Movements of grey seal that haul out on the UK coast of the southern North Sea

Report to DECC

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1 Contents

Table of Contents

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2 Executive Summary

DECC's Offshore Energy Strategic Environmental Assessment programme (SEA), requires robust evidence on which to base the relevant assessments. Currently little is known about the movements of grey seals (*Halichoerus grypus*) which haul out on the UK coast of the southern North Sea; only ten grey seals have previously been tracked. Since that deployment in 2005, there has been dramatic increases in the summer foraging and winter breeding populations of grey seals in the southern North Sea. Over the same time period, harbour seal (*Phoca vitulina*) populations on the UK south-east coast have recovered from earlier declines and are now at historic high levels. These populations are primarily based at The Wash and Blakeney which are part of The Wash and North Norfolk Coast Special Area of Conservation (SAC) for which harbour seals were a primary reason for designation). There have also been extensive windfarm developments with many more planned. These changes in population and environment may have affected the at-sea distribution of grey seals. In this DECC funded study, 21 tags were deployed at the two main haul out sites in the south-east UK: Donna Nook (part of the Humber Estuary SAC for which grey seals are a qualifying feature), and Blakeney. The data from these tags indicated that there are extensive movements between haul out sites on the UK south-east coast. Even once we exclude the breeding season, there are extensive movements within the foraging (non-breeding season) thus the grey seals in this area appear to encompass one, rather than multiple, populations. The disproportionately large foraging population, in comparison to the breeding population, on the UK south-east coast suggests that some individuals are foraging in the southern North Sea but breeding elsewhere. Supporting this suggestion, one female tagged at Donna Nook pupped in the northern North Sea. Four other tagged females appeared to pup on the UK south-east coast. There was extensive overlap between grey seal movements and, present and planned, windfarms; 17 of the 21 individuals entered at least one operational windfarm. There was no indication of overt avoidance or use of windfarms, or other anthropogenic structures. In comparison to 2005, it appears that offshore usage by seals emanating from Donna Nook in 2015 was not restricted to discrete patches. The dispersed foraging areas, and the greater maximum extent, may be a result of an increasing grey seal population and thus a depletion of prey resources or increase in competition at key foraging areas since 2005. This finding highlights the importance of updating at-sea usage maps with recent telemetry data, on the basis of which policy and marine spatial planning decisions may be made, especially when changes in population have occurred. With the rapidly increasing populations of both species it is likely that competition

for resources will increase in the near future. Knowledge of the degree of overlap between grey and harbour seal foraging areas will provide a valuable baseline for comparison with the future, if and when, competition becomes important.

3 Introduction

Currently little is known about the movements of grey seals (*Halichoerus grypus*) which haul out on the UK coast of the southern North Sea (UK south-east coast); only ten grey seals have previously been tracked. These tags were all deployed at one haul out site, Donna Nook, in 2005. The deployment pre-dated the current, high resolution GPS tags and relied instead on Argos position fixes with their sometimes large location errors of 50m to > 2.5km (Vincent *et al.* 2002). This precluded the use of these data for examining fine scale movements or behaviours. Since that deployment, there has been dramatic increases in both the summer foraging (20% p.a. increase) and breeding populations (12% p.a. increase) of grey seals on the UK south-east coast (Duck & Morris 2014; Duck, Morris & Thompson 2014). Over the same time period, harbour seal (*Phoca vitulina*) populations have recovered from earlier declines and are now at historic high levels (Duck, Morris & Thompson 2014). There have also been extensive windfarm developments since the last telemetry deployment with many more planned (Fig 1a). These changes in population and environment may have affected the at-sea distribution of grey seals.

The population of grey seals in the southern North Sea is currently estimated to be about 13,500 (95% CIs: 8,500 - 28,000) with the main haul out sites being at Donna Nook (the largest grey seal haul out concentration in Europe and part of the Humber Estuary Special Area of Conservation (SAC) for which grey seals are a qualifying feature), and Blakeney (part of The Wash and North Norfolk Coast SAC for which harbour seals were a primary reason for designation). In addition, there are three other key grey seal haul out sites on the UK south-east coast (Fig 1): The Wash (part of The Wash and North Norfolk Coast SAC), Horsey and Scroby Sands. Little is known about the current movements of individuals from and between these haul out sites. Such information is key for appropriate marine spatial planning; specifically in understanding where any anthropogenic impacts may be reflected in the foraging populations of grey seals, especially with regard to the Donna Nook SAC. In 2005, some individuals displayed an inshore distribution (Fig 1). In Donna Nook, the population of grey seals has tripled since 2005 (Duck et al. 2005) and thus prey availability in the area surrounding the haul out site may have been depleted. This depletion may have caused individuals to travel further or work harder to obtain their energetic requirements.

