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Measuring the interaction between marine features of Special Protection Areas with offshore wind farm development zones through telemetry: second year report

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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. 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 zones;
   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 2011, GPS tags were fitted to 14 Lesser Black-backed Gulls at Orford Ness, part of the Alde-Ore Estuary SPA. This was in addition to 11 birds tagged at this site in 2010. Following the tagging of four Great Skuas on the Foula SPA in Shetland in 2010, a further 10 birds were tagged in 2011. Ten Great Skuas were also tagged on Hoy SPA in the Orkney archipelago. All individuals tagged were members of breeding pairs, and were caught on the nest. No adverse effects of tagging were observed (although there were high levels of nest failure for the gulls, this was typical for the colony as a whole).

5. Sufficient data for analysis were obtained in 2011 for 13 Lesser Black-backed Gulls, 10 Great Skuas at Foula, and nine Great Skuas at Hoy. Movements away from the colony, many of which were presumed to be for foraging, were classified as "trips". In total 10% of the 3404 trips recorded in 2011 for Lesser Black-backed Gulls contained a marine component. The maximum foraging range offshore in 2011 during breeding was 91 km. Some individual gulls never ventured offshore, whilst others spent more than half their time away from the colony at sea.

6. For Great Skuas at Foula, 839 offshore trips were recorded in 2011, with a maximum foraging range during breeding of 265 km with foraging predominately focused to the north-west of the colony. For Great Skuas at Hoy, from a total of 552 offshore trips, a maximum foraging range of 138 km was recorded.

7. For Lesser Black-backed Gulls that spent substantial periods of time at sea, there was considerable temporal and spatial overlap with consented Round 1 and 2 wind farms (in this case, sites which are under construction), as well as with the proposed extensions and Round 3 development sites. There was also spatial and temporal overlap between Great Skuas from both Foula and Hoy and medium term renewable development options in Scottish Territorial Waters.

8. Three of the six Lesser Black-backed Gulls for which we have data outwith the breeding season crossed the sites of existing and proposed wind farms on migration.

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 zones 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 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 zones;
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 second year of this study, covering the migrations of birds tagged in 2010 and tracking undertaken during the second breeding season in 2011. The third aim is not addressed, as the methodology is still being developed. The final report will include a full analysis and discussion of flight altitude data.

For background information on tagging and the projects' focal species, the Lesser Black-backed Gull (*Larus fuscus*) and the Great Skua (*Stercorarius skua*), please see Thaxter *et al.* (2011).

2. METHODS

2.1 Field sites

As in 2010 (see Thaxter *et al.* 2011), Lesser Black-backed Gull fieldwork was conducted at Orford Ness, Suffolk, UK (52°06'N, 1°35'E). There were approximately 550 apparently occupied nests (AONs) for Lesser Black-backed Gulls at this site in 2010 and 2011 (Marsh, personal communication).

Fieldwork for Great Skuas was again conducted at Foula SPA, Shetland, UK (60°8'N, 2°5'W), as in 2010 (Thaxter *et al.* 2011), but also at Hoy SPA, UK (58°52'N, 3°24'W). Work at Hoy is being undertaken as part of a separate on-going study, led by the University of the Highlands and Islands (UHI) – with data shared between the two studies – and so we present fewer data here for this site.

