BTO Research Report No. 639

Measuring the Interaction between Marine Features of Special Protection Areas with Offshore Wind Farm Development Sites Through Telemetry: Third Year Report

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Report of work carried out by the British Trust for Ornithology[1]
in association with the University of Amsterdam[3]
and collaboration with the Environmental Research Institute[2]
on behalf of the Department of Energy and Climate Change

June 2013

CONTENTS

Page No.

List of Tables 3
List of Figures 5

EXECUTIVE SUMMARY 7

1. INTRODUCTION 9

1.1 Background 9
1.2 Project Aims 9

2. METHODS 11

2.1 Field Sites 11
2.2 The GPS System 11
2.3 Assessment of Tag Effects 11
2.4 Data Gathered During 2012 12
2.5 Data Processing and Analysis 13
2.5.1 Defining trips and calculating trip statistics 13
2.5.2 Connectivity with the areas of proposed and consented wind farms 13
2.5.3 Spatial overlap of home ranges with consented and proposed wind farms 13
2.5.3.1 *Seasonal variation* 13
2.5.4 Time budgets of birds 14
2.5.4.1 *Seasonal variation* 14
2.5.5 Formal statistical tests – spatial overlap and time budgets 14
2.5.6 Flight altitudes 15
2.5.6.1 *Altitude Analysis* 15
2.5.6.2 *Precision and accuracy in measurements* 15
2.5.6.3 *The modelling process* 15
2.5.6.4 *Outputs* 17

3. RESULTS 19

3.1 Descriptive Trip Statistics 19
3.1.1 Annual Variation in trips 20
3.2 Connectivity with the Areas of Proposed and Consented Wind Farms 22
3.2.1 2012 breeding season 22
3.2.2 Migration 22
3.2.2.1 *Data summary* 22
3.2.2.2 *Wind farm overlaps* 24
3.3 Spatial Overlap of Home Ranges with Consented and Proposed Wind Farms 28
3.3.1 Seasonal variation in home ranges 30
3.4 Time Budgets 32
3.4.1 Seasonal variation 33
3.5 Flight Heights 33

Page No.

4. DISCUSSION 35

4.1 Overview 35
4.1.1 Lesser Black-backed Gulls 35
4.1.2 Great Skuas 35
4.2 Seabird-Wind Farm Interactions in 2012 35
4.3 Effects of Wind Farms on Lesser Black-backed Gulls 36
4.4 Concluding Comments 36

Acknowledgments 37

References 39

LIST OF TABLES

Page No.

Table 1 Current data holdings for tags on Lesser Black-backed Gulls during the breeding season……. 14

Table 2 Descriptive trip statistics for Lesser Black-backed Gulls at Orford Ness in 2012 for all trips. Trip duration and total distance travelled are computed for all trips, however offshore foraging range is calculated only from those trips with an offshore component 22

Table 3 Migration information for all birds from both 2010/11 winter and 2011/12 winter period…..25

Table 4 Overlap analysis of "individual bird" kernels (pooled analysis) with wind farms (WF) for individual Lesser Black-backed Gulls for Orford Ness using a 1800 s rate. 30

Table 5 Information on (a) Time budgets of Lesser Black-backed Gulls during 2012 (hrs), including time spent offshore and in wind farm (WF) sites; and (b) Number of trips, and number of trips offshore that overlapped with offshore wind farm sites during 2012. 34

LIST OF FIGURES

Page No.

Figure 1 Altitudinal readings from one lesser black-backed gull during 2010 when stationary. 17

Figure 2 Schematic diagram of the state-space modelling approach proposed. 18

Figure 3 Smoothed Terms from a general additive model (GAM) for (a) offshore foraging Range, and (b) trip duration showing annual variation in seasonal patterns....................23

Figure 4 Plot of all Orford Ness data for birds tagged in 2012. Purple = Round 3; orange = Rounds 1 and 2; grey = extensions. 24

Figure 5 Flight paths of tagged Lesser Black-backed Gulls leaving and returning to Orford Ness on migration between July 2011 and April 2012. Tracks of different individuals are shown in different colours, and UK offshore developments are shown in blue. 27

Figure 6 Flight paths of tagged Lesser Black-backed Gulls showing their movements throughout migration and overwinter. Tracks of different individuals are shown in different colours, and UK offshore developments are shown in blue.. 28

Figure 7 Repeatability of migration routes for two Lesser Black-backed Gulls tracked for consecutive migration periods 2010/11 and 2011/12: (a) bird 407 and (b) bird 395, (c) bird 336 (the straight yellow line here represents data not yet downloaded on the return route in 2011/12 for this bird.. 29

Figure 8 Home ranges for all foraging trips of Lesser Black-backed Gulls tracked from the Orford Ness colony in 2012...31

Figure 9 Kernels for all birds from 2012 showing seasonal variation – each map is a five-day period, using a 1800s filtering rate.. 32

Figure 10 Seasonal variation in 2012 for all birds showing (a) total home range (95% KDE) and (b) area overlap with all offshore wind farms. Also shown are the total number of birds both contributing data to averages (as presented in a), and the total number of individuals overlapping in any one period (as presented in b).. 33

Figure 11 Seasonal time budget across all birds for 5-day consecutive periods during 2012 showing time spent at the nest, time spent away from the nest inland, time spent away from the nest offshore outside wind farm sites, and time spent offshore in wind farm sites.. 35

EXECUTIVE SUMMARY

1. The UK government has a commitment to obtain 15% of the UK's energy from renewable sources by 2020, of which wind energy is likely to form a major part (DECC 2009). Consequently many wind farms are currently under construction and more developments are proposed (e.g. Round 3 zones, Scottish Territorial Waters sites and extensions to Round 1 and Round 2 sites). There is, however, much concern as to the effects that offshore wind developments may have on seabird populations.

2. Many seabirds designated as feature species of Special Protection Areas (SPAs) might potentially be affected by these developments, as their breeding season foraging ranges and migratory routes may overlap with wind farm sites. The effect of wind farms on particular species is likely to be influenced by altitude at which birds fly, and the avoidance behaviour they might show.

3. This study uses the latest tracking technology to investigate the movements of two seabird species that are features of SPAs – Lesser Black-backed Gull and Great Skua. The aims of this study are threefold:
   i. To understand the connectivity of these feature species with the areas of consented wind farms (i.e. those which have already been constructed or are under construction) and proposed wind farm development sites;
   ii. To understand the extent to which these feature species use the areas of wind farms which have already been constructed or are under construction;
   iii. To provide an assessment of the flight altitudes of these feature species that could usefully inform collision risk modelling.

4. In summer 2012, 17 GPS-tagged Lesser Black-backed Gulls returned to breed at Orford Ness (Alde-Ore Estuary SPA), including all 14 tagged in 2011 and three tagged in 2010. As well as providing data for the 2012 breeding season, the tags on these birds also provided additional information for the 2011/12 migration and winter periods. Only one tagged Great Skua returned to the Foula and Hoy breeding colonies in 2012, and this bird had lost its tag and harness, whereas a control group for skuas at both colonies showed a high return rate. No adverse effect had been seen during the 2011 breeding season, but clearly the attachment of the tags caused an adverse effect over the migration / winter period. While it is conceivable that the remaining tagged skuas just skipped a breeding attempt, this is considered unlikely. Consequently, the skua study was immediately terminated. A full discussion of this issue is presented in Thaxter *et al.* (in prep a,b) and all new GPS movement information presented are from data obtained from Lesser Black-backed Gulls.

5. In total 13% of the 2,717 trips recorded in 2012 for Lesser Black-backed Gulls contained a marine component. The maximum foraging range offshore in 2012 during breeding was 159 km. Some individual gulls never ventured offshore, whilst others spent a substantial amount of time away from the colony at sea.

6. During the 2012 breeding season (mid-February-mid-July), Lesser Black-backed Gulls showed connectivity with consented Round 1 and 2 wind farms, proposed extensions, and Round 3 sites (overlap of 95% KDE, mean of 1.0±1.9% across birds; and mean 2.2±3.8% time offshore). During the 2011/12 migration and non-breeding period, 10 of the 15 Lesser Black-backed Gulls left the UK but five remained in the UK overwinter. During migration, six of the 15 birds crossed the sites of existing and proposed wind farms but all birds came near to wind farm sites at some point.

7. Considerable variation in behaviour was recorded over the season. Early in the season (pre-breeding), use of offshore areas was low and birds stayed relatively close to the colony apparently resting on the sea-surface overnight. As incubation approached during May, nest site attendance increased, but thereafter dropped from late-May onwards. Only after 20/05/2012 were spatio-temporal overlaps with offshore wind farm sites recorded more extensively, reaching up to 14% spatial overlap and just less than 5% of the total time budget (19/06/2012 – 24/06/2012). These results serve to highlight the importance of considering seasonal investigations when assessing the extent of seabird-wind farm interactions.

8. Full analysis of the results from across the three breeding seasons and three non-breeding seasons covered of the project, incorporating data from the 2012/13 non-breeding seasons, will be provided in a final report later in 2013. This final report will provide an overall picture of all movements and how these SPA feature species interact with wind farms both during breeding and non-breeding periods. The final report will also include full analyses of flight height data, for which the methodology is described here, including information on the distribution of flight altitudes and analysis of environmental factors such as weather that may affect altitude.

1. INTRODUCTION

1.1 Background

The UK government has a commitment to obtain 15% of the UK's energy from renewable sources by 2020, of which wind energy is likely to form a major part (DECC 2009). Consequently many wind farms are currently under construction and more developments are proposed (e.g. Round 3 zones, Scottish Territorial Waters sites and extensions to Round 1 and Round 2 sites). There is, however, much concern as to the effects that offshore wind developments may have on seabird populations.

Potential areas for development of offshore wind farms include locations that may hold large numbers of seabirds, seaduck and other waterbirds. Both consented and proposed development sites within the North Sea may also overlap the foraging areas of seabirds that are features of protected sites. Offshore wind farms may potentially have an impact on these bird populations through four main effects: (1) displacement due to the disturbance associated with developments; (2) the barrier effect posed by developments to migrating birds and birds commuting between breeding sites and feeding areas; (3) collision mortality; (4) indirect effects due to changes in habitat or prey availability. When assessing the potential effects of proposed wind farms on local bird populations, it is important to establish not only the use that birds make of the proposed wind farm area, but also in the assessment of collision risk, whether they are likely to come into contact with the turbines. The latter is largely determined by the height at which the birds fly, and any avoidance behaviour that they may show towards the turbines.

Before construction is consented, an Environmental Impact Assessment (EIA) is required to identify the possible risks posed by a development. As part of this process, where a "likely significant effect" upon a Natura 2000 site (Special Protection Area, SPA[1], or Special Area of Conservation, SAC) is identified, an Appropriate Assessment (AA) needs to be conducted, to understand and predict the effects on the feature species found at those sites. SPAs are designated under the European Bird's Directive (79/409/EEC), which protects sites within the European Union of international importance for breeding, wintering, feeding, or migrating vulnerable bird species. Wind farms have the potential to affect breeding seabirds or wintering waterbirds that are features of SPAs if they forage in areas where wind farms are proposed, or pass through these areas on migration. Thus, it is important to understand the connectivity between features of SPAs with development regions.

1.2 Project Aims

This study uses the latest tracking technology to investigate the movements of two seabird species that are features of SPAs – the Lesser Black-backed Gull (*Larus fuscus*) and the Great Skua (*Stercorarius skua*). The aims of this study are threefold:

i. To understand the connectivity of these feature species with the areas of consented wind farms (i.e. those which have already been constructed or are under construction) and proposed wind farm development sites;

ii. To understand the extent to which these feature species use the areas of wind farms which have already been constructed or are under construction;

iii. To provide an assessment of the flight altitudes of these feature species that could usefully inform collision risk modelling.