The three females tagged in 2005 for which pupping behaviour was deduced, pupped at Donna Nook. Currently in comparison to the rest of the UK, the summer foraging population in the southern North Sea is disproportionately large compared to the breeding population. This implies that a substantial proportion of the individuals foraging in the southern North Sea breed elsewhere. Understanding the spatial link between where animals forage and breed is critical for effective population management (Russell *et al.* 2013).

The southern North Sea is an area of extensive anthropogenic activity, including activities related to oil and gas, shipping, fishing and windfarm development. Since the tagging at Donna Nook in 2005, eleven windfarms, totalling 740 turbines have been installed; two are adjacent to the Donna Nook haul out site. Recent research, funded by DECC, showed that some individual grey seals clearly use pipelines as foraging opportunities likely as a result of an artificial reef (Russell *et al.* 2014) but their reaction to windfarms is unknown. The same study also showed that harbour seals do not avoid operational windfarms (Russell *et al.* 2016) and that some individuals appear to forage at windfarm foundations (Russell *et al.* 2014). Information regarding the interactions between grey seals and windfarms is important as four further windfarms are consented with many more planned in the southern and central North Sea. Much of this development will be in offshore waters that are expected to be exploited mainly by grey rather than harbour seals.

In the current study, tags were deployed on grey seals at Donna Nook (n=11) and Blakeney (n=10). The use of Sheringham Shoal windfarm, just off Blakeney, by a harbour seal indicates that an artificial reef (Pickering & Whitmarsh 1997) exists on some of the foundations (Russell *et al.* 2014). This makes Blakeney an ideal site from which to examine the relationship between grey seals and operational windfarms. Here we report on the movements of these tagged seals; the breeding status of the tagged females; their interactions with anthropogenic structures (windfarms and pipelines); and the change in distribution between 2005 and 2015 of grey seals that make return trips to Donna Nook.

4 Methods

4.1 Telemetry data

The tags were deployed in early May 2015 (Table 1). This time of year was chosen as it co-insides with the end of the moult in this region and thus allowed the tags to collect data for as long as possible before the following moult. The tag settings were adjusted to ensure that the battery would last through the pupping season (November-January). Seals were caught on or close to haul out sites using hand or seine nets. Telemetry tags were attached to the fur at the back of the neck using a fast setting two-part epoxy adhesive or Loctite® 422 Instant Adhesive. All seal handling and procedures were carried out under Home Office Licence 70/7806. Ten individuals were tagged at Donna Nook with GPS/GSM tags. In addition, a solar GPS/Argos tag, provided by SMRU Instrumentation to test, was also deployed at Donna Nook. Ten tags were then deployed at Blakeney. As per the SMRU protocol for cleaning telemetry data (Russell, Matthiopoulos & McConnell 2011), the data were cleaned and the end dates adjusted when necessary. If the data ended while the tag recorded a haul out event then the end date was adjusted to the start of that haulout period, on the basis that was not possible to determine if and when the tag fell off the individual. In some cases it is likely the individual hauled out to pup and then the tag fell off, but this cannot be confirmed.

4.2 Breeding Status and Location

Following a previous DECC funded study (Russell *et al.* 2013), we assumed that females that were hauled out for the majority of an 18 day period had pupped; the approximate period of maternal care in grey seals (Twiss, Duck & Pomeroy 2003). This was a conservative proxy for pupping; individuals that pupped but the pup did not survive may have hauled out for a shorter duration.

4.3 Overlap with anthropogenic structures

There are both operational and proposed windfarms within the range visited by the seals (Fig 1a). There are two newly built windfarms (Humber Gateway and Westermost Rough), 15 and 30 km from the Donna Nook haul out site, respectively. These windfarms became fully operational in 2015 and so were a similar age to Sheringham Shoal when utilised by a harbour seal for foraging in 2012.

Sheringham Shoal (partially operational since 2011) is less than 20 km offshore from the Blakeney haul out site. In addition, there are four other operational windfarms in the surrounding area (Lynn, Inner Dowsing, Scroby Sands and Lincs; Fig. 1a). We examined which individuals entered the site of either an existing or planned windfarm.