2.2 Wind farm Zones

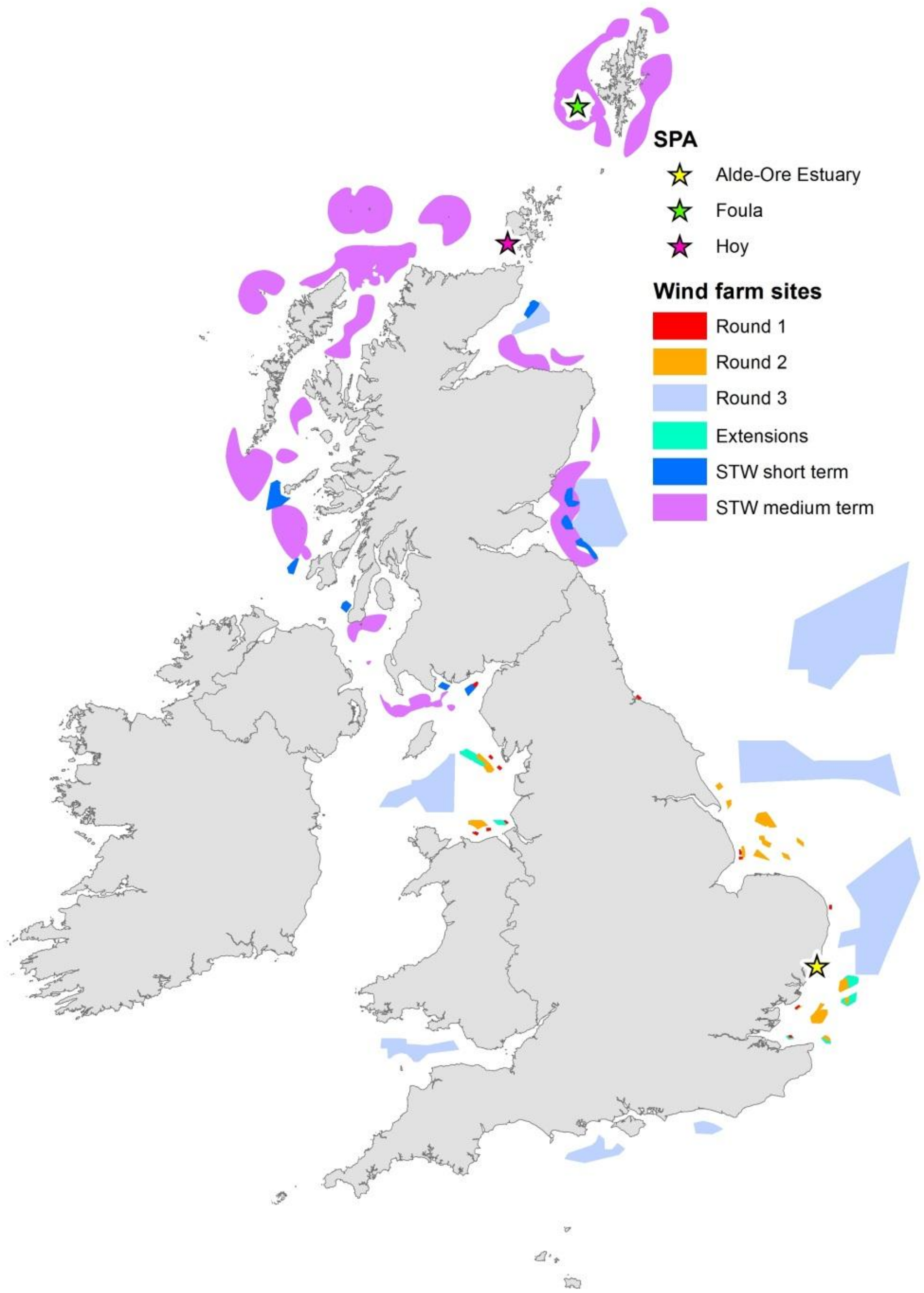
As in Thaxter *et al.* (2011), here we assess seabird-wind farm interactions for all possible consented and proposed wind farms near to the breeding colonies during the breeding season. For Lesser Black-backed Gulls, we also consider interaction with UK wind farms during the migration and non-breeding period 2010/11. However, we also build upon Thaxter *et al.* (2011) for Great Skuas by assessing interactions with Scottish wind farm zones proposed by the Scottish Government (Marine Scotland 2011). We used medium term 2020 development zones for this purpose (Fig. 3, in Marine Scotland 2011), and many are situated near to Hoy and Foula. Fig. 1 shows all zones around the UK considered for interaction. Here we also present the location of existing turbines on all maps, supplied by the Crown Estate.

2.3 The GPS system

The GPS devices used in 2011 were the same as those used in 2010. The system allows information from the tags to be remotely downloaded to a central base station (see Thaxter *et al.* 2011 and http://www.uva-bits.nl/system/ for more details). As in 2010, each tag was deployed only once per bird and the same remote systems used in 2010 (base station and relays) were used in 2011 for Foula and Orford Ness. However, a new system was installed for tracking birds at Hoy.

A perimeter of approximately 200 m^2 was used around the Orford Ness gull colony and the two skua colonies, 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 – see section 2.6).

Figure 1 Location of all wind farm sites in the UK in relation to study colonies at Orford Ness, Foula and Hoy. In addition to the UK wind farm zones (Rounds 1, 2, and 3 plus extensions) presented in Thaxter *et al.* (2011), we also present Scottish Territorial Waters (STW) short and medium term options for Scotland, as described in Marine Scotland (2011).



2.4 Capturing and attaching devices

In addition to the birds tagged in 2010 (Thaxter *et al.* 2011), five of which returned to Orford Ness with functioning tags in 2011, a further 14 Lesser Black-backed Gulls were tagged at Orford Ness on 21 May 2011. Ten Great Skuas were captured and tagged on Foula between 3 June and 9 June 2011 and ten Great Skuas were captured and tagged on Hoy between 11 June and 14 June 2011. The capturing and tagging process was the same as that described in Thaxter *et al.* (2011) except that wing harnesses were used on all individuals, as this method was found to be the most successful in 2010 (Table 1).

Table 1 Deployment periods for tags on (a) Lesser Black-backed Gulls and (b) Great Skuas. Note, for Great Skuas in 2011, one tag (488) malfunctioned and so the same bird was recaptured and another tag (487) deployed on the same bird (*).

(a) Lesser Black-backed Gull

Tag	Date tagged	First data downloaded at colony 2011	Last data downloaded at colony 2011	Harness type
334	15/06/2010	11/04/2011 19:11:47	29/06/2011 09:18:39	Wing
336	15/06/2010	27/03/2011 19:13:00	29/03/2011 21:22:10	Wing
391	15/06/2010	03/04/2011 17:53:11	28/07/2011 20:20:52	Body
395	15/06/2010	30/01/2011 05:19:07	16/07/2011 00:32:38	Body
407	15/06/2010	20/03/2011 10:56:21	28/07/2011 06:25:41	Wing
457	21/05/2011	21/05/2011 17:55:00	08/06/2011 14:25:58	Wing
459	21/05/2011	21/05/2011 19:00:00	24/07/2011 05:31:40	Wing
460	21/05/2011	21/05/2011 19:21:00	10/08/2011 06:18:06	Wing
478	21/05/2011	21/05/2011 14:50:00	29/07/2011 05:44:22	Wing
479	21/05/2011	21/05/2011 15:30:00	20/08/2011 00:39:12	Wing
480	21/05/2011	21/05/2011 17:10:00	12/08/2011 04:46:00	Wing
481	21/05/2011	21/05/2011 19:41:00	11/07/2011 01:28:22	Wing
482	21/05/2011	21/05/2011 18:30:00	09/08/2011 19:27:12	Wing
483	21/05/2011	21/05/2011 18:12:00	14/08/2011 02:53:13	Wing
484	21/05/2011	21/05/2011 14:32:00	28/07/2011 20:32:06	Wing
485	21/05/2011	21/05/2011 16:15:00	21/07/2011 11:37:56	Wing
486	21/05/2011	21/05/2011 18:45:00	11/08/2011 17:56:26	Wing
492	21/05/2011	21/05/2011 16:40:00	01/07/2011 02:41:42	Wing
493	21/05/2011	21/05/2011 15:08:00	29/07/2011 06:35:12	Wing