[1] http://www.naturalengland.org.uk/ourwork/conservation/designatedareas/spa/default.aspx

Here, we present the findings of the third year of this study. This report presents new movement information and seabird-wind farm interactions for Lesser Black-backed Gulls for the migration period 2011/12 and subsequent breeding season movements of returning birds in 2012. Comparisons of movements through the season are provided, together with some comparisons to previous years. No new data was gathered on movements of Great Skuas (see Thaxter *et al.* in prep a,b). However, we report on the field work that was carried out at Foula and Hoy in 2012. Complete analyses of data from the three breeding seasons and three non-breeding seasons covered of the project, incorporating data from the 2012/13 non-breeding seasons, will be provided in a final report later in 2013. This final report will also include full analyses of flight height data (the third aim of the study) – the methodology developed for this is described here – which will provide distribution of altitudes and investigations of how factors such as weather affect flight altitude.

2. METHODS

2.1 Field Sites

As in 2010 and 2011 (see Thaxter *et al.* 2012), Lesser Black-backed Gull fieldwork was conducted at Orford Ness, Suffolk, UK (52°06'N, 1°35'E), part of the Alde-Ore Estuary SPA. There were approximately 550 apparently occupied nests (AONs) for Lesser Black-backed Gulls at this site in 2010 and 2011 (M. Marsh, personal communication). Fieldwork for Great Skuas was again conducted at the Foula SPA, Shetland, UK (60°8'N, 2°5'W), as in 2010 and 2011 (Thaxter *et al.* 2012) and at the Hoy SPA, UK (58°52'N, 3°24'W) as in 2011, the latter work led by the University of the Highlands and Islands (UHI). For background information on tagging and the project's focal species, see Thaxter *et al.* (2011, 2012).

2.2 The GPS System

The GPS devices deployed on birds in 2011 and 2012 are discussed in Thaxter *et al.* (2010 and 2011). The system allows information from the tags to be remotely downloaded to a central base station (Bouten *et al.* 2012). A perimeter of approximately 200 m^2 was used around the Orford Ness gull colony, to allow calculation of when birds were "within" the colony attending nests, and "outside" the colony indicating nearby bathing or foraging trips. This same "perimeter fence" was used to automatically switch the device from quicker sampling rates to less frequent rates (i.e. to conserve battery power when the bird was at the nest).

2.3 Assessment of Tag Effects

In previous seasons (Thaxter *et al.* 2011, 2012), nest sites were monitored for productivity and attendance to assess tag effects on birds. We found no significant effect on productivity or attendance for either species during 2011. These results are also presented in Thaxter *et al.* (in prep a,b). Building on these results, we were also able to assess the return rates (apparent survival) of tagged individuals between one breeding season and the next and compare the return rates of tagged birds to those of control colour-ringed birds in an unbiased assessment. Details of survey methods and visits to the respective colonies are also given in Thaxter *et al.* (in prep a,b).

As in 2011, an excellent return rate of Lesser Black-backed Gulls was recorded at Orford Ness in 2012. All 14 of the birds previously tagged in 2011 returned to the colony, 12 with working tags – the remaining tags had either stopped working or lost aerials meaning that data transmission was weak or absent. A further three birds from the previous year (2010) also returned, two with working tags; however, one of these birds had patchy data stored, thus giving an incomplete temporal perspective.

In contrast to the gulls, only one tagged Great Skua at Foula was recorded back and this bird had lost its tag and harness. This bird was a female that laid two eggs and upon re-trapping showed no sign of having had a harness or any feather wear, with a weight well within the typical range for this species at this stage of the season (see Thaxter *et al.* in prep a,b). No tagged birds were seen back at Hoy. However, 10 out of 10 and 8 out of 10 birds colour-ringed in 2011 were seen back at the colony in 2012 at Foula and Hoy respectively. During migration, one Great Skua was recovered dead on the German coast (tag 419 from Foula) with the tag in place. Another Great Skua (tag 467) was recovered recently on the Portuguese coast (see Thaxter *et al.* in prep a,b). The exact cause of death in both cases was unknown. Another skua was seen alive in flight, from a fishing boat off the coast of Cornwall in November 2011. Hence, a clear over-winter tag effect was recorded for Great Skuas giving no migration data, and the study for this species has now been terminated. Thaxter *et al.* (in prep a,b) give further details and discussion.

2.4 Data Gathered During 2012

Table 1 gives the data gathered during 2012 for Lesser Black-backed Gulls. Due to technical difficulties with a relay malfunction, we were unable to gather a complete full breeding season for some individuals, with the bulk of data available prior to the end of May. However, for several individuals, we were still able to obtain data for a considerable period (Table 1). It is hoped that outstanding data may be obtained for those birds during the 2013 breeding season.

At the end of the 2011 breeding season, all tags from Lesser Black-backed Gulls were set on a 30 minute sampling rate. Tags from Lesser Black-backed Gulls returning from migration were changed to a 10 minute sampling rate when feasible to do so. Based on battery life assessment, a five minute rate for tags in their second year of deployment was deemed potentially unsustainable and may otherwise have given gaps in the dataset. As in previous years, we also used an energy surplus setting enabling a five-fold faster sampling rates when tags were fully charged. Additional 3 second sampling rates were collected in short bursts between 1200-1400 hours on some days, weather permitting, to allow further investigation into sample rate effects on flight height precision and accuracy (see Thaxter *et al.* 2011).

Table 1 Current data holdings for tags on Lesser Black-backed Gulls during the breeding season.

		2010			2011			2012		
Year tagged	**Bird**	**Start**	**End**	**Duration (days)**	**Start**	**End**	**Duration (days)**	**Start**	**End**	**Duration (days)**
2010	334	15/06/10	09/07/10	23.8	15/04/11	29/07/11	105.3			
	335	05/06/10	06/07/10	31.2						
	336	15/06/10	12/07/10	26.9	28/03/11	27/04/12	395.5	27/04/12	04/05/12	7.2
	345	06/06/10	09/07/10	33.6						
	347	05/06/10	na							
	384	15/06/10	21/06/10	5.7						
	388	15/06/10	08/07/10	22.6						
	391	15/06/10	05/07/10	19.6	04/04/11	28/07/11	115.3			
	395	15/06/10	21/07/10	35.6	29/03/11	15/07/11	108.5	23/03/12	01/07/12	99.7
	407	15/06/10	17/07/10	31.4	20/03/11	29/07/11	131.5	13/03/12	09/07/12	117.5
	408	15/06/10	14/07/10	29.3						
2011	457				21/05/11	10/06/11	19.8			
	459				21/05/11	24/07/11	63.3	21/03/12	18/05/12	57.7
	460				21/05/11	10/08/11	80.4	15/03/12	15/07/12	121.3
	478				21/05/11	01/08/11	72.2	28/02/12	26/05/12	88.1
	479				21/05/11	19/08/11	90.2	26/03/12	29/05/12	63.8
	480				21/05/11	12/08/11	82.4	08/04/12	06/06/12	59.4
	481				21/05/11	10/07/11	50.0			
	482				21/05/11	09/08/11	79.9	17/02/12	26/05/12	98.9
	483				22/05/11	17/08/11	86.6	19/03/12	17/06/12	89.6
	484				21/05/11	31/07/11	71.2	16/03/12	25/05/12	70.5
	485				21/05/11	21/07/11	60.7	27/03/12	29/05/12	63.0
	486				22/05/11	11/08/11	81.4	24/03/12	30/06/12	97.9
	492				21/05/11	01/07/11	41.0	16/03/12	19/06/12	94.5
	493				21/05/11	03/08/11	73.5	20/02/12	25/06/12	126.4
Total				259.6			1808.8			1255.5
Mean				26.0±8.7			95.2±77.3			83.7±30.9

2.5 Data Processing and Analysis

2.5.1 Defining trips and calculating trip statistics

Following Thaxter *et al.* (2012), we considered all trips for assessment of interaction with wind farm sites, but defined those trips that were offshore, inland, or a mixture of both. We therefore calculated an “offshore foraging range” (the maximum point reached offshore from the colony). For all trips we calculated the total distance travelled per trip, by summing distances between GPS points from the moment the bird left the colony until its return. Trip duration was calculated from the time the bird left the colony to the time it returned.

2.5.2 Connectivity with the areas of proposed and consented wind farms

As in 2010 and 2011 (see Thaxter *et al.* 2012), the connectivity between Lesser Black-backed Gulls and consented and proposed wind farms was assessed. The data collected between autumn 2011 and spring 2012 allowed connectivity to be evaluated on migration as well as during the breeding season.

2.5.3 Spatial overlap of home ranges with consented and proposed wind farms

We investigated the overlap of areas used at sea with wind farm sites using kernel analysis (Worton 1989) to estimate the 50%, 75% and 95% kernel density estimates (KDEs) of the birds’ utilisation distributions to define core, middle, and total foraging “home ranges” respectively, using Least Squares Cross Validation (LSCV) (e.g. Hamer *et al.* 2007; Thaxter *et al.* 2009, 2010), following methods presented in Thaxter *et al.* (2012). We also distinguished between observations for which travelling speed was greater or less than 4 $km.h^{-1}$, the speed below which it is thought that birds are unable to sustain flight (Shamoun-Baranes *et al.* 2011; Thaxter *et al.* 2011), so as to provide some indication of likely resting and foraging locations (hereafter termed “KDE foraging”). All kernel analyses were conducted using Package ‘adehabitat’ (Callenge 2006) in R 2.16.0 (R Development Core Team 2012).

2.5.3.1 Seasonal variation

Previously (Thaxter *et al.* 2012), an attempt was made to define periods of “breeding” and “non-breeding”. This approach was originally taken to investigate wind farm interactions during incubation or chick-rearing (before 09/07/2011), and a likely non-breeding period when the majority of birds were thought to no longer have chick-rearing duties and therefore no central-place foraging restriction (after 09/07/2011). However, such a distinction can be refined further making full use of the extensive dataset we have now collected. Due to difficulties of nest monitoring inherent for gulls (see Thaxter *et al.* in prep a,b), we were not able to determine laying dates or hatching dates precisely enough to define specific periods of incubation and chick-rearing for individuals in 2012. Therefore, here we refined the previous approach in Thaxter *et al.* (2011) by investigating the behaviour of birds in 5-day consecutive time periods across the season from mid-February to mid-July 2012. This approach allowed us to assess individual seasonal variation in seabird-wind farm interactions at a finer scale throughout the pre-breeding, incubation and chick-rearing periods, and serves also to highlight the advantage of a long-term tracking approach.

For assessment of space use, we computed separate utilisation distributions (KDEs: 95%, 75% and 50%) for each 5-day period for all individuals. We then computed mean overlaps of the 95% KDE with consented and proposed offshore wind farm sites. As previously (Thaxter *et al.* 2010, 2011), GPS data were filtered to a 30 minute rate for spatial analysis to allow a wider time period of investigation. This analysis was also repeated for all individuals pooled together in a single assessment representing a kernel for the "population". Such an approach was also necessary to avoid spurious comparisons with the results from previous years that may be influenced by when in the season most data were available. Annual variation using this seasonal approach will be a central subject to the final report.

2.5.4 Time budgets of birds

As previously (Thaxter *et al.* 2011, 2012), we assessed the temporal overlap of all foraging trips with all offshore trips. We calculated the time spent in wind farms in relation to the total time budget of the bird and the total time spent by the bird offshore. This was achieved through assessment of the track of the bird with wind farm shapefiles using custom-written R scripts.