4.4 Use of structures

As well as windfarms there are also pipelines and other oil and gas infrastructure within the foraging range of seals at both Donna Nook and Blakeney (Fig 1b). Following Russell *et al.* (2014) we inspected whether or not any seals appeared to spend prolonged periods at anthropogenic structures and exhibited any behaviour consistent with foraging.

4.5 Comparison of usage: 2005 to 2015

Please note parts of this section are extracted from Russell *et al.* (2016) as the same analysis (on a different data set) was carried out in both studies.

The movements of grey seals are likely to be affected by time of year; long trips and changes in haul out site may be associated with breeding or moulting. Thus to allow a fair comparison between at-sea usage in 2005 and 2015, the data from tags were restricted to mid-July (deployment time of tags in 2005) to end of October (start of breeding season in southern North Sea). Grey seals are effectively central place foragers, returning regularly to land between foraging trips, and thus their distribution at sea is likely to be affected by the location of that central place (haul out site). To ensure an unbiased comparison between the 2005 and 2015 data, only return trips from Donna Nook were included. This resulted in a sample of seven and 12 individuals for 2005 and 2015, respectively. Following Russell *et al.* (2016) we used a 2 dimensional spatial smooth of longitude and latitude to explain their distribution in 2005 and 2015.

The location of an individual is a reflection of both where it can go (accessibility) and where it chooses to be (preference; Matthiopoulos 2003). The maximum geodesic distance (shortest path at-sea) of the return trips from Donna Nook was used to define the accessible area. For each presence point, within the accessible areas randomly positioned absences were generated (2005, n= 1397; 2012, n=2562). These pseuo-absence data can be thought of as representative samples of points from the region of space that is accessible to the seals, and therefore as a means of communicating to a model the contrast between the space actually used by the seals and the space that is broadly available to them in their environment (Beyer *et al*. 2010). The distribution was modelled as a binomial process (0 as absence and 1 as presence) as a function of a two-dimensional smooth of longitude and latitude and an interaction with year (2005 or 2015).

A Complex Region Spatial Smoother (CReSS; Scott-Hayward *et al.* 2014) with a Spatially Adaptive Local Smoothing Algorithm (SALSA; Walker *et al.* 2011), was used to parameterise the model. Model selection was conducted to choose the most appropriate number and locations of knots for each smooth. Knot location was chosen by minimising AIC within the model run (SALSA) and the number of knots was chosen using the Spearman rank correlation (Boyce et al 2002) with a 3-fold cross validation framework. Entire data (presences and pseuo-absences) were assigned to each fold; three folds were chosen so that each fold included at least two individuals from 2005. Once the optimal model was selected, it was rerun in a Generalised Estimating Equation (GEE; Hardin & Hilbe 2002) framework. This allowed us to test whether or not the distribution of seals making return trips from Donna Nook in 2005 differed from that in 2015; i.e. was there a significant interaction between spatial usage (2-D smooth) and year? The GEE framework also allowed robust estimation of the precision associated with the spatial predictions because by using the independent working correlation structure any residual autocorrelation within defined panels of data was accounted for (Pirotta *et al.* 2011). A separate panel was used for the presences relating to each individual. Each absence was assumed to be independent and thus was included in a separate panel. For more details of the modelling see Russell *et al.* (2016).

For the area available to the seals, we predicted the seal usage on a 5 by 5 km grid. A parametric bootstrap from the GEE model was used to calculate 95% confidence intervals (CIs) for the predicted usage (percentage of the at-sea population) in 2005 and 2015. All data preparation and analysis was carried out using R (R Core Team 2012) within packages fields (Furrer, Nychka & Sain 2012), geepack (Højsgaard, Halekoh & Yan 2006), rgdal (Keitt *et al.*

2013), sp (Pebesma & Bivand 2005), splancs (Rowlingson *et al.* 2013) and MRSea (Scott-Hayward *et al.* 2013).

5 Results

5.1 Telemetry data

The median adjusted tag duration in 2015 was 196 days (range: six-239 days). Only two tags stopped transmitting within 100 days (six and 24 day duration); the reason for these short durations is not known and could be due to tag failure, tag attachment failure or animal death. The tags deployed in July 2005 (five females and five males) had a median duration of 163 days (range: 12-257).

