at a fine spatial scale, such as within and around the Draft Plan Option Areas.

Limitations - Temporal and seasonal considerations

The SCANS surveys are conducted on an approximately decadal scale and are centred around the month of July. They provide a snapshot of cetacean distribution in summer when the weather is more favourable for survey and when the distribution of harbour porpoise is thought to be spread more homogeneously across the survey area than at other times of the year (Haelters et al, 2011; Camphuysen et al, 2014), which helps to improve precision of abundance estimates for this species. They thus provide no information on seasonal variation in distribution/abundance, which may be important for some species. In particular, the minke whale migrates between high latitude feeding areas in summer and low latitude breeding areas in winter. The northern feeding areas have been well surveyed in summer since 1987 by the series of North Atlantic Sightings Surveys (NASS) and Norwegian Independent Line transect Surveys (NILS) conducted by Iceland, the Faroe Islands and Norway, as well as SCANS, but information on distribution and abundance in European waters in the rest of the year is patchy and sparse.

Logistical considerations of conducting surveys in Scottish waters in seasons other than the summer should not be underestimated. Available daylight hours are limited (e.g. <6 hours in December), and good weather with low sea state is required. For example, porpoise data is only used when recorded in sea state 2 or less (4 or less for other species), so surveys would require sufficient time at low sea state to get enough data. The lack of daylight hours and likelihood of poor weather leading to delay and shortening of survey days in the winter months would largely increase the survey length and therefore the overall cost.

Use of SCANS survey data as a baseline for characterisation

The three SCANS surveys have recorded 14 species of cetacean in the regional areas overlapping with Draft Plan Option Areas. This reflects the cetacean fauna likely to be encountered in Scottish waters overall, though there is regional variation (i.e. not all fourteen species were observed in all survey blocks or regions). The species sighted within survey blocks relevant to each Draft Plan Option area could form a species list when characterising each Draft Plan Option area, though it would still be important to consider seasonal variation, as SCANS provide an indication of summer species presence only. Draft Plan Option areas that span more than one SCANS survey block would need to combine species presence lists from all the relevant blocks that the Draft Plan Option area spanned.

SCANS surveys are designed to be implemented at a large scale; each survey covers a wide area and the frequency reflects the intention for them to form a long time series as befits the life histories of the focal species.

For some species (e.g. harbour porpoise and white-beaked dolphin), the whole of the population inhabiting European waters is covered within the area surveyed. For most species, however, the surveyed area is part of a much larger range; for these species, one might expect inter-annual variation in the number of animals present in European waters and consequently in estimates of abundance. This should be recognised when considering estimates of abundance for these species during baseline characterisation of Draft Plan Option areas. For example, the number of minke whales present in the North Sea in summer may vary from year to year depending on factors influencing their distribution in Norwegian waters (e.g. Bøthun et al., 2009).

Adequacy of the survey area

The SCANS-III survey area covers all the Draft Plan Option Areas. It includes the majority of the Scottish EEZ, extending west to the 200 nm limit. However, the northern boundary of the area is at 62^0N so it does not cover the full northern extent of the EEZ. To obtain full coverage of Scottish waters, the survey area would need to be extended northwards.

Spatial models can sometimes generate so-called “edge effects” in maps of predicted density resulting from the shape of the fitted relationships between density and environmental covariates. The effect is typically manifested as higher predicted density at the edge of the survey area. None of the Draft Plan Option Areas are near the edge of the SCANS-III survey area, so the results for these Areas are not affected by any such edge effects.

Relative vs absolute abundance

To address questions related to trends in abundance over time (years) at any spatial scale, it may be appropriate to estimate relative abundance (i.e. an index of abundance) rather than the absolute number of animals in an area (as achieved by SCANS). Calculating the absolute abundance of cetaceans requires a more complex survey methodology, more survey personnel, and is only successful for species and areas where you will collect enough sightings. By contrast, an index of abundance is not constrained by these limitations. It may not provide a precise estimate of population size, but it will be proportional to true abundance, so that variation in the index reflects variation in abundance. When considering trends, as long as variation in the index is not confounded with trend in the true abundance, it may still be a valid indicator of that trend. However, the greater that variability, the less likely that a trend can be determined.