2.5.4.1. Seasonal variation

As with the kernel analyses, we also assessed the time budgets of birds throughout the 2012 season, quantifying the amount of time birds spent within consented and proposed wind farm sites offshore in relation to their total time budgets.

2.6.5 Formal statistical tests – spatial overlap and time budgets

To assess the difference of trip duration and foraging range to previous years, we used generalized additive mixed-effects models (GAMMs) with a negative binomial or Poisson error distributions accounting for Julian date fitted as a smoothed effect, sex of birds as a fixed effect and BirdID as a random effect to account for repeated trips made by individual birds. This approach allowed annual signals to be detected in absence of other variation. Smoothed effects were specified with a gamma of 1.4 and degrees of freedom for the smooth were set to k = 6 (Wood 2006).

To assess 5-day spatial overlaps with offshore wind farms across the season, the area of the 95% KDE estimate overlapping was assessed in a GAMM accounting for s(Julian Date), Sex, and Year, and an offset of total kernel area, thus assessing the proportional overlap. A similar approach was taken to assess the time spent in offshore wind farms. In addition to bird-specific analyses, a total "all bird" analysis was conducted for kernel overlap.

All GAMMs used F tests to assess the significance of fixed effects and, with the most significant variables selected through stepwise forward selection. Random effects were tested with and without the term fitted (using delta AIC). Values are given as the mean ±1 SD unless otherwise stated. All analyses were performed using R Version 2.14.0 (R Development Core Team 2012).

2.5.6 Flight altitudes

2.5.6.1 Altitude Analysis

The following outlines the analyses that are being undertaken to describe the flight height distributions of the Lesser Black-backed Gulls tagged at the Alde-Ore SPA, and the complete outputs that will be provided in the final project report in 2013. A full analysis of flight height data will enable improved assessment of collision risk, by providing modelled distributions of altitudes, and assessment of the influence of environmental variables, and also specific information of the heights flown through wind farm sites. This analysis will fulfil the third main aim of the study.

2.5.6.2 Precision and accuracy in measurements

To analyse the flying altitude of birds, it is important to consider the error in the altitudinal measurements from the tags, both in terms of their precision and accuracy. Examining the altitudes from stationary birds (i.e. those for which are likely to be on the sea or at the colony and thus at 0m altitude) gives an indication of the amount of error in the estimates. Whilst a few recordings of negative altitude may be expected when sea level is low or swell takes birds below the mean sea surface, the data show a large number of negative altitudinal readings, extending below 40 m in the example below (Figure 1). As there is no plausible reason for accurate altitudinal readings that low, we suppose that much of the variation is error or bias in the altitudinal estimates. Bias (accuracy) may be introduced from two sources. Firstly, the difference between sea level and mean sea level and secondly the assumption that the world is a perfect sphere. The first of these can be corrected for by calculating the sea level for the time of each observation, and adjusting the altitudinal reading accordingly. The second of these is thought to introduce a negative bias of 6m to the altitudinal measurements (see first year report). Once accounting for these sources of bias (inaccuracy) in the measurements, we need to account for the error (or precision) of the observations.

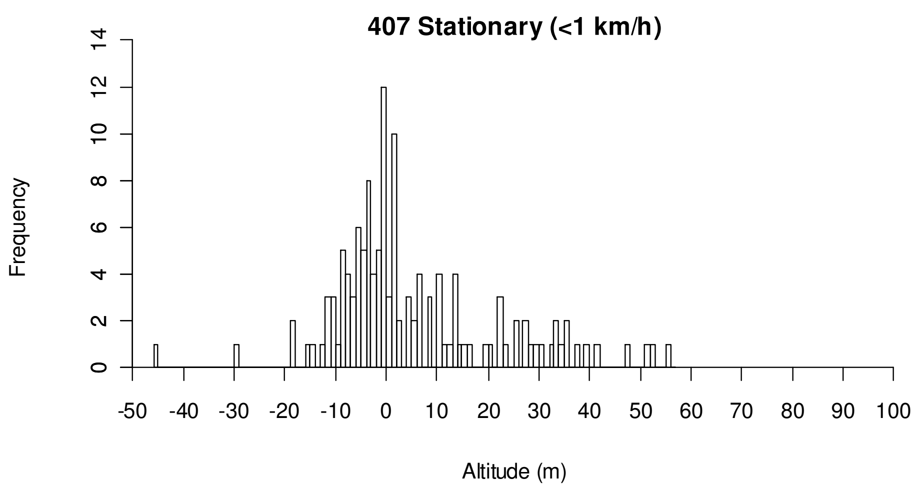


Figure 1 Altitudinal readings from one lesser black-backed gull during 2010 when stationary.

2.5.6.3 The modelling process

Given the need to account for the error in the estimates and the division of bird behaviour into discrete states with different flight height distributions (Shamoun-Baranes *et al*. 2012), a Bayesian state-space model (e.g. Newman *et al.* 2009, Harrison *et al.* 2011, King 2012) is a natural choice for the analytical framework. The model processes are divided into 'observation model' and 'state/process model'.

The 'observation model' is in this context the relationship between the true altitude and the altitude we observe. This is likely to be dependent on the number and position of satellites used to calculate the altitude and the weather at the time (Figure 2). For the process model we propose assuming a fixed number of discrete states, of which each bird is in one state at any given time. The states are assumed to be strongly linked to acceleration (Bouten *et al.* 2012, Shamoun-Baranes *et al*. 2012), and therefore acceleration is used as a proxy for state, although some error is assumed in the assignment of states from acceleration alone. Several factors are assumed to affect the probability of a bird being in a given state at a given time and also transitioning into a state. These are sex, season – breeding season, migration, winter – time of day, weather, whether a bird is over land or the sea and whether or not the bird is in a constructed wind farm area (Figure 2). Each activity state is assumed to have a distribution of flight heights; some of these are assumed to be Gaussian, whilst some are more complex or non-parametric distributions. The form of these distributions will be determined *a priori* by expert opinion and previous studies (e.g. Cook *et al.* 2012). The distributions are assumed to describe the altitudinal distribution of a given bird in a given state. However, a number of factors can potentially also affect the absolute altitude of a bird, and these are thought to include weather, individual effects and whether the bird is in a constructed wind farm area or not (Figure 2). The model shown in Figure 2 describes the optimal model we aim to fit; however, given the complex nature of the data and the complexities inherent in this modelling approach, the final model may be a simpler version of the model in Figure 2.

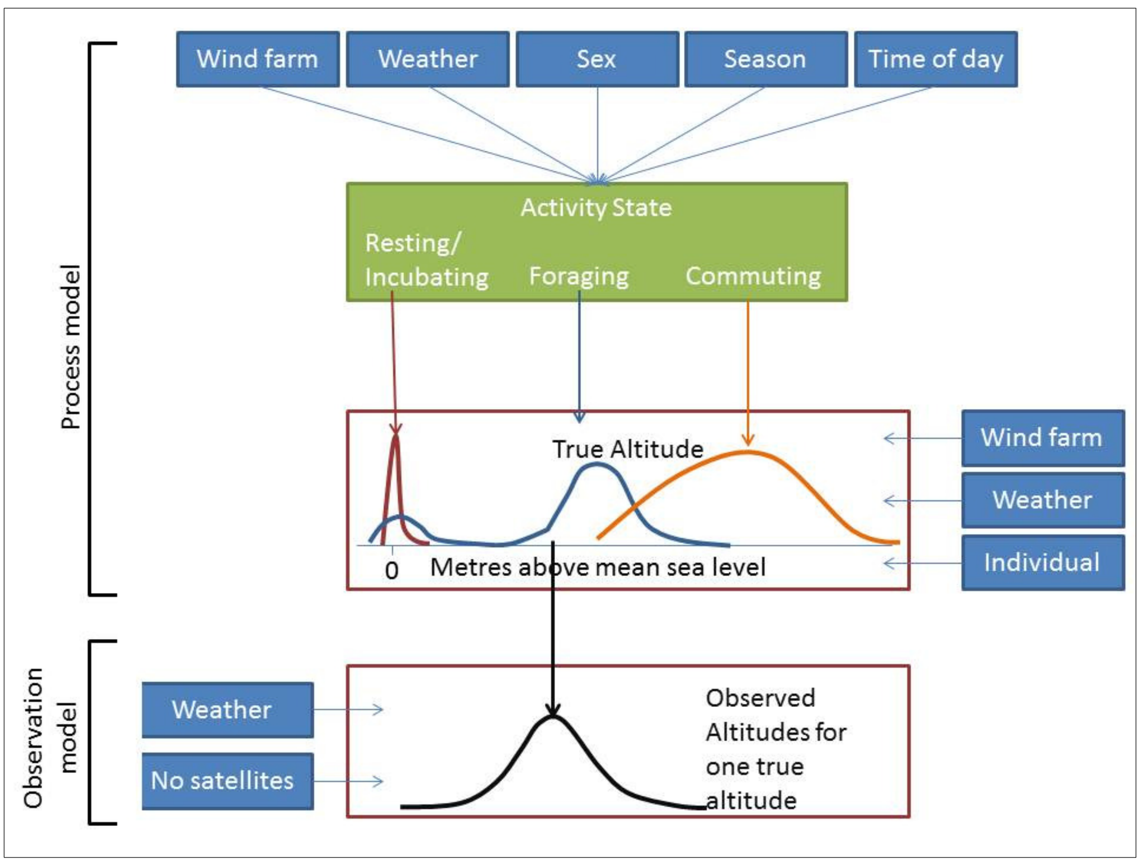


Figure 2 Schematic diagram of the state-space modelling approach proposed.

We are fitting this model with Markov Chain Monte Carlo (MCMC) methods (Gilks *et al*. 1996) in OpenBUGS (Lunn *et al*. 2009) or JAGS (Plummer 2003).

2.5.6.4 Outputs

Full analyses and results will be included in the final project report, based on data from the three breeding seasons and three non-breeding seasons covered by the study. The outcome from this modelling process will be a distribution of altitudes for each of the discrete states that we model. We will also be able to infer how factors such as weather affect which states the birds are in and altitude within the states (although we may have limited power to detect this, given the poorer accuracy in poor weather), and whether birds behave differently and fly at different altitudes when in a constructed wind farm area.

3. RESULTS

3.1 Descriptive Trip Statistics

A total of 17 Lesser Black-backed Gulls tagged in previous years returned to the Orford Ness breeding colony in 2012. All of the 14 birds that were tagged in 2011 returned to the colony and of these, 12 had fully functional tags. Some tags had become damaged over the winter, with external aerials missing and therefore preventing communication. In addition, three birds tagged in 2010 also returned to the colony, of which two had fully functional tags providing information through the breeding season (bird 336 had an outward migration information available but no breeding season movements for 2012), giving a total of 14 birds for assessment of breeding season, and 15 birds with migration and non-breeding.

As in previous years, the Lesser Black-backed Gulls that had active tags during the 2012 breeding season made a mixture of solely inland trips and coastal trips (88%), trips that were offshore (2%) (hereafter "offshore"), and trips that straddled both inland and offshore habitats (11%) (Table 2). Note that some very short trips, e.g. visits to fields adjacent to the colony, were included in these totals. In total, 3,104 trips across all birds (those tagged in 2010 and in 2011) were recorded, and these are summarised in Table 2.