In 2015, of the 21 tagged individuals, 16 used multiple haul out sites. One tagged at Donna Nook hauled out in the Netherlands (Wadden Sea) and one tagged at Blakeney went to northern France and did not return. In 2005, only two of the 10 study individuals (both male) used multiple haul out sites. One hauled out at The Wash, approximately 50 km south of Donna Nook. The second appeared to haul out at the Farne Islands (approximately 270 km north of Donna Nook). He visited other haul out sites but this was during the breeding season and thus may have been associated with breeding behaviour.

The percentage of individuals using multiple haul out sites in 2005 (20%) and 2015 (75%) is not directly comparable. Long trips or changes in haul out site may be associated with post-moulting or breeding. Furthermore, many individuals tagged at Blakeney in 2015 (at which no tags were deployed in 2005) used nearby Horsey and Scroby Sands. Thus to compare with the use of multiple haul out sites in 2005, for the 2015 data we examined the tracks of seven individuals which were both tagged at Donna Nook and used it as a haul out site between mid-July (start of data from 2005) and end of October. Five of seven did not use any additional haul out sites during this period. Thus despite the large differences in the proportion of individuals using multiple haul outs sites in 2015 compared to 2005, it appears that the differences may be largely attributed to differences in tagging site and time of year.

5.2 Breeding Status and Location

In 2005, of the five females tagged, three showed behaviour consistent with pupping (Russell *et al.* 2013). In 2015, behaviour of five females was consistent with pupping (as described in Russell *et al.* 2013): three tagged in Donna Nook and two tagged in Blakeney. For the females tagged in Donna Nook, one appeared to pup at Fast Castle (300 km north of Donna Nook; Fig 1b) and two at Donna Nook. One of these tags was recovered after a prolonged haulout at Donna Nook indicating that the tag fell off during a haulout and continued to transmit. It cannot be confirmed that this individual pupped but the position of her haulout is consistent with a high density breeding area (pers comm. Rob Lidstone-Scott, Outer Humber Warden) rather than an inter-trip haul out site, so we have assumed pupping in this case. The other female that appeared to pup at Donna Nook was confirmed to have a pup (Lizzie Lemon, Assistant Outer Humber Warden). Two of the females tagged at Blakeney also pupped; both at Blakeney. They were both confirmed to have given birth to a pup which they successfully weaned (Ajay Tegala and George Baldock, National Trust).

5.3 Overlap with anthropogenic structures

We found that 17 of the 19 individuals, whose tag duration were over 100 days, entered an operational windfarm. The majority (nine) entered more than one operational windfarm, with five individuals entering three or more operational windfarms. One individual entered nine operational windfarms as well as a windfarm under construction. From visual inspection of the tracks there was no apparent overt avoidance of any windfarms. Eight individuals entered areas for which windfarm construction has been consented and six entered areas of proposed windfarms. In addition, 17 individuals entered areas of search. The operational windfarms visited by the highest number of individuals were those near the haul out sites: Humber Gateway (12), Westermost Rough (six), Inner Dowsing (three), Lincs (five), Scroby Sands (five), Sheringham Shoal (four) and Lynn (two).

5.4 Use of structures

The telemetry data from 2015 indicated there was no overt use of structures, i.e. there was no evidence for of area restricted search behaviour (associated with foraging) at any anthropogenic structures.

5.5 Comparison of usage: 2005 to 2015

There was a significant interaction between the 2-D spatial smooth and year; the at-sea usage of grey seals making return trips from Donna Nook in 2015 significantly differed from the usage in 2005. The optimal model, selected using cross validation, comprised eight knots. The distribution in 2005 appears to have two to three hotspots, one very near shore (Fig 3) and two offshore (120 and 180 km from Donna Nook, respectively). In contrast, only a clear hotspot of inshore usage was evident in 2015 (Fig. 4). Overall the usage appeared to be much more spread out than in 2005, both in direction and distance from Donna Nook (Fig 4).

6 Discussion

The data from the tags deployed in 2015 indicated that there are extensive movements between haul out sites on the UK coast of the southern North Sea. Even once we excluded the breeding season, there were extensive movements within the foraging (non-breeding) season thus the grey seals in this area appear to encompass one, rather than multiple, populations. However, it does seem that within this area, grey seals do preferentially breed at the sites at which they typically haul out – the four females breeding at Donna Nook and Blakeney were tagged at the same site. The disproportionally large foraging population on the UK south-east coast, in comparison to the breeding population, suggests that some individuals are foraging in the southern North Sea but breeding elsewhere. Supporting this, one female, tagged at Donna Nook, did pup in the northern North Sea.