(b) Great Skua - Foula

Tag	Date tagged	First data downloaded at colony 2011	Last data downloaded at colony 2011	Harness type
415	03/06/2011 17:41	03/06/2011 17:48:18	13/07/2011 02:20:48	Wing
470	04/06/2011 11:40	04/06/2011 12:02:18	17/08/2011 19:49:17	Wing
465	04/06/2011 19:20	04/06/2011 19:45:25	18/09/2011 14:00:56	Wing
451	04/06/2011 20:24	04/06/2011 20:43:44	15/08/2011 13:45:00	Wing
450	05/06/2011 10:56	05/06/2011 11:06:00	29/08/2011 06:04:14	Wing
418	05/06/2011 19:06	05/06/2011 19:10:31	17/08/2011 19:44:38	Wing
454	06/06/2011 17:12	06/06/2011 17:16:37	11/09/2011 18:41:24	Wing
476	06/06/2011 20:55	06/06/2011 21:15:34	27/08/2011 06:35:13	Wing
419	07/06/2011 07:45	07/06/2011 07:59:40	25/08/2011 19:58:36	Wing
488*	04/06/2011 09:32	04/06/2011 09:46:58	06/06/2011 19:43:36	Wing
487*	09/06/2011 10:20	09/06/2011 10:39:17	23/08/2011 05:30:28	Wing

(c) Great Skua - Hoy

Tag	Date tagged	First data downloaded at colony 2011	Last data downloaded at colony 2011	Harness type
473	11/06/2011 14:02	11/06/2011 14:12:36	21/08/2011 06:01:02	Wing
471	11/06/2011 17:01	11/06/2011 17:01:58	24/08/2011 18:04:23	Wing
448	11/06/2011 18:38	11/06/2011 18:53:06	24/08/2011 09:16:09	Wing
420	12/06/2011 09:43	12/06/2011 09:46:23	07/07/2011 10:45:36	Wing
472	12/06/2011 11:30	12/06/2011 11:38:23	14/06/2011 16:49:40	Wing
409	12/06/2011 12:50	12/06/2011 13:08:59	24/07/2011 04:31:00	Wing
475	12/06/2011 16:20	12/06/2011 16:48:33	30/06/2011 15:32:51	Wing
467	12/06/2011 17:05	12/06/2011 17:15:51	20/08/2011 19:33:16	Wing
400	12/06/2011 18:15	12/06/2011 18:25:27	19/07/2011 12:19:06	Wing
392	14/06/2011 10:20	No data downloaded	No data downloaded	Wing

2.5 Nest monitoring

2.5.1 Lesser Black-backed Gulls

As in 2010 (Thaxter *et al.* 2011), birds returned to their nest after tagging. Certain individuals were observed again in the colony during the breeding season. The departure from the colony at the end of the season indicated that post-breeding dispersal took place as normal. Systematic nest monitoring was also carried out in 2011 consisting of weekly visits to Orford Ness beginning in early May so that candidate nests for capturing breeding adults could be identified. Nests with at least two eggs at the time of tagging were chosen, as it was thought that breeding adults would be more likely to return promptly to incubation if this behaviour was already well established by that stage of the breeding season. After tagging, nests were visited approximately once a week until fledging. Eggs, where present, were measured (width, length and mass), and the number of eggs and chicks were noted on each visit (Table 2).

Table 2 Fate of all Lesser-black Backed Gull nests in this study (one bird tagged per nest). Numbers denote the number of eggs (E) or chicks (C).

Tag	05 May	12 May	17 May	21 May*	25 May	30 May	4 Jun	13 Jun	20 Jun	09 Jul
457	1E	3E	3E	3E	3E	3E	3E	1E,2C	1E,1C	
459	1E	3E	3E	3E	3E	3E	3E	1E,2C	1E	
460	1E	3E	3E	3E	0	0	0	0	0	0
478		2E	3E	3E	3E	3E	3E	3E	2E	
479		2E	3E	3E	3E	3E	3E	2C	1C	
480		2E	4E	4E	4E	4E	4E	4E	3C	
481			1E	3E	3E	3E	3E	3E	3C	
482**	1E	3E	3E	3E	3E	3E	3E	2E,1C		
483**	1E	3E	3E	3E	3E	3E	3E	2E,1C		
484		2E	2E	2E	2E	2E	2E	2C	1C	
485		1E	2E	3E	3E	3E	3E	1E,1C		
486		3E	3E	3E	3E	3E	3E	1C		1C
492	NA	2E	2E	2E	2E	2E	2E	2C		
493	1E	3E	3E	3E	3E	3E	3E	0E,1C		

* Date of tagging.
** 482 and 483 were a pair.