It is advisable to minimise variability in estimates of abundance to maximise the probability of identifying a trend, if there is one. The SCANS methodology minimises variability as best as possible through the survey design.

SCANS survey costs

The total cost of the SCANS-III survey in 2016 was a little over €2M, of which approximately €1.8M was the cost of conducting the survey (excluding co-ordination, preparation, analysis, and reporting etc). The total transect length was 51,600 km, and the total area surveyed was approximately 1.8M km^2. In SCANS-III, both ship and aerial surveys were conducted but the entire European Atlantic continental shelf was surveyed by air. In SCANS-III, the aerial survey cost €880,000 to cover an area of 1.2M km^2. Whilst visual aerial surveys are generally cheaper to run than ship surveys, logistical and data quality problems prevent them being the main survey method in all areas. For example, aerial surveys require airport availability, suitable aircraft for surveying, and that the planes are capable of long-distance travel to more offshore areas. With regards the data, aerial surveys are perhaps less useful for deep divers due to their low time spent at the surface vs the aircraft survey speed. The DPO areas were covered by aerial survey.

Future plans

The group of researchers that proposed the first SCANS survey initially envisioned that surveys would take place at an approximately decadal scale. This “vision” was based partly on the results of computer simulations conducted by the IWC Scientific Committee as part of the development of the Revised Management Procedure (RMP), which showed that surveys every 5-10 years were adequate to provide information needed to meet RMP conservation/management objectives. It was also recognised that large scale multinational surveys were challenging to organise and required considerable resources to be conducted successfully so frequent surveys were unlikely to be logistically feasible.

In recent years, two additional considerations have led to the recognition that a more appropriate inter-survey interval would be 6 years. First, SCANS results have been an important input to assessments of Favourable Conservation Status under the Habitats Directive and Good Environmental Status under the Marine Strategy Framework Directive. Both EU Directives require reporting on a 6-year cycle. With the current survey frequency, only approximately one report in two will have the benefit of up to date information from a recent survey. Second, a focal species of SCANS surveys for many participating Member States is the harbour porpoise, which has a relatively short life span compared to other cetacean species in the European Atlantic. Current knowledge of harbour porpoise life history indicates that few animals live more than 10 years; surveys every 11 years are thus a very blunt tool for studying the population dynamics of this species and monitoring trends in its abundance.

Cutting the inter-survey interval to 6 years now would mean the next SCANS survey taking place in 2022, which seems optimistic given that there are currently no concrete plans for another survey. In addition, the next MSFD assessment is due in 2023 and there may not be time for results from a survey conducted in summer 2022 to inform this assessment. Thus, if there is to be a fourth SCANS survey, it is unlikely to be before 2023.

An additional consideration is that SCANS surveys have hitherto been organised by interested researchers “from the bottom up”, rather than being organised “from the top down” by those responsible for delivering the policy requirements that depend on the survey results. A better arrangement would be for North Atlantic EU member States and other interested countries (e.g. Norway has supported and participated in all three SCANS surveys) to define and fund the survey, and to contract appropriate organisations to conduct the scientific work. This model has been followed in the recent survey of the Mediterranean and Black Seas, organised by ACCOBAMS.

Although there are currently no plans for SCANS-IV, a small group comprising researchers and those responsible for delivering policy will initiate discussions this year.