There was extensive overlap between grey seal movements and windfarms, both already present and planned; 17 of the 19 individuals (with tag duration of over 100 days) entered an operational windfarm. Although no quantitative analysis was conducted, there was no indication of avoidance of windfarms by grey seals. There was also no evidence of overt use of windfarm foundations. A key fish species at Sheringham Shoal windfarm, at which a tagged harbour seal foraged, was pouting (*Trisopterus luscus;* Russell pers. comm). Small gadoid fish including this species appears to be more popular in the diet of harbour seals than grey seals in the southern North Sea (Wilson & Hammond 2015). Previous tagging has demonstrated grey seals foraging along pipelines (Russell *et al.* 2014). Despite extensive overlap between grey seal tracks and pipelines in the southern North Sea, there was no evidence of use of these structures for foraging. However, there is not a centralised database indicating which pipelines are buried or on the surface and so available to act as an artificial reef. It may be the case that most of the pipelines that grey seals encountered were not exposed and thus not able to host artificial reefs. In any case, foraging at structures may represent an individual specialism; only one of 24 tagged harbour seals foraged at foundations of Sheringham Shoal windfarm. Thus it may simply be that such individuals were not included in the sample tagged. To understand whether such structures are important on a population level, the number of encounters of structures by seals needs to be quantified as well as the number of these encounters which constitute foraging to allow a use-encounter rate to be defined.

There was a significant difference in at-sea usage during return trips from Donna Nook in 2005 and 2015. Quantifying such change was limited by the sample size in 2005. Furthermore, it should be noted that one individual which performed trips predominantly within the Humber Estuary in 2005 was excluded from this analysis: the extent of Argos error and low temporal resolution of points meant there were not enough locations identified as being within the estuary (rather than on land) to enable inclusion in the analysis. Looking at the raw tracks it is clear that there is considerable individual variation in the movements of individuals in 2015; some appear to forage up the coast and others offshore. Unlike in 2005, the offshore usage is not restricted to discrete patches. The apparent dispersed foraging areas may be a result of an increasing grey seal population and thus a depletion of prey resources or increase in competition at previous key foraging areas. These findings highlight the importance of updating usage maps on the basis of which policy decisions are being made with recent telemetry data, especially when changes in population have occurred.

As well as the findings reported here, the telemetry data can be utilised to address further applied research questions. Most critically are grey seal usage maps; these are available for download (Jones *et al.* 2015) and are used in Environmental Impact Assessments. Currently in the southern North Sea, usage maps for grey seals based on the data from the tags deployed in 2005. As discussed above the usage (at least for return trips to Donna Nook) appears to have significantly changed. Furthermore, these tags provide the first data from the three other key haul out sites of the UK south-east coast: Blakeney, Scroby Sands and Horsey.

In a previous DECC funded study, the activity budgets of seals were estimated (McClintock *et al.* 2013; Russell *et al.* 2015). This allowed the proportion of time spent hauled out, resting at sea, foraging and travelling to be estimated. Such foraging effort metrics may be more reliable than traditional metrics such as trip distance or effort because seals can adjust both trip duration, time spent resting at sea and inter-trip haul out duration. For example, harbour seals hauling out in The Wash forage further from their haul out than harbour seals at any other haul out site in the UK. It is unlikely this is indicative of particularly high foraging effort associated with nutritional stress because their time spent resting is similar to elsewhere and the southern North Sea population is the only increasing harbour seal population in the UK. Previous activity budgets were estimated on a six hour resolution (determined by the temporal resolution of Argos data). The recent high quality GPS data collected in the southern North Sea on grey and harbour seals will allow high resolution activity budgets to be defined. Foraging locations could then be used to define the foraging habitat preference of both species in the southern North Sea. This would allow us to define their key habitats; these may differ in the southern North Sea compared to elsewhere due to differences in prey availability and consumption (Wilson & Hammond 2015). With the rapidly increasing populations of both species it is likely that competition for resources will increase in the near future. Knowledge of the degree of overlap between grey and harbour seal foraging preference and areas will provide a valuable baseline for comparison with the future if and when competition becomes an important driver of population dynamics. Such an understanding is particularly important for harbour and grey seals hauling out at The Wash and Donna Nook, Special Areas of Conservation for harbour seals and grey seals, respectively.