2.5.2 Great Skuas

At Foula, Great Skuas tagged in 2011 were monitored closely, with daily nest checks until 15 July when chicks were approaching fledging (typically late July – August) (Table 3). At Hoy, Great Skuas were monitored following tagged through approximately weekly visits to the colony until 15 August, when the last chicks had fledged (Table 3). All eggs were weighed and measured (length, width and mass). All birds returned to the nest after tags were deployed (Thaxter *et al.* 2011) and departures of birds from the colony at the end of the season indicated normal post-breeding dispersal.

Table 3 Fate of all Great Skua nests in this study (one bird tagged per nest). Numbers denote the number of eggs (E) or chicks (C). First dates with monitoring information for each bird in the table correspond to the date of tagging, and "?" denotes uncertain but likely nest status. Weekly visits were made at Hoy, but where the nest status was the same on two consecutive visits, the status in between checks has been inferred and therefore entered with the same information.

(a) Foula

Tag	03 Jun	04 Jun	05 Jun	06 Jun	07 Jun	11 Jun	14 Jun	16 Jun	17 Jun	18 Jun	19 Jun	21 Jun	26 Jun	27 Jun	29 Jun	02 Jul	05 Jul	14 Jul	15 Jul
415	1E	1E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
451		2E	2E	2E	2E	2E	2E	2E	2E	2E	1C1E	1C1E	1C1E	1C	1C	1C	1C	1C	1C
487		2E	2E	2E	2E	1C1E	2C	2C	2C	2C	2C	2C	2C	2C	2C	2C	2C	2C	0
470		2E	2E	2E	2E	2E	2E	2E	2E	2E	1C1E	2C	2C	2C	2C	2C	2C	2C	2C
465		2E	2E	2E	2E	2E	2E	2E	2E	2E	2E	2E	2E	1C1E	2C	2C	2C	2C	2C
450			1E	1E	1E	1E	1E	1E	1E	1E	1E	1E	1E	1E	1E	1C	1C	0	0
418			2E	2E	2E	1C1E	1C1E	2C	0	0	0	0	0	0	0	0	0	0	0
454				2E	2E	2E	2E	1C1E	1C1E	1C	1C	1C	1C	1C	1C	1C	1C	1C	1C
476				2E	2E	2E	2E	2E	1C1E	2C	2C	2C	2C	2C	2C	2C	2C	2C	2C
419					2E	2E	2E	2E	1C1E	1C1E	2C	2C	?2C	?2C	?2C	?2C	0	0	0

(b) Hoy

Tag	11 Jun	12 Jun	13 Jun	14 Jun	15 Jun	16 Jun	17 Jun	24 Jun	01 Jul	05 Jul	12 Jul	22 Jul	02 Aug	15 Aug
448	2E				1E1C			?0	0	0	0	0	0	0
471	2E				2C	2C	2C	2C	1C	1C	1C	1C	1C	1C
473	2E	2E	2E	2E	2E	2E	2E	0	0	0	0	0	0	0
400		2E	2E	2E	2E			1C	0	0	0	0	0	0
409		2E	2E	2E	2E			1C	?0	0	0	0	0	0
420		2E	2E					0	0	0	0	0	0	0
467		1C1E			2C			1C	1C	1C	1C	1C	1C	1C
472		1E	1E	1E	1E	0	0	0	0	0	0	0	0	0
475		2E	2E	2E	2E	2E	2E	2E	2E	2E	2C	?0	0	0
392				2E	1E1C			0	0	0	0	0	0	0

2.5.3 Assessing tag effects – productivity, attendance, and return rates

Attaching tags to birds may affect individuals in ways that could result in atypical behaviour. For instance, tags could act as a hindrance to flight and foraging ability during breeding, therefore (1) influencing attendance of birds at the nest as they spend longer to find food, (2) influencing overall productivity if birds find it harder to feed themselves and their chicks, or (3) affecting overwinter survival of birds. We attempted to gather the information necessary to assess these possible effects. However, at the time of writing, insufficient data were available to assess overwinter survival. This will be addressed once such data are available. Along with the birds captured for tagging, a total of 28 adult Lesser Black-backed Gulls, 10 Great Skuas at Foula, and 10 Great Skuas at Hoy were captured using the same technique as for tagged birds and were colour-ringed only, in order to act as control birds. We also followed an extra 21 nests at Orford Ness and 37 nests at Foula where adults were not marked at all. In all cases nests identified (tagged, colour-ringed, or unmarked) were monitored in the same fashion for productivity (Tables 4 and 5).

2.5.3.1 Productivity

For Lesser Black-backed Gulls, monitoring productivity is difficult, as nesting densities can be high, and chicks can wander between territories. This problem is compounded as chicks approach fledging, since highly mobile chicks can be found in neighbouring nests, and offspring from apparently empty nest sites may have wandered from the nest to hide in nearby vegetation. Therefore for both egg hatching and chick presence productivity measures, we assumed both minimum and maximum scenarios. For incubation, the minimum scenario was based on the number of chicks found, while the maximum scenario assumed all eggs that were present throughout incubation subsequently hatched. For chick productivity, the minimum scenario assumed that all chicks not seen on the 20 June 2011 did not survive, while for the maximum scenario, all chicks that hatched successfully were assumed to be alive until 9 July (when monitoring ceased), unless specific observations such as deceased chicks suggested otherwise. For hatching success, the picture was clearer, but if the fate of eggs was unknown, the maximum and minimum scenario was given for that nest.