During 2012, a total of 1255.5 bird-hrs data were available (mean per bird: 83.7±30.9 days), which compared with 1808.8 (mean: 95.2±77.3 days) in 2011 and 259.6 (mean: 26.0±8.7) in 2010 (see Table 2). However, the length of time individuals were tracked also varied depending on tag functionality and download of data. Returning birds that provided data in 2012, from all tag-cohorts, provided data from Julian day 48 (i.e. 17 February; mean: 79±18) up to day 193 (mean: 161±20). In contrast, during 2010, birds were tracked between Julian dates of 157 and 199, with a mean end date of 188±7, and during 2011, birds tagged in 2010 returned from day 79, but on average the date was 91±10, and their data lasted the full season up to day 211 (mean, 177±51). Therefore, more data was available later in the season in 2011 and more data earlier in 2012 (in part because of an earlier return of birds). Some trips away from the colony had gaps in the GPS record, for instance when trialling faster 3s sampling rates, and were therefore excluded from further analysis of distance travelled and trip duration.

Across the whole 2012 breeding season, gulls had an offshore foraging range of up to 158.47 km (mean 13.21±15.05 km) and travelled up to a total cumulative distance per trip of up to 788.78 km (mean 20.34±40.62 km), these trips lasting up to 253.89 hrs (mean 5.65±10.98 hrs). The two birds tagged in 2010 that returned with active tags showed similar trip summary statistics to those 12 tagged in 2011 that also returned with active tags.

Table 2 Descriptive trip statistics for all trips of Lesser Black-backed Gulls tracked from the Orford Ness colony in 2012. Trip duration and total distance travelled are computed for all trips, however offshore foraging range is calculated only from those trips with an offshore component.

Year tagged		Number of trips			Trip duration (hrs)		Offshore foraging range (km)		Total distance (km)	
	Bird	Inland	Offshore	Total	Mean	Max	Mean	Max	Mean	Max
2010	395	232	2	234	5.47±17.12	253.89	7.16±4.98	10.68	10.92±51	771.45
2010	407	204	45	249	8.46±13.87	154.3	16.02±25.96	158.47	29.31±67.08	677.76
2010	336*	1	1	2	85.34±116.37	167.62	-	0.4	73.23±96.44	141.43
2011	459	143	14	157	5.03±5.56	35.66	16.01±25.27	100.75	15.19±27.72	272.3
2011	460	272	49	321	4.71±12.92	206.16	10.46±11.41	47.8	16.6±26.59	377.77
2011	478	243	40	283	3.94±8.44	130.66	11.15±4.3	18.65	15.99±27.98	429.83
2011	479	179	4	183	4.61±4.79	34.21	10.75±6.38	19.73	21.95±23.9	149.55
2011	480	111	8	119	9.44±9.28	52.82	11.98±2.89	16.14	20.21±36.13	280.86
2011	482	153	40	193	10.48±14.89	174.81	12.39±7.42	30.47	25.81±32.21	219.99
2011	483	216	19	235	3.62±3.56	19.7	7.77±3.78	16.32	25.47±37.69	220.29
2011	484	127	30	157	9.16±8.48	46.24	9.87±7.23	39.09	17.43±20.94	119.15
2011	485	74	16	90	5.13±5.4	27.56	10.36±10.49	42.92	21.32±28.41	131.49
2011	486	247	34	281	3.71±3.53	21.5	20.31±20	66.98	20.33±25.93	222.73
2011	492	199	25	224	4.8±6.66	74.36	8±4.85	19.02	17.06±38.28	405.01
2011	493	316	60	376	4.96±14.49	193.92	18.34±17.17	71	25.02±58.98	788.78
	All*	2717	387	3104	5.65±10.98	253.89	13.21±15.05	158.47	20.34±40.62	788.78

* Bird 336 moved to nest at nearby Havergate and very few data were available, hence grand totals exclude this bird

3.1.1 Annual variation in trips

Analysing information from trips in 2010, 2011, and 2012, the distance reached offshore varied significantly over the season (GAMM, edf = 4.47, F = 26.04, P < 0.001), with trips generally reaching further from the colony as the season progressed. However, there was significant annual variation in this pattern (Figure 3), with a model specifying differences between years significantly improving the model (dAIC = 37.01, df = 2). In contrast to 2010, in 2011 and 2012, trips after Julian date 175 showed no further increase in distance from the colony, and even showed a decrease in offshore range in 2011. There was further model improvement when individual ID was fitted as an interaction variable with the smoothed term of Julian date (dAIC = 52.10, df = 19), indicating significant individual variation in these patterns. After accounting for seasonal variation, there was a significant difference in overall foraging range offshore between years (fixed effect of Year: F = 9.120, df = 2, P < 0.001), with 2011 trips significantly closer to the colony than 2010 (β = -0.253±0.123, P = 0.002), and 2012 trips shortest of all (-0.587±0.140), significantly more so than 2010 (P <0.001). The reasons underpinning these differences will be explored in the final report. There was no difference between sexes in distance reached from the colony (F = 0.144, df = 1, P = 0.705). Individuals also varied significantly in their distances reached offshore (Bird ID Std Dev = 0.330, residual = 3.489; dAIC comparison with and without random effect= 5507.634).

The time birds spent away from the nest (trip duration) increased over the season (GAMM negbin(1.17), edf = 4.437, F = 71.35, P < 0.001). There was also a significant difference between years in this pattern (Figure 3) (dAIC = 80.32, df = 2), with a clear increase in trip duration after Julian Date 150 in 2011 and 2012. There was also significant individual variation (dAIC = 336.60, df = 19) in these patterns. After accounting for this variation, trips were significantly longer in 2010 (F = 30.06, df = 2, P < 0.001; 2010, 8.37±19.26 hrs, 2011, 4.72±7.53 hrs, 2012, 5.65±10.98 hrs; β_{2011} = -

0.636 ± 0.107, $P < 0.001$, $\beta_{2012} = -0.355 \pm 0.114$, $P = 0.002$) and females made longer trips overall than males ($F = 17.96$, $df = 1$, $P < 0.001$; means, female: 6.70±10.60 hrs; male: 4.79±10.35 hrs; $\beta_{male} = -0.355 \pm 0.084$, $P < 0.001$).

Birds generally travelled further per trip as the season progressed (analysis included inland and offshore areas) (GAMM negbin(0.73), edf = 4.78, $F = 59.18$, $P < 0.001$). There was also a significant difference between years in this pattern (Figure 3) (dAIC = 50.27, df = 2), and significant individual variation (dAIC = 55.97, df = 19) in these patterns. After accounting for this variation, birds travelled significantly further per trip in 2010 compared to 2012 ($F = 6.61$, $df = 2$, $P = 0.001$; $\beta_{2011} = -0.180 \pm 0.143$, $P = 0.209$, $\beta_{2012} = -0.369 \pm 0.152$, $P = 0.015$) but there was no difference between sexes ($F = 0.22$, $df = 1$, $P = 0.637$).

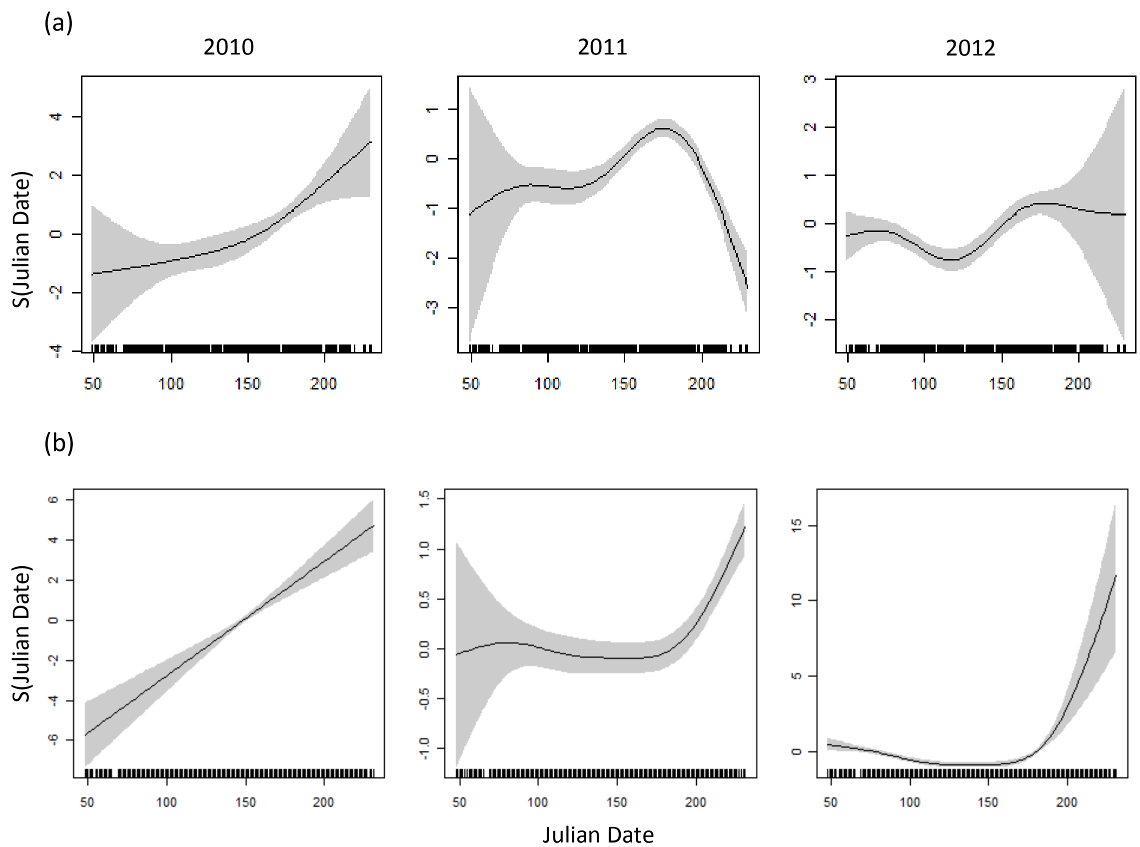


Figure 3 Smoothed Terms from a general additive model (GAM) for (a) offshore foraging range, and (b) trip duration showing annual variation in seasonal patterns.

3.2 Connectivity with the Areas of Proposed and Consented Wind Farms

3.2.1 2012 breeding season

During the 2012 breeding season, a total of five of the 14 birds with active tags (407, 459, 460, 486, and 493) showed overlaps with offshore wind farm sites, all of which showed connectivity with the large Round 3 East Anglia zone (Figure 4). However, four also showed connectivity with Galloper extension, three showed connectivity with the Greater Gabbard Round 2 development, and one bird (407) with the Round 1 development at Scroby Sands. All other birds, although some did forage offshore, showed no connectivity with offshore wind farms.