7 Acknowledgements

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9 Figures

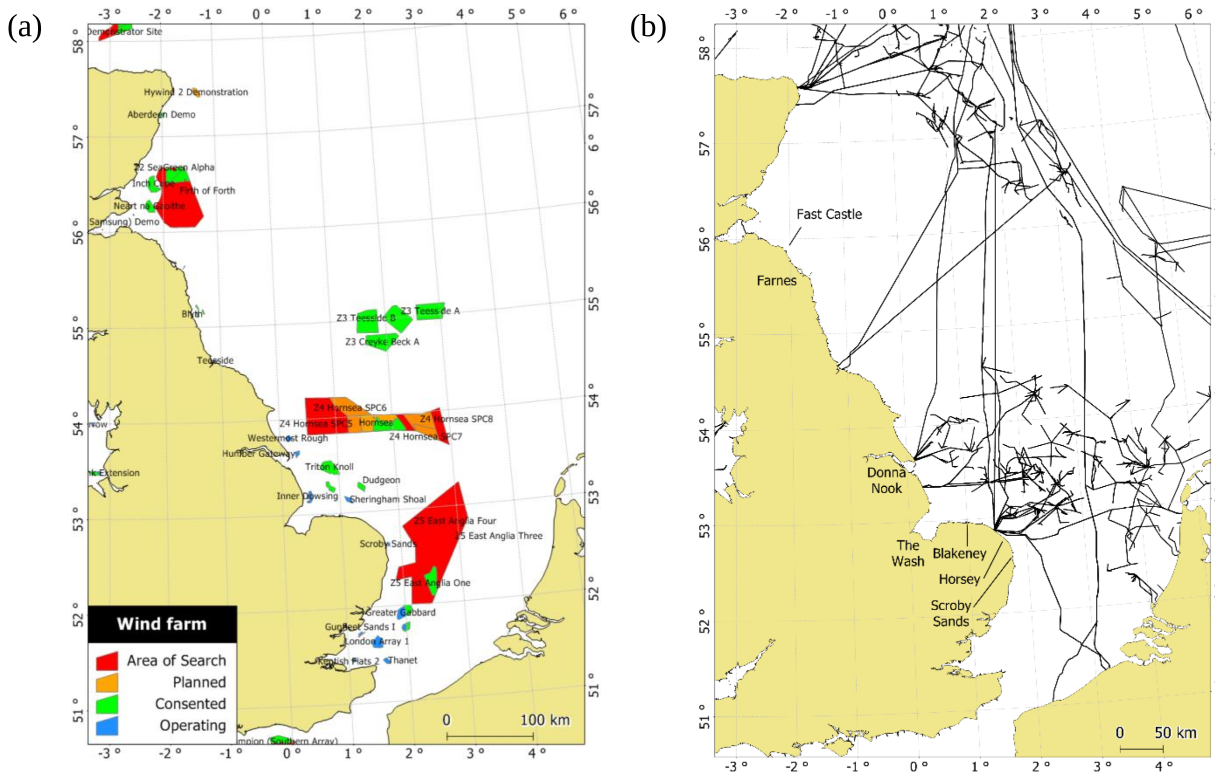

Figure 1. The man-made structures (a) wind farms (only UK shown) and (b) pipelines. The main grey seal haul out sites on the UK coast of the southern North Sea are also shown in (b).