Table 4 Productivity of Lesser Black-backed Gulls at Orford Ness, 2011

Stage	Measure	Tagged nests	Colour-ringed nests	Other nests	All
Egg	No nests	13	25	21	59
	Clutch size	2.92±0.49	2.56±0.51	2.42±0.77	2.60±0.62
	No eggs hatched / nest min	1.85±1.07	1.20±1.00	1.14±1.10	1.32±1.07
	No eggs hatched / nest max	2.62±0.96	2.56±0.51	1.43±1.25	2.17±1.07
	Prop hatched / egg laid min	0.65±0.37	0.50±0.42	0.52±0.44	0.54±0.41
	Prop hatched / egg laid max	0.90±0.29	1.00±0.00	0.63±0.48	0.85±0.36
Chick up to 9 July	Chicks / nest min	0.83±1.11	0.72±1.02	0.43±0.51	0.67±0.93
	Chicks / nest max	2.08±0.79	2.08±0.86	1.79±0.80	2.00±0.82
	Prop chicks / egg laid min	0.27±0.34	0.31±0.41	0.17±0.21	0.26±0.35
	Prop chicks / egg laid max	0.73±0.28	0.82±0.29	0.81±0.24	0.80±0.27

For gulls, there was no significant difference between the three categories of nests of tagged, ringed, or unmarked birds (binomial GLM, success overall minimum, delta dev = -0.722, df = 2, P = 0.697; success overall maximum, delta dev = -2.790, df = 2, P = 0.248), nor was there a difference between the nests of tagged and colour-ringed birds (success overall minimum, delta dev = -0.008, df = 1, P = 0.927; success overall maximum, delta dev = -0.001, df = 1, P = 0.973) (Table 4).

At Foula, Great Skua nests were monitored until the 15 July 2011. Fifty-seven nests were covered in total, including 10 nests of tagged birds, 10 nests of colour-ringed birds, and 37 additional nests in the same area (Table 5). Due to uncertainty in final numbers of chicks at nests, we again calculated minimum and maximum scenarios. An additional 53 Great Skua nests were also monitored at a "separate plot" (Table 5), adjacent to the main plot, for clutch size. At this separate plot, chicks were also ringed and final fledgling success was determined. This plot had a similar clutch size (1.74) to the main plot (1.79, Table 5). However, nests at the separate plot were checked for chicks more than 10 days later than those on the main plot, and therefore revealed a lower proportion on site compared to those in the main plot (Table 5). Birds from the main site may have therefore shown similar survival between the 15 July 2011 and 28 July 2011. There was some uncertainty in the fledging success for the separate plot, but it is likely only a small proportion (min 0.12, max 0.40) of chicks per egg laid eventually fledged here. This, however, was an improvement on 2010, when very few or no chicks were thought to have fledged successfully (S. Gear, personal communication).

There was no significant difference in productivity for Great Skuas at Foula between all three groups monitored (nests of colour-ringed, tagged or other birds: binomial GLM, delta dev = -1.321, df = 2, P = 0.517), nor was there a significant difference in productivity between just the colour-ringed and tagged birds (delta dev = -0.966, df = 1, P = 0.326). The productivity of Great Skuas at Hoy is subject to further ongoing work.

Table 5 Productivity of Great Skuas at Foula, 2011

Stage	Measure	Nests of tagged birds	Nests of colour-ring birds	Nests of other birds	Main plot, all birds	Separate plot[c]
Eggs	No. of nests	10	10	37	57	53
	Clutch size	1.80±0.42	2.00±0.00	1.73±0.45	1.79±0.41	1.74
	No. of eggs hatched / nest	1.50±0.71	1.70±0.48	1.29±0.74	1.40±0.70	
	Prop hatched / egg laid	0.80±0.35	0.85±0.24	0.77±0.38	0.79±0.35	
Chicks	Min chicks / nest	0.80±0.92	0.90±0.74	0.78±0.75	0.81±0.76	
	Max chicks /nest	1.00±0.94	1.50±0.85	0.92±0.83	1.03±0.87	
	Prop chicks / egg laid[a]	0.55±0.49	0.55±0.36	0.54±0.46	0.54±0.45	0.41
Fledglings[b]	Min prop Fledged / laid					0.12
	Max prop fledged / laid					0.40
	Prop fledged / laid unknown					0.26

[a] Nests monitored up until 15 July 2011; additional plot chicks surveyed 23 – 27 July 2011
[b] Separate plot: fledglings assessed on 14 August 2011 (by S. Gear)
[c] The separate plot was monitored less intensively throughout incubation and early chick rearing and so equivalent measurements at that period of the season could not be included to compare to the main plot

2.5.3.2 Attendance

Further monitoring of the attendance patterns of both tagged and untagged (colour-ringed) Great Skuas was conducted at Foula. This was achieved by regular 1-2 hour observations of the nests of the 10 tagged and 10 colour-ringed birds from a vantage point on a hillside. Watches were conducted two to three times a day (over the same monitoring period as presented in Table 3a) covering morning (06:00-10:00), middle day (10:01-16:00) and late afternoon/evening (16:01-21:00) periods. This enabled a presence-absence assessment of all tagged and non-tagged individuals to answer tag effect question (1) above in section 2.5.3. Similar monitoring of adult Lesser Black-backed Gull presence at the Orford Ness colony, and Great Skuas at Hoy, was more difficult due to time restrictions. Therefore, the detailed attendance comparison was restricted to Great Skuas at Foula only in 2011.