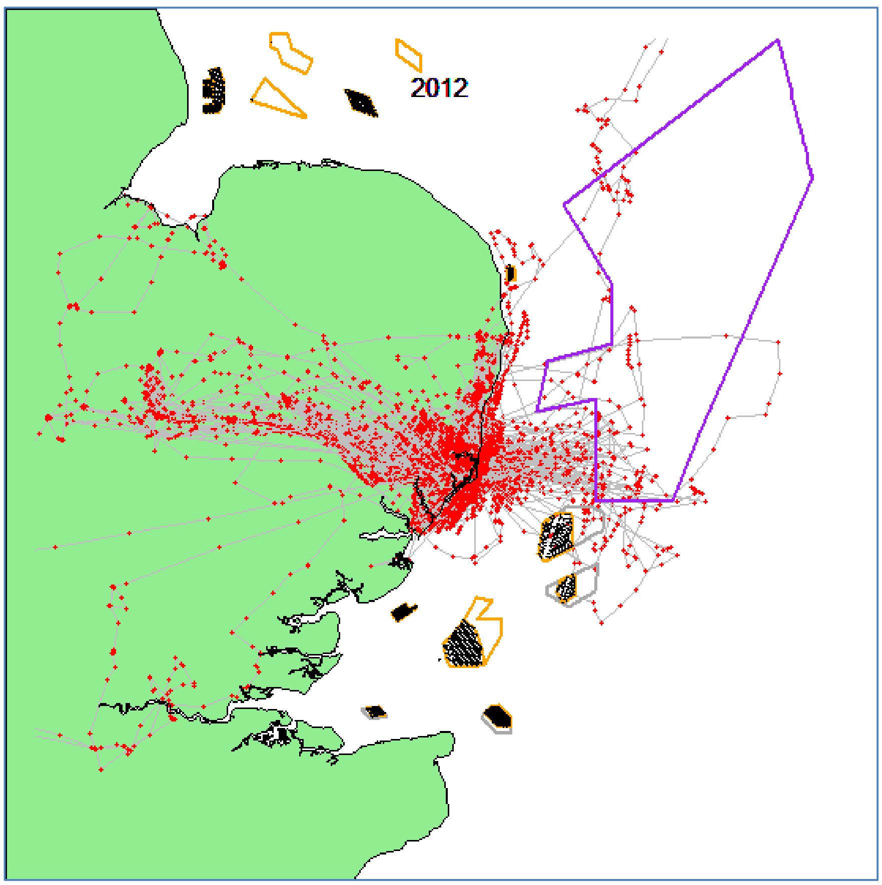


Figure 4 Plot of all Orford Ness data for Lesser Black-backed Gulls tracked from the Orford Ness colony in 2012. Purple = Round 3; orange = Rounds 1 and 2; grey = extensions.

3.2.2 Migration

3.2.2.1 Data summary

A total of 15 Lesser Black-backed Gulls provided information on migration routes between July 2011 and April 2012, 12 from birds tagged in 2011, and 3 from birds tagged in 2010. Birds travelled on average 1,344±841 km from the colony over a total distance of 12,493±4,694 km, 227±20 days away from the colony. The maximum distance from Orford Ness for any bird in 2011/12 was 2,211 km (bird 460), but a different bird travelled further overall (20,481 km, bird 481). A further bird was away from the colony for a total of 259 days (492). For many birds, gaps were noticeable in the data records (Table 3). These gaps were due some birds remaining in the UK late into autumn and early winter before migration, and for five individuals, not leaving the UK at all (see below). The largest gap for any bird in 2011/12, for which we subsequently recorded 2012 breeding season movements, was a period of 157 days (tag 485) out of the total migration absence of 250 days, see Table 3. Another bird (336) returned to the colony but is thought to have bred away from Orford Ness and coupled with tag downloading malfunction, only data from the outward migration route (gap of 251 days) have so far been downloaded.

Table 3 Migration information for all birds from 2010/11 and 2011/12 winter periods.

Migration	Bird	Sex	Left colony	Returned to Colony	Maximum distance from colony (km)	Total Travel Distance (km)	Time away from colony (days)	Time tag not recorded (days)
2010/11	334	M	09/07/10	15/04/11	2233	20874	280.03	15.71
2010/11	336	M	12/07/10	28/03/11	1947	20863	259.14	29.61
2010/11	395	M	21/07/10	29/03/11	2114	15599	251.05	16.52
2010/11	407	F	17/07/10	20/03/11	1970	14804	246.22	6.75
2010/11	391		05/07/10	04/04/11	2490	14431	272.97	2.43
2010/11	388		08/07/10	17/05/2011[2]	4226	-[3]	-[3]	17.44
2011/12	336	M	-[1]	27/04/12	1947	-[3]	-[3]	250.96
2011/12	395	M	16/07/11	23/03/12	1881	13795	251.05	17.90
2011/12	407	F	29/07/11	13/03/12	1965	13564	227.59	13.90
2011/12	459	F	24/07/11	21/03/12	1893	20080	241.11	2.24
2011/12	460	M	10/08/11	15/03/12	2211	14066	218.48	0.00
2011/12	478	M	02/08/11	28/02/12	180	10007	210.08	26.67
2011/12	479	(M)	20/08/11	26/03/12	2028	15913	219.28	0.00
2011/12	480	F	12/08/11	08/04/12	1720	20481	240.00	1.62
2011/12	482	F	09/08/11	17/02/12	300	7190	191.49	49.05
2011/12	483	M	17/08/11	19/03/12	1723	9852	215.43	0.00
2011/12	484	F	31/07/11	16/03/12	1909	13949	228.45	3.28
2011/12	485	F	21/07/11	27/03/12	212	4712	250.27	156.51
2011/12	486	M	11/08/11	24/03/12	1842	14982	226.03	58.19
2011/12	492	F	01/07/11	16/03/12	211	7773	258.78	-[4]
2011/12	493	(M)	03/08/11	20/02/12	132	8539	201.12	42.30

1 Bird believed to be breeding at different colony at Havergate, hence no start to migration from Orford Ness
2 Last time stamp - bird was caught by a fishermen in Mauritania
3 Incomplete migration information, no return journey
4 Bird departed with tag sampling at 3s; on 24/08/2011, the sampling rate increased to over 300 s until the bird's return

3.2.2.2 Wind farm overlaps

In total, the migration routes of six of the 15 birds for which we had data overlapped with offshore wind farm sites during the 2011/12 migration and winter periods. In contrast to the 2010/11 migration period, five of the 15 birds stayed in the UK overwinter during 2011/12 (birds 478, 482, 485, 492 and 493 – see Figures 5 and 6), hence distances reached from the colony of these individuals were much lower than other birds (Table 3). All five birds spent nearly all of their time inland, and four of these birds did not overlap with any offshore wind farms. However, bird 493 overlapped once with East Anglia Round 3 zone and 492 came very close to Inner Dowsing off the east coast of England.

The other 10 birds all left the UK, many making movements to the Midlands and the south of England before heading off on migration, and of these, five overlapped with offshore windfarms. Three of these birds overlapped with the Isle of Wight Round 3 zone (483, 479, 407), with an additional bird (486) coming very close, and another (395) overlapped with the Southern Array Round 3 zone. Bird 460 overlapped with the existing London Array wind farm, as well as the Thanet proposed extension, coming very near to the existing Thanet wind farm, and 459 came very close to the existing Greater Gabbard wind farm. Five birds (459, 480, 484, 486, and 336) showed no overlaps; however, for 336 only, the outward migration route has so far been downloaded, and birds 459 and 484 also had considerable gaps on migration where no GPS data were recorded due to low battery. As in 2010/11 migration, birds also few in the vicinity of a proposed French offshore wind farm (http://eoliennes-deux-cotes.com/) and since many flew over Spanish, Portuguese and Moroccan waters, future offshore developments by these countries could potentially affect this species.

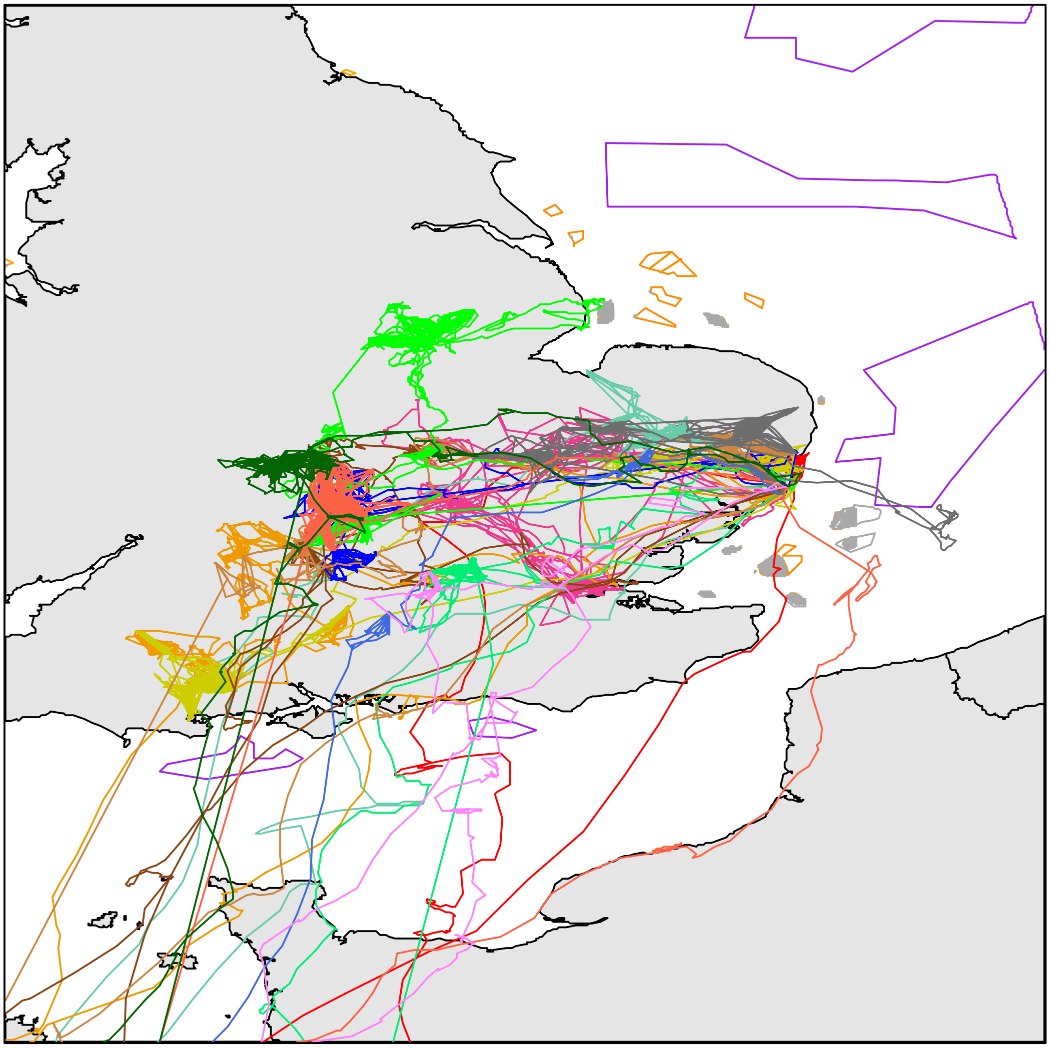


Figure 5 Flight paths of tagged Lesser Black-backed Gulls leaving and returning to Orford Ness on migration between July 2011 and April 2012. Tracks of different individuals are shown in different colours, and UK offshore developments are shown in blue.