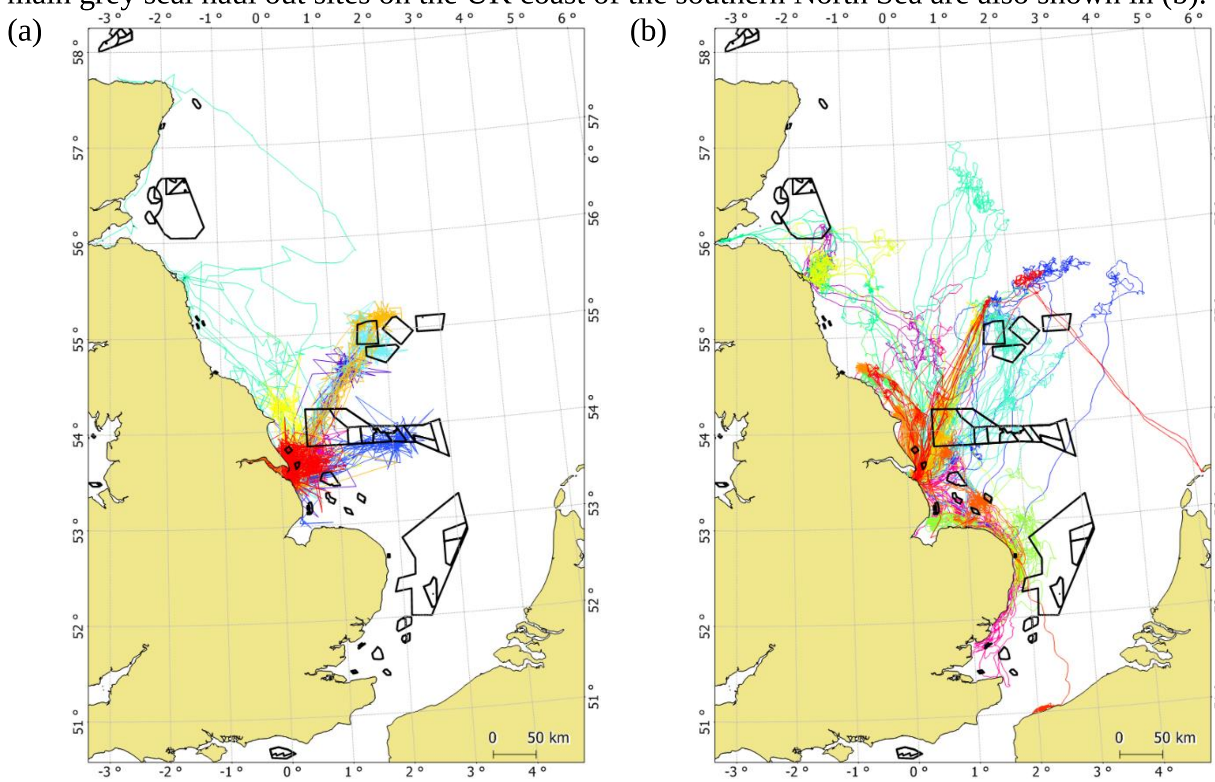

Figure 2. Tracks from grey seal tagged in 2005 (a; n=10) and in 2015 (b; n=21). These maps are not directly comparable as they refer to individuals tagged only at Donna Nook in 2005, and both Donna Nook and Blakeney in 2015. Furthermore, they encompass different durations and times of the year and may show trips to breeding sites by some individuals.