At Foula, there was no significant difference between colour-ringed control groups and tagged birds in the probability of a bird being present at the nest at the two-three watch checks throughout the day (binomial GLM, accounting for period of day and Julian date: delta dev = -1.323, df = 1, P = 0.250; probability of resighting colour-ring = 0.740±0.440, tag = 0.711±0.454). This suggested that tagged Great Skuas did not make longer foraging trips as a result of finding it harder to find food.

2.6 GPS Data collection protocols, and post-processing of data

Tags from Lesser Black-backed Gulls caught in 2010 were set on a 15 to 30 minute sampling rate between the 2010 and 2011 breeding seasons. At the end of the 2011 breeding season, all tags from Lesser Black-backed Gulls were set on a 30 minute sampling rate. This longer sampling rate was chosen in 2011 to avoid a pitfall encountered in 2010, when two tags of gulls that remained in the UK until late in the year temporarily cut out, presumably due to poor winter weather and a lack of sunlight limiting the power from the tags' solar panels. For Great Skuas, a mixture of settings was tested to enable some faster sampling during migration periods when birds were still in UK waters. This was achieved through using a GPS fence around the UK. To avoid unrealistic rates that could fill up the tag's memory and result in gaps in any future migration data, we used three options; (1) a flat 30 minute rate with five-fold faster sampling if the battery was near full; (2) a 30 minute rate except for a 60 second rate for 15 minutes (between 1200 and 1215 hours); and (3) a 15 minute rate, with a 60 second rate for 15 minutes between 1200 and 1215.

As in 2010, GPS devices were set to sample every 30 minutes to reduce data collection when birds were at the colony and less active (Thaxter *et al.* 2011). However during 2010, GPS data were collected at a variety of sampling intervals (3 seconds, 60 seconds, 5 minutes, 15 minutes, and 30 minutes) as we trialled out the system and conducted investigations into effects of sampling rate on altitude precision. During 2011, we used 5 to 10 minute sampling rates for Great Skuas at Foula and Hoy (depending on weather), and 5 minutes for Lesser Black-backed Gulls at Orford Ness (owing to better overall weather in southern England). We also used an energy surplus setting for both species enabling five-fold faster sampling rates when loggers 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).

Accelerometers were also activated in 2011 for identifying specific behaviours that could prove useful in defining where foraging is focused. These data are still being processed and are not presented in this report.

2.6.1 Breeding and post-breeding distinction

Here, we build on Thaxter *et al.* (2011), and define periods of “breeding” for both species. This distinction allowed for a more refined assessment of wind farm interactions when birds are restrained to central place foraging during incubation and chick-rearing. For both Great Skuas and Lesser Black-backed Gulls, nest failure was assumed to have occurred only if all eggs or chicks had been lost.

For Great Skuas on Foula, constant monitoring took place up to 15 July 2011, such that breeding movements could be discerned. Five Great Skuas lost eggs or chicks by this point. For the remaining five birds, movements after this period may have still encompassed breeding behaviour but were classed as unknown status. At Hoy, the weekly visits of nests meant there was some uncertainty when breeding ended when nests had failed. However, monitoring until 15 August allowed the fate of all nests to be established. Similar to Foula, we presented data for periods of certain and likely “breeding” and a separate certain category of a category of “failed”.

For Lesser Black-backed Gulls, we attempted to split movements of birds into “likely breeding” (incubation and chick-rearing) and all other movements. Checks of tagged bird nests up until the 9 July 2011 found nests with chicks (although some chicks could have originated from neighbouring nests). Indeed a separate visit to ring chicks found many on 19 July. However, we treated all movements of birds where breeding failure was not established, as “likely breeding” up until 9 July. The grouping of movements after 9 July allows a presentation of remaining data to give a complete perspective across the period of tag deployment – this will have included some late breeding foraging trips, as well as post-breeding movements, either after nest failure or fledging of chicks. Here, we also present movements during 2011 of birds tagged in 2010 (n = 5 birds). However, as we did not locate and monitor these birds’ nests, we make no distinction in their breeding status, such that we present data together that are likely to include movements before, during and after breeding.