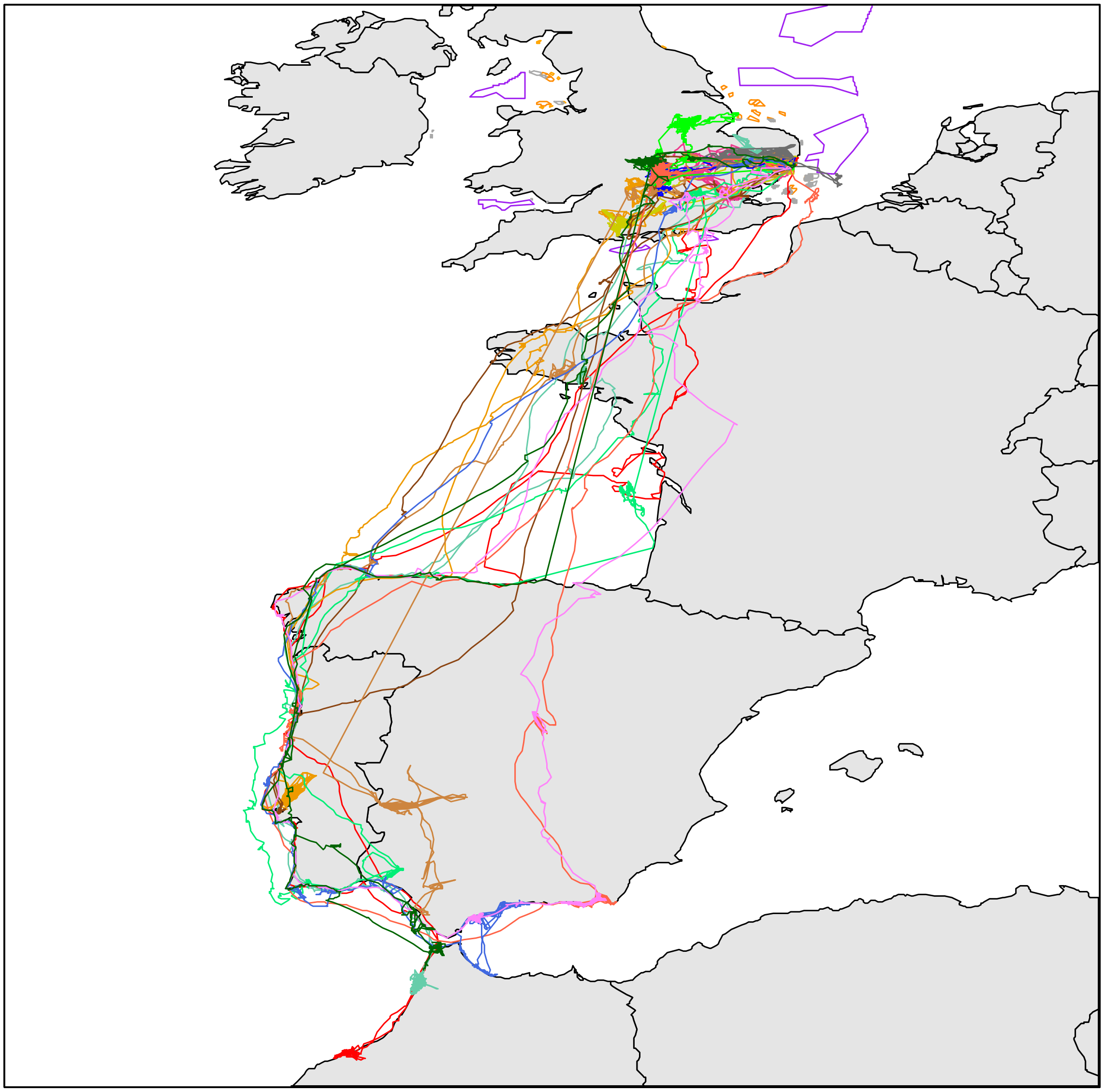
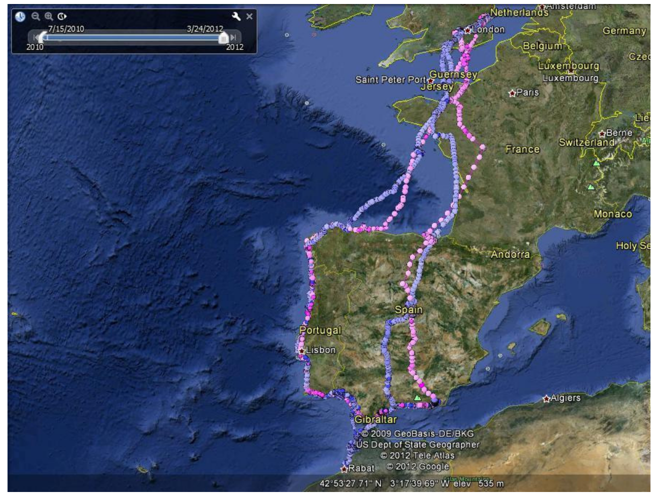


Figure 6 Flight paths of tagged Lesser Black-backed Gulls showing their movements throughout migration and overwinter. Tracks of different individuals are shown in different colours, and UK offshore developments are shown in blue.

Further full migration data was gathered for two birds tagged in 2010, and another individual (336) for the outward migration route in 2011/12, hence providing longitudinal data spanning consecutive migration periods. A gap in the migration record for bird 395 was also apparent on outward migration. However, these data showed the individual Lesser Black-backed Gulls migrated along similar routes between 2010/11 and 2011/12, suggesting consistency in migration strategy between years (Figure 7). These results are relevant for potential repeatability of seabird-wind farm interactions during migration for the same individuals.

(a)

(b)



(c)

Figure 7 Repeatability of migration routes for two Lesser Black-backed Gulls tracked for consecutive migration periods 2010/11 and 2011/12: (a) bird 407 and (b) bird 395, (c) bird 336 (the straight yellow line here represents data not yet downloaded on the return route in 2011/12 for this bird).

3.3 Spatial Overlap of Home Ranges with Consented and Proposed Wind Farms

Percentage overlaps of the 50% KDE, 75% KDE and 95% KDE with consented and proposed offshore wind farm sites are presented for each individual bird (kernel analysis for GPS locations of individual birds) in Table 4. A full "population" kernel analysis for all birds across the season was attempted but did not converge, hence an average across all birds is given to provide a relative population perspective.

Lesser Black-backed Gulls from the Orford Ness colony showed up to 5.6% overlap with all offshore wind farms (bird 407), but more typically showed on average only 1.0±1.9% across all birds. Up to 5.0% overlap of the 95% KDE was recorded with the East Anglia Round 3 zone (1.3% 95% KDE "foraging" overlap, bird 407), however in contrast to 2011, no birds had core foraging areas overlapping with any offshore wind farm sites. Birds showed further overlaps to a lesser degree with the Galloper extension and the Greater Gabbard Round 2 site, as well as one overlap (bird 407) with the Scroby Sands Round 1 site; however, all such overlaps were less than 1%.

As with previous years, there was considerable individual variation in the behaviour of tagged gulls (Figure 8). Varying amounts of data (number of fixes in Table 4) were available for each bird, ranging between 548 filtered fixes and 3050. The home ranges of only four individuals overlapped with offshore wind farms. A single foraging trip of an additional bird also overlapped with one offshore wind farm area, though this was not reflected in its home range (see Table 5, time budgets).

Table 4 Overlap analysis of "individual bird" kernels (pooled analysis) with wind farms (WF) for individual Lesser Black-backed Gulls tracked from the Orford Ness colony in 2012 using a 1800 s rate.

Bird	Name	Total (%)			"Foraging" (%)			Area (km^2)			No. fixes
		50	75	95	50	75	95	50	75	95	
395								68.2	156.1	819.6	1810
407	East Anglia			5.0			1.3	124.3	360.1	1899.8	2966
	Galloper Extension			0.4			0.2	124.3	360.1	1899.8	2966
	Scroby Sands			0.3			0.3	124.3	360.1	1899.8	2966
459	Galloper Extension			0.4				73.5	155.9	567.1	1016
460								112.9	220.2	412.0	1943
478								140.2	333.5	865.3	1265
479								84.5	161.6	393.7	1033
480								67.3	155.6	608.9	1705
482								86.9	191.4	578.0	3050
483								74.4	208.0	628.9	847
484								59.0	121.7	392.7	2223
485								133.1	271.1	649.4	548
486	East Anglia			3.5			0.0	86.1	180.3	496.3	1059
	Galloper Extension			0.7			0.0	86.1	180.3	496.3	1059
	Greater Gabbard			0.1				86.1	180.3	496.3	1059
492								99.6	280.3	887.8	1393
493	East Anglia			3.6			0.6	171.6	410.7	1156.4	2138

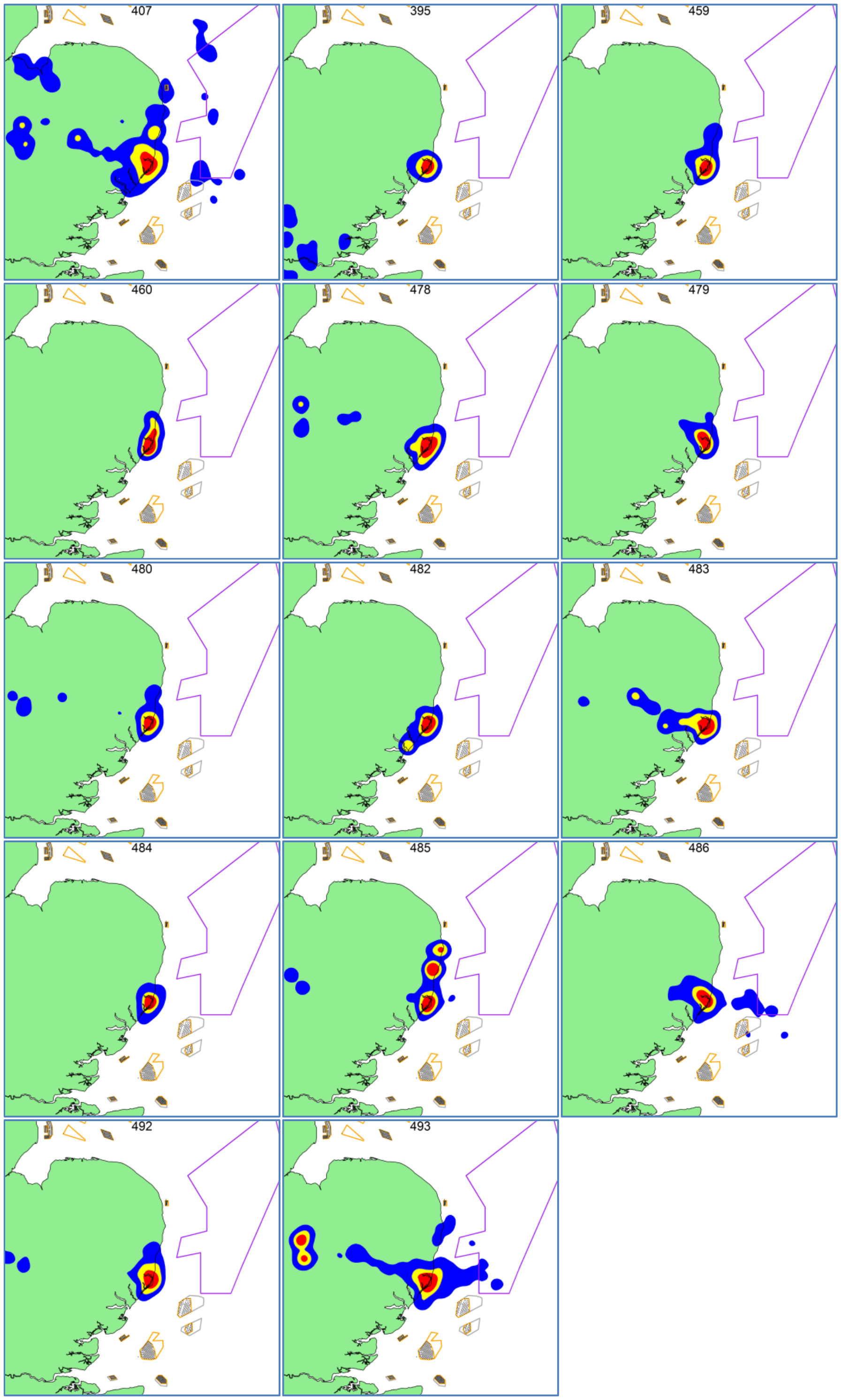


Figure 8 Home ranges for all foraging trips of Lesser Black-backed Gulls tracked from the Orford Ness colony in 2012. Data were filtered to a 1800 s rate to allow focus across the season. Rounds 1 and 2 = orange shapes, Round 3 = purple, extensions = dark grey; 95% KDE = blue; 75% KDE = yellow; 50% KDE = red.