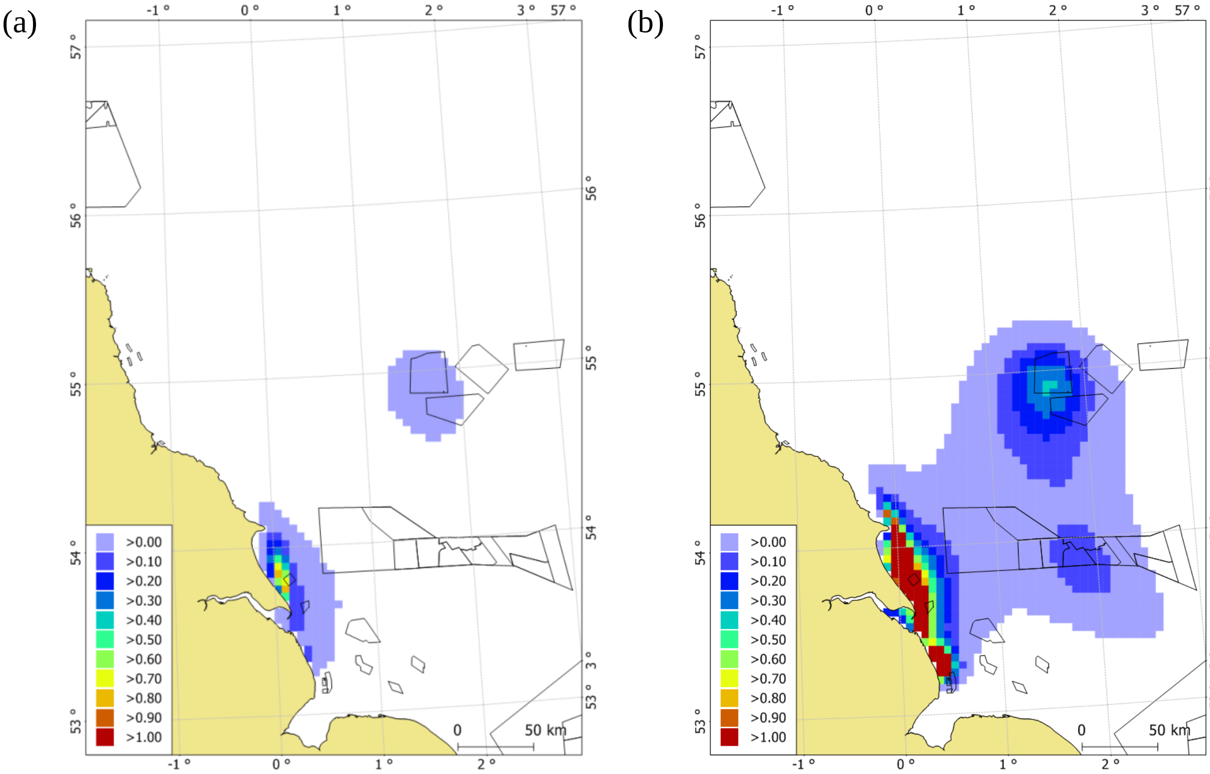

Figure 3. The predicted distribution of grey seals on return trips from Donna Nook on a 5 km resolution in 2005. The metric is the percentage of the at-sea population with the lower (a) and upper (b) 95% confidence limits per cell shown.

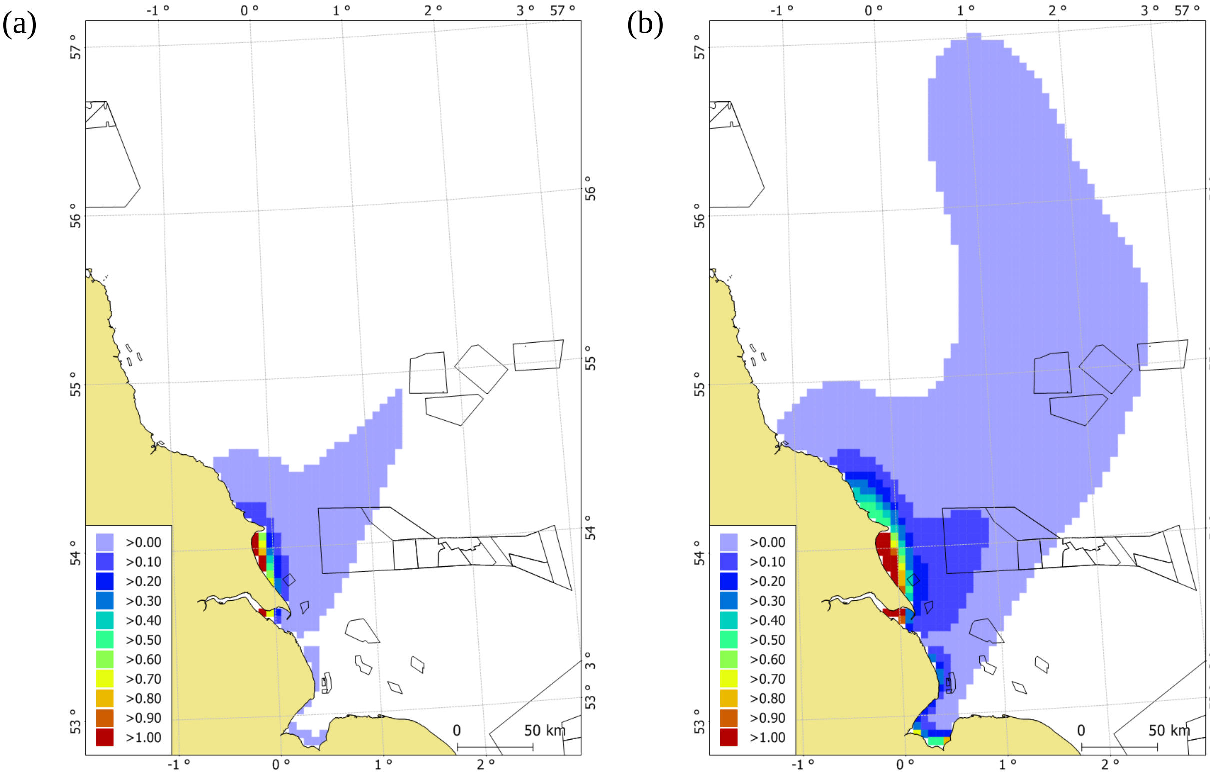

Figure 4. The predicted distribution of grey seals on return trips from Donna Nook on a 5 km resolution in 2015. The metric is the percentage of the at-sea population with the lower (a) and upper (b) 95% confidence limits per cell shown.