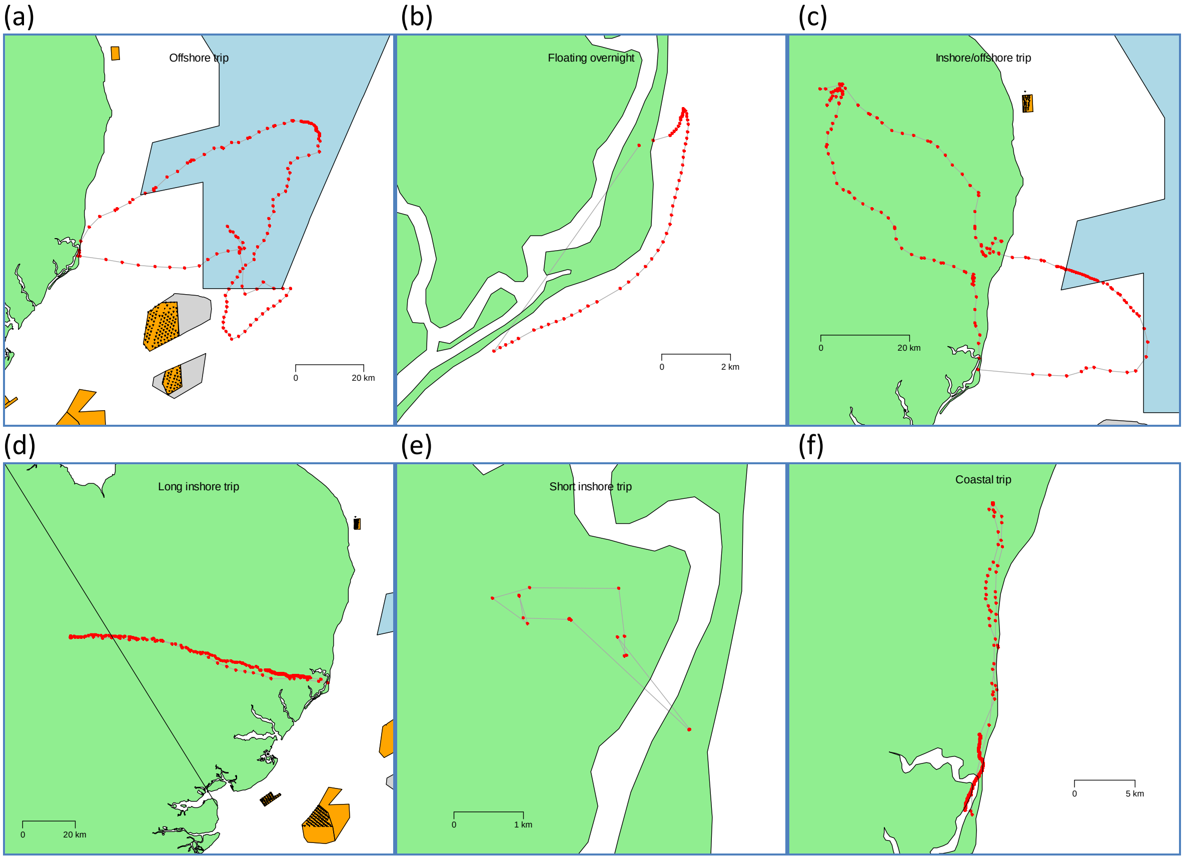
2.6.2 Defining trips and calculating trip statistics

Lesser Black-backed Gulls visited a variety of habitats during the 2011 breeding season, including inland fields, pig farms, coastal sites, estuaries, and buildings, as well as habitats offshore. Trips were categorised as: (1) offshore, (2) inshore (including long and short trips near colony and along the coast), (3) inshore and offshore, and (4) floating overnight at sea, close to shore (Fig. 2).

In order to assess the overall interaction with wind farm zones we considered all trips. However, for the purposes of calculating offshore foraging ranges (here defined as the maximum point reached offshore from the colony), we considered trip types (a) and (c) (“offshore” and “inshore/offshore”). For all trips (including those where offshore foraging range was calculated) 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.

At both Foula and Hoy, both field observations and matches between GPS output and aerial imagery (Google Earth ©) showed that Great Skuas made short bathing trips to nearby lochs. While these trips (total of 262 for Hoy and 422 for Foula) may have encompassed time spent hunting for terrestrial prey, they were excluded in order that analyses focussed on offshore foraging. Given all Great Skuas trips could be classified as bathing or foraging, there was no need for further categorisation in the same manner as gulls.

Figure 2 Example trips for Lesser Black-backed Gulls and how trips were defined for further analysis: (a) Offshore trip, (b) Floating overnight at sea near to colony; (c) inshore/offshore trip; (d) longer inshore trip; (e) short inland trip in nearby fields; (f) coastal trip. For the purposes of calculating offshore foraging range, we considered types (a) and (c). Also shown are Rounds 1 and 2 wind farms (orange), East Anglia Round 3 wind farm (blue), and positions of turbines (black dots).



2.7 Analysis of data

2.7.1 Connectivity with the areas of proposed and consented wind farms

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

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

Following Thaxter *et al.* (2011), we investigated the overlap of areas used at sea with wind farms sites using kernel analysis (Worton 1989) to estimate the 50%, 75% and 95% kernel density estimates (KDEs) of the bird's utilisation distributions to define the core, middle, and total foraging "home ranges" respectively. Three methods to estimate the smoothing parameter were tested in Thaxter *et al.* (2011) for this purpose including an h-ref ad-hoc methods, Least Squares Cross Validation (LSCV), and Brownian Bridge (Horne *et al.* 2007; Ens *et al.* 2008). Here, we also tested these three methods again. Although there are still some uncertainties in the best method to estimate the best smoothing parameter, LSCV is widely accepted as the most robust (Hamer *et al.* 2007; Thaxter *et al.* 2009, 2010; Wilson *et al.* 2009). However, Thaxter *et al.* (2011) reported problems of convergence with LSCV and so focused on an ad-hoc method to present preliminary results. Here, we overcame this issue by incorporating a jitter of points allowing the LSCV routine to converge. In particular, the utilisation distribution previously estimated (Thaxter *et al.* 2011) was most likely "over-smoothed" using the "href" method. Therefore, we consider these results to be most reliable, and given the different method used for the smoothing parameter, estimates should not be directly compared with those presented in Thaxter *et al.* (2011).