3.3.1 Seasonal variation in home ranges

The pattern of area use for all gulls combined varied throughout the season. Investigating sequential 5-day time periods, it was clear that although there was some use of offshore areas early in the season, overlaps with consented and proposed wind farm sites were only recorded almost entirely from 25/05/2012 to 29/06/2012.

The total area coverage by individual birds (expressed as a proportion of the maximum area of the 95% KDE in any 5-day section), showed a non-linear decrease and subsequent increase as the season progressed. The average KDE proportion was at its lowest between 30/05/2012 and 04/06/2012 with a minimum of 21.8±6.1 SE %. This was when birds increasingly spent time at the nest site (see time budget analyses). The largest proportional overlap of the 95% KDE with all offshore wind farm sites was seen between 19th June and 24th June (Figures 9 and 10) reaching up to 14.1±6.7 %SE.

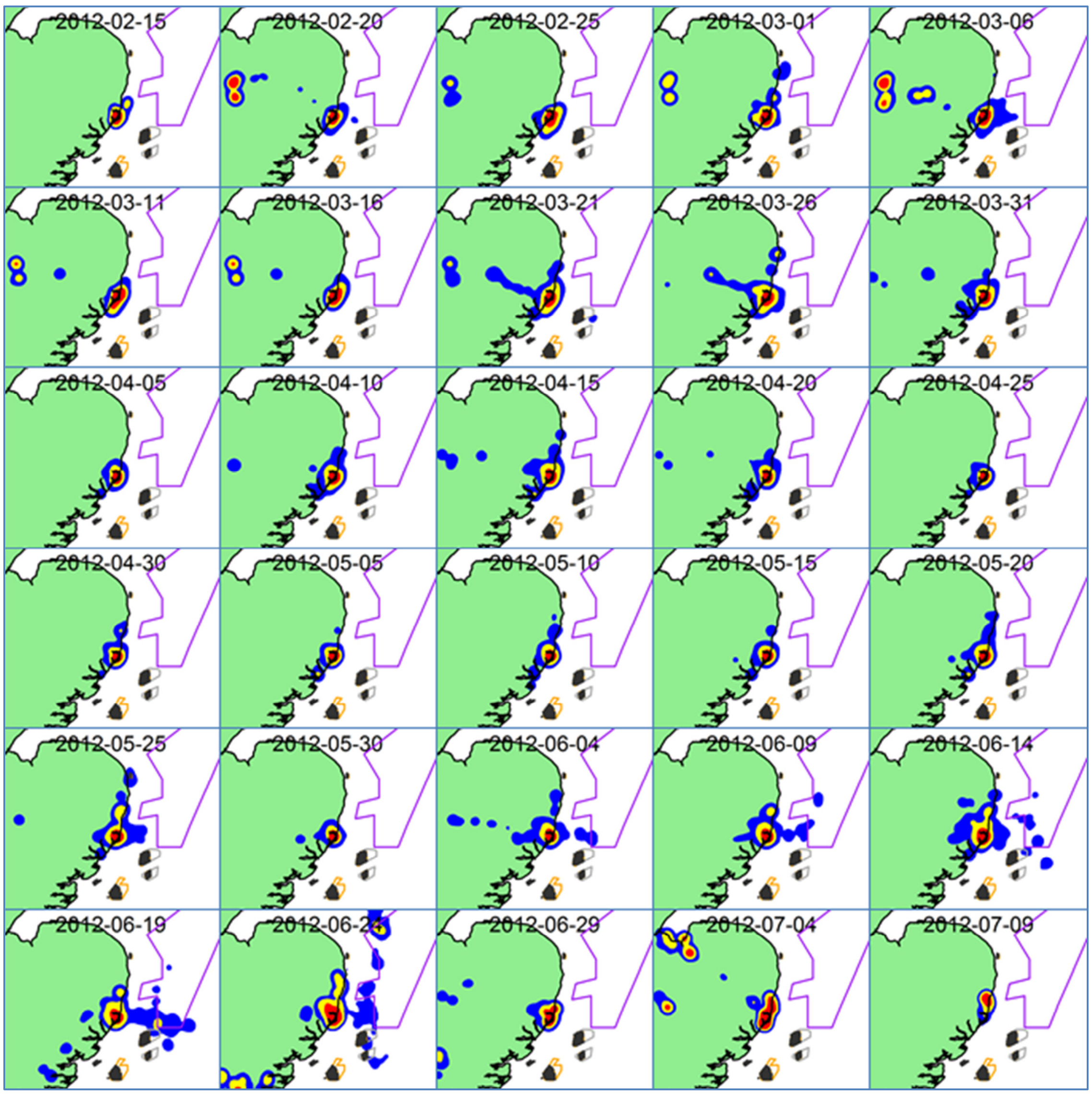
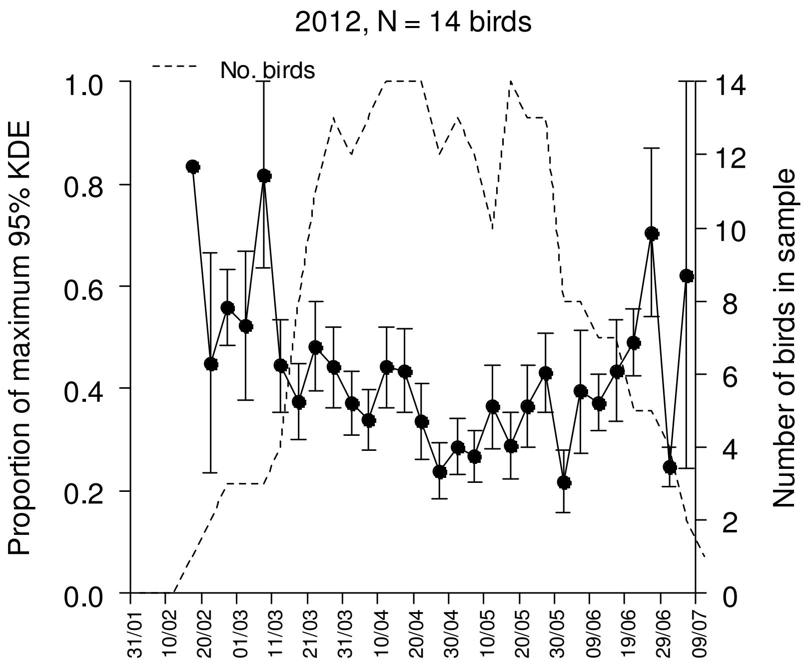


Figure 9 Kernels for all Lesser Black-backed Gulls tracked from the Orford Ness colony in 2012 showing seasonal variation – each map is a 5-day period, using a 1800s filtering rate. Note, these are pooled data across all individuals dependent on the number of birds available in each five-day period.

(a)



(b)

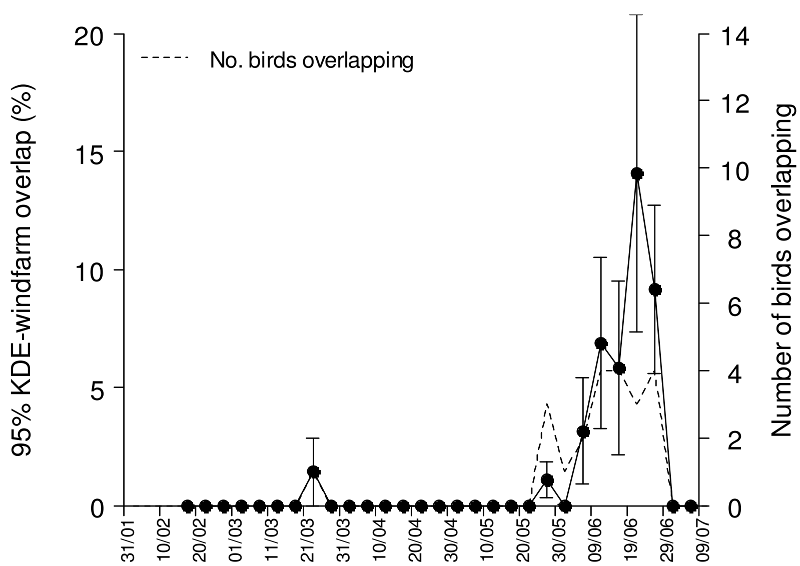


Figure 10 Seasonal variation in 2012 for all birds showing (a) total home range (95% KDE) and (b) area overlap with all offshore wind farm sites. Also shown are the total number of birds both contributing data to averages (as presented in a), and the total number of individuals whose ranges overlapped with offshore wind farm sites in any one period (as presented in b).

3.4 Time Budgets

Between 17/02/2012 and 15/07/2012, Lesser Black-backed Gulls spent between 0% and 10.3% (average, 2.2±3.8) of their offshore time in wind farm sites (Table 5). However, the time spent in wind farms was less than 1% of the total time budget for all but one bird (407, 1.1%). Nine individuals did not visit wind farm sites at all. As previously, the wind farm site in which the greatest proportion of gulls' time was passed was the East Anglia Round 3 Zone, which is the largest in the vicinity of Orford Ness. As in 2011, birds also showed temporal overlap with the Greater Gabbard Round 2 site and the Galloper extension, and bird 407 also interacted with a Round 1 site (Scroby Sands).

Table 5 Information on (a) Time budgets of Lesser Black-backed Gulls during 2012 (hrs), including time spent offshore and in wind farm (WF) sites; and (b) Number of trips, and number of trips offshore that overlapped with offshore wind farm sites during 2012.

(a)

Year tagged	Bird	Total time	At Nest	On trip								
				On trip total	Inland	Offshore						
						Offshore total	Not in WF	In WF				
								Total	East Anglia	Galloper Ext	Greater Gabbard	Scroby Sands
2010	395	2115.3	824.4	1290.8	1288.0	2.8	2.8					
	407	3000.0	831.7	2168.3	1858.4	309.9	278.0	31.9	28.2	2.3	0.0	1.4
2011	459	1440.0	642.1	797.9	709.7	88.2	84.3	3.9	1.3	2.5		
	460	3120.0	1493.8	1626.2	1417.9	208.3	204.6	3.7	3.3	0.1	0.3	
	478	2160.0	1096.5	1063.5	715.2	348.2	348.2					
	479	1680.0	731.9	948.1	935.5	12.7	12.7					
	480	1560.0	385.3	1174.7	1107.2	67.4	67.4					
	482	2442.1	358.5	2083.6	1793.3	290.3	290.3					
	483	2280.0	1366.7	913.3	782.4	130.9	130.9					
	484	1800.0	258.7	1541.3	1329.0	212.3	212.3					
	485	877.6	269.1	608.4	553.6	54.8	54.8					
	486	2400.8	1260.1	1140.7	980.3	160.4	146.0	14.4	10.6	1.9	1.9	
	492	2400.0	1212.7	1187.3	1000.5	186.8	186.8					
	493	2967.8	1093.8	1874.1	1484.7	406.4	369.5	26.2	26.2			
	Total	**30243.6**	**11825.4**	**18418.2**	**15955.7**	**2479.5**	**2388.7**	**80.2**				

(b)

Year tagged	Bird	All trips	Offshore trips	East Anglia	Galloper Ext	Greater Gabbard	Scroby Sands
2010	395	234	2				
	407	244	45	4	2	1	1
2011	459	156	14	1	1		
	460	317	49	4	1	1	
	478	283	40				
	479	183	4				
	480	119	8				
	482	193	40				
	483	235	19				
	484	157	30				
	485	90	16				
	486	273	34	7	3	3	
	492	224	25				
	493	366	60	10			
	Total	**3074**	**386**	**26**	**7**	**5**	**1**

3.4.1 Seasonal variation in time budgets

In the 2012 season, the early return of a large number of tagged birds with functioning tags provided good temporal coverage from the early breeding season through until mid-July, spanning pre-breeding, incubation, and part of the chick-rearing period. Note, data were not available for five birds (485, 486, 493, 395, and 482) for some of the breeding season, and thus the sample size for the 5-day periods analysed varies from nine to 14 birds.