Conclusions

Cetaceans are highly mobile, wide ranging species - even in European coastal waters. Tagged porpoises in Denmark were found to range over 100 km from tagging location during the time tags were operational (Teilmann et al., 2008); minke whales are known to regularly move between UK and Norwegian waters (Bøthun et al., 2009), and photo identification studies have shown that even species with “resident” populations, such as bottlenose dolphins, have demonstrated regular movements to areas in excess of 300 km away from the site where they were originally photographed (e.g. Arso Civil et al., 2019). As a result, it is imperative to get a good understanding of distribution and abundance in regions and areas at a variety of spatial scales, and not only focus specifically on small areas of interest. The SCANS surveys help provide some of the important context on abundance and summer distribution of different species. The SCANS surveys are a useful population level monitoring tool. Sightings information from SCANS surveys in terms of site baseline characterisation of Draft Plan Options sites can provide information on species likely to be present in the area (in summer), information on broadscale density and abundance of those species over a large spatial and temporal scale, and an indication of the relative importance of that area to the summer species range of those species. The SCANS surveys do not provide detailed characterisation of a site (spatially or temporally) at the Draft Plan Option scale.

References

Arso Civil, M., Quick, N.J., Cheney, B., Pirotta, E., Thompson, P.M., Hammond, P.S. 2019. Changing distribution of the east coast of Scotland bottlenose dolphin population and the challenges of area-based management. Aquatic Conservation. 29. S1 Supplement. doi.org/10.1002/aqc.3102

Becker, E.A., Forney, K.A., Fiedler, P.A., Barlow, J., Chivers, S.J., Edwards, C.A., Moore, A.M. & Redfern, J.V. 2016. Moving towards dynamic ocean management: how well do modelled ocean products predict species distributions? Remote Sensing 8: 149. doi:10.3390/rs8020149.

Becker, E.A., Forney, K.A., Thayre, B.J., Debich, A.J., Campbell, G.S., Whitaker, K., Douglas, A.B., Gilles, A., Hoopes, R. & Hildebrand, J.A. 2017. Habitat-based density models for three cetacean species off southern California illustrate pronounced seasonal differences. *Frontiers in Marine Science* **4**: 121. doi:10.3389/fmars.2017.00121.

Bøthun, G, Skaug, HJ, & Øien, N (2009). Abundance of minke whales in the Northeast Atlantic based on survey data collected over the period 2002-2007. Paper SC/61/RMP2 presented to the IWC Scientific Committee.

Camphuysen, K.C.J., 2004. The return of the harbour porpoise (*Phocoena phocoena*) in Dutch coastal waters. *Lutra* **47**: 113–122.

CODA (2009). Cetacean Offshore Distribution and Abundance in the European Atlantic (CODA). Final Report. University of St Andrews, UK. http://biology.st-andrews.ac.uk/coda/

Degraer, S., 2011. The harbour porpoise *Phocoena phocoena* in the Belgian part of the North Sea: trends in abundance and distribution. *Belg. J. Zool*. **141**: 75–84.

Gilles, A., Viquerat, S., Becker, E.A., Forney, K.A., Geelhoed, S.C.V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., van Beest, F.M., van Bemmelen, R., Aarts, G. 2016. Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment. *Ecosphere* **7**: e01367. 10.1002/ecs2.1367

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. & Øien, N. 2002. Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology* **39**: 361-376.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D. & Gordon, J. 2013. Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation* **164**: 107-122.

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Boerjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M., Scheidat, M. & Teilmann, J. 2017. Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Final Report. 39pp https://synergy.st-andrews.ac.uk/scans3/category/researchoutput/

Scheidat, M., Gilles, A., Kock, K-H., Siebert, U. 2008. Harbour porpoise *Phocoena phocoena* abundance in the southwestern Baltic Sea. Endangered Species Research. 5:215-223.

Teilmann, J., Sveegaard, S., Dietz, R., Petersen, I.K., Berggren, P. & Desportes, G. 2008: High density areas for harbour porpoises in Danish waters. National Environmental Research Institute, University of Aarhus. 84 pp. – NERI Technical Report No. 657. http://www.dmu.dk/Pub/FR657.pdf