Splitting individual bird time budgets into 5-day periods showed that on average, the time spent at the nest gradually increased until mid to late May when incubation begins (Figure 11). Inland movements were consistently more frequent than offshore movements prior to late May, and no birds interacted with offshore wind farm sites until late May. Use of offshore areas prior to incubation (pre-breeding) was mostly limited to birds drifting on the sea overnight close to the colony. The time spent offshore increased up to an initial peak of 27.6% (between 15/02/2012 and 20/02/2012), with another lesser peak of 13.5% between 24/06/2012 and 29/06/2012 (Figure 11). Time spent in offshore wind farm sites peaked between 19/06/2012 and 24/06/2012. Time away from the nest inland decreased until the 30/04/2012, thereafter increasing markedly.

This simple analysis reveals how time budgets, and therefore time spent in the areas of offshore wind farm sites, varied considerably throughout the season. Further analyses of seasonal patterns will be conducted for the final report using all years' data.

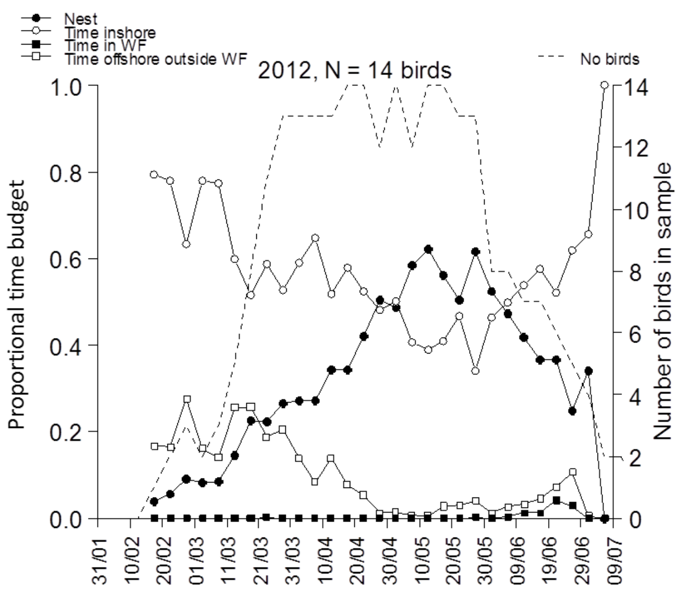


Figure 11 Seasonal time budget across all birds for 5-day consecutive periods during 2012 showing time spent at the nest, time spent away from the nest inland, time spent away from the nest offshore outside wind farm sites, and time spent offshore in wind farm sites.

3.5 Flight Heights

Work is currently in progress analysing flight height data. Following the methodology presented in the methods (section 2), a full analysis will be included in the final report.

4. DISCUSSION

4.1 Overview

4.1.1 Lesser Black-backed Gulls

The 2012 field season for Lesser Black-backed Gulls was very successful. In particular, the high number of tagged individuals from 2011 and 2010 returning with functioning tags has provided some excellent data. Although relay malfunction prevented downloading of all the data from birds towards the end of the breeding season, some interesting seasonal patterns have been revealed. For Lesser Black-backed Gulls at Orford Ness, the 2012 season was a less successful season in terms of productivity than in 2011. As in 2010, many nests failed at the egg stage and chick fledging success was believed to be low. Therefore, it is likely that annual variations in seasonal behaviour may be apparent, hence a full comparison of seabird wind-farm interactions will be investigated and presented in the final report.

A degree of inter-annual variation was demonstrated between 2010, 2011, and 2012 for Lesser Black-backed Gulls in terms of the distances travelled and time spent offshore, as well as seasonal patterns in distances reached offshore and trip duration. These findings highlight the importance of such studies spanning more than one season to gain a better understanding of seabird-wind farm interactions

4.1.2 Great Skuas

In contrast to the gulls, only one Great Skua tagged from 2011 returned to breed in 2012, and this bird had lost its tag and harness. A further two birds have been recovered outside the UK during migration, and nearly all colour-ringed control birds returned to both Foula and Hoy in 2012. The differences between species were wholly surprising and unanticipated, and are discussed in more detail in Thaxter *et al.* (in prep a,b). Consequently no migration data was obtained for skuas, and the study for this species has now been terminated. Furthermore, for Great Skuas, the 2012 breeding season was very poor at both Foula and Hoy, and as in previous years, birds fledged a very low proportion of chicks (Thaxter *et al.* in prep a,b).

4.2 Seabird-Wind Farm Interactions in 2012

As in 2010 and 2011, the results show that certain individual Lesser Black-backed Gulls from Orford Ness visited areas of proposed and consented wind farms at various points during the breeding season. Information downloaded at the start of the season, from birds tagged in 2010 and 2011 that returned to breed in 2012, showed that Lesser Black-backed Gulls also interacted with sites of proposed and existing wind farms on passage. However, the data also revealed a degree of intraspecific variation in the extent of spatial and temporal overlap between each individual and wind farms, with some birds foraging almost solely inland. This difference between individuals may reflect foraging specialisations and constraints due to age, sex or learned preferences, as has been widely reported in gulls of several species at other breeding colonies (e.g. Annett & Pierotti 1999; Davis 1975; Delhey *et al.* 2001; Greig *et al.* 1985; McCleery & Sibley 1986; Pierotti & Annett 1987; Skórka *et al*. 2005).

It is becoming clear that the way in which birds use the marine environment (including offshore wind farm sites) varies substantially during breeding. During pre-breeding (up to the end of April), birds used offshore areas but analyses of trips suggested areas closer to the colony were used, with many birds resting offshore overnight floating on the sea surface close to the colony. However, across all birds the time spent offshore on foraging trips was far less than that spent inland. As incubation progressed during May, the time at the nest increased, but subsequently dropped, presumably as chicks hatched requiring progressively less attendance, or reflecting changes in dietary requirements or nest failure. Thereafter, the time spent in both inland and offshore habitats increased. Only after late May (mostly after 25/05/12 were spatio-temporal overlaps recorded more extensively with offshore wind farm sites reaching mean spatial overlap of up to 14% (across birds), but less than 5% of the total time budget (19/06 – 24/06). Consequently, taking a snapshot of behaviour during May would have revealed a very different extent of wind farm interaction than that in June. These results serve to highlight the importance of seasonal investigations when assessing the extent of seabird-wind farm interactions.

4.3 Effects of Wind Farms on Lesser Black-backed Gulls

The implications of these results for Lesser Black-backed Gulls will become clearer once the final analyses have been conducted. For instance, while gulls showed clear overlaps with some existing wind farms, a more refined assessment of precise movements near individual turbines as not yet been undertaken. Nevertheless, these data indicate that birds from the Orford Ness colony do use or fly through the areas of existing wind farms. A comprehensive analysis of flight altitude is being conducted, the study of which will inform the collision risk of both species during the breeding season and on passage.

The spatial and temporal overlap with both proposed and consented wind farms, coupled with the known behaviour of gulls in offshore wind farms (recorded passing through constructed wind farms, perching on structures) provisionally suggests displacement for this species from this colony might not be substantial. Furthermore, the overall time spent offshore may have decreased over the three years of study, but this requires further investigation accounting for inter-annual season variation. Further characterisation of diurnal movements, time spent in flight, time spent flying at night within wind farm sites, would also be valuable and will be presented as part of the final report.

Efforts were undertaken to define birds' behaviours in terms of flight and foraging. However, a more refined assessment would require diving, floating and other movements to be characterised, for instance using accelerometer measurements (Shamoun-Baranes *et al.* 2012). This approach would help to show whether birds are using wind farm area for foraging, for example, suggesting the importance of these sites to SPA features.

4.4 Concluding Comments

The data presented here build on Thaxter *et al.* (2011, 2012) and reveal the substantial value of GPS tagging studies in assessing both connectivity and potential interactions between SPA features and offshore wind farms.

Although some aims of the project have been fulfilled, inclusion of data from the 2012/13 non-breeding seasons will build an overall picture of all movements and how these SPA feature species interact with wind farms within and outside the breeding season. For Great Skuas, we have been unable to fulfil migration questions originally proposed due to unforeseen poor return rates. While this is deeply regrettable, the skuas have provided us with some valuable breeding season information when we reported no effects of the tags on the foraging behaviour of the birds. More finer-scaled seasonal investigations will be conducted for the final report for Great Skuas in line with the approach taken for gulls. The final report will also include full analyses of flight height data – the methodology developed for this is described here – which will provide distribution of altitudes and investigations of how factors such as weather affect flight altitude, thus fulfilling the aims and objectives of this project.

Acknowledgements

This work was funded by the Department of Energy and Climate Change (DECC). Particular thanks go to Mark Rehfisch (formerly of the BTO) for his help in initiating the work, to John Hartley of Hartley Anderson for managing the contract and to Emma Cole, Mandy King, Sophie Thomas and James Burt at DECC. Thanks also to the National Trust, Scottish Natural Heritage and Natural England for permission to work at the SPAs. We thank Kieran Bell and Anne Savage at the Crown Estate who provided information on location of wind turbines, and Judy Shamoun-Baranes (University of Amsterdam) for assistance in the setup of base stations at Orford Ness, Foula, and Hoy, and help with queries with regard to databases, and equipment. We are very grateful to Mike Marsh, Dave Crawshaw and Gill Stannard at Landguard Bird Observatory for assistance in capturing and tagging Lesser Black-backed Gulls at Orford Ness. We thank Mark Bolton and Sarah Davis (RSPB) for assistance in field work at Orford Ness, and also to Grant Lohoar, Dave Fincham, Dave Cormack, Duncan Kent and Matt Guilliatt (National Trust) for advice and assistance in erecting the relay masts on site at Orford Ness. We are very grateful to Bob Furness (McArthur Green Ltd) and Eliza Leat (University of Glasgow) for tagging and trapping of Great Skuas at Foula and Hoy, Angus Jackson (ERI) and Emily Coleman (BTO) for arranging the data sharing agreement between ERI and BTO, and additional field assistants Guillam McIvor and Vikki Smith for fieldwork assistance during 2010. Thanks also to Chris Booth for providing productivity data for Hoy, Soeren Hoejlund for development of a solar powered relay for the Hoy base station, Aileen Adam (ERI) for molecular sexing of skuas at Hoy, Jason McIlvenny, Astrid Harendza, Neil James and Mona Larsen (ERI), and Andy Knight (RSPB), for help with colony walks and monitoring productivity at Hoy. We also thank Fran-Dyson Sutton for excellent hospitality and further assistance in monitoring the Foula base station, Magnus Holburn for assistance in erecting the relay pole at Foula, Sheila Gear for monitoring the plot of Great Skuas adjacent to our study plot, and Marion at Leraback B&B and Isobel Holburn for hospitality at Foula. We also thank “Kiwi” Kev Drew (Landcare Research), Jeff Davey (Anglia Ruskin University), Nadia Thornton (Harrison Clinical Research Ltd), Neil Calbrade, Aonghais Cook, Nick Moran and Lucy Wright (BTO) for further field assistance during 2010 and 2011.

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