We produced KDEs of all locations of all birds pooled (population level kernel) and individual bird kernels, and thereafter calculated the overlaps of core, middle, and total home ranges with respective wind farm zones. In all cases, we investigated all movements and those where travelling speed was < 4 $km.h^{-1}$, the latter of which gives some indication of likely resting and foraging locations (hereafter termed "KDE foraging") where the speed is thought to be below that needed to sustain flight (Shamoun-Baranes *et al.* 2011; Thaxter *et al.* 2011). Here we present results of the movements of all birds from the colony, and unlike Thaxter *et al.* (2011) for Lesser Black-backed Gulls, we did not produce separate distributions for offshore movements for this report. This allowed a better understanding of the overall weighted use of offshore areas. All kernel analyses were conducted using Package 'adehabitat' (Callenge 2006) in R 2.14.0 (R Development Core Team 2012)

We also filtered GPS data to a 10 minute rate for assessment of breeding area usage, prior to spatial analysis. Data were filtered to a 30 minute rate to assess post-breeding or failed area usage as tags were then set to this rate in anticipation of birds departing for migration (see section 2.6).

2.7.3 Time budgets of birds

As in the first-year report, 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.

2.7.4 Flight altitudes

Flight altitudes are the subject of further investigation, to be presented in the final report, once the methodology has been developed to allow modelling of the error that surrounds these measurements. Before analyses of flight heights can be undertaken, the inaccuracy of the tags' altitude measurements and the associated error need to be accounted for (discussed in Thaxter *et al*. 2011). To help address this, we performed a series of ground-truthing tests (Thaxter *et al.* 2011) at Orford Ness on 19 July 2011 and on Foula on 13 July 2011.

Once these difficulties have been overcome, there are two different approaches we could take to analyse these data. The first and simplest of these would be to use mixed models (Bolker *et al.* 2009). These models account for the issue of non-independence of data and errors that arises because multiple measurements are associated with the same individual. This would be dealt with by fitting the identity of the bird as a random effect. Analysis could be carried out using several packages in R (R Development Core Team 2012), including 'lme4' (Bates & Maechler 2010) or 'Zelig' (Imai *et al.* 2011).

An alternative, more complicated, but perhaps better way to analyse altitude data would be through employing a Bayesian approach (Wade 2000, Ellison 2004). In contrast to mixed modelling, based on hypothesis testing and significance tests, Bayesian statistics rely on probability statements originating from a distribution that describes the probability of all parameter values for a given dataset (Wade 2000). This analysis could also be carried out in R (Albert 2007) using a number of additional packages. Bayesian statistics have been applied in models of animal movements in the past (e.g. Forester *et al.* 2007), although not in the capacity of flight altitude. However, this approach, although difficult, would be elegant and give a more realistic reflection of the biological processes underlying the data than one based on hypothesis testing (Johnson, personal communication).

2.7.5 Formal statistical tests

For formal tests, we used generalized linear models (GLMs) for data with normal errors, and generalized linear mixed-effects models (GLMMs) for those with Poisson or binomial error distributions. To account for repeated foraging trips made by individual birds, "bird identity" (BirdID) was included as a random effect. All GLMs used likelihood ratio tests (LRTs) comparing AIC for terms with and without the parameter of interest, and GLMMs used χ^2 tests (or delta deviance) to assess the significance of effects and interactions, with the most significant variables selected through stepwise forward selection. 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).

3. RESULTS

3.1 Descriptive trip statistics

3.1.1 Lesser Black-backed Gull

As in 2010, Lesser Black-backed Gulls tagged in 2011 made a mixture of solely inshore trips and coastal trips (87%), trips that were offshore (6%) (hereafter "offshore"), trips that straddled both inshore and offshore habitats (4%), or those that were floating on the sea just offshore (2%). Some trips were very short just visiting fields adjacent to the colony, but nonetheless were included here as "trips". In total, 3404 trips across all birds (those tagged in 2010 and in 2011) were recorded, and these are summarised in Table 6.

For offshore and offshore/inshore trips during breeding, gulls had an offshore foraging range of up to 91 km (mean 38 km) and travelled up to a total cumulative distance per trip of 360.56 km (mean 113.23±68.69 km), lasting up to 28.98 hours (mean 6.99±6.07 hours). Thereafter, gulls had a maximum offshore range of 124.04 km (mean 37.13±22.86 km) with up to 1432.00 km distance travelled cumulatively (mean 133.72±153.00 km), up to 277 hours (mean 13.95±31.72 hours).

For gulls tagged in 2010 and recorded again in 2011, the maximum offshore foraging range in 2011 was 92.97 km (mean 21.61±9.97 km), travelling a total distance of up to 310.84 km (mean 60.27±33.52 km), lasting up to 43.73 hours (mean 5.17±4.34 hours) (Table 6).

3.1.1.1. Annual Variation

Although in both 2010 and 2011, the majority of trips were inshore or coastal (2010: 80.3%; 2011: 87.5%) the frequency of trips containing a marine component was significantly greater in 2010 than in 2011 (2010: 18.5%; 2011: 10.1%), (GLMM, bird identity as random factor: LRT = 4.057, df = 1, P = 0.044), suggesting a slightly more marine focus during 2010 overall. However, during periods of likely breeding, there was no difference (LRT = 1.334, df = 1, P = 0.248). Similarly, the time spent on trips that contained a marine component across the whole season (breeding and unknown status), was significantly greater in 2010 than 2011 (GLMM, proportional time arcsine transformed, LRT = 5.999, df = 1, P = 0.014; β = -0.340±0.140). However, when only focusing on time during breeding, there was again no difference between years (LRT = 0.072, df = 1, P = 0.788).

During breeding (data mostly up to 1 July in 2010 and 9 July in 2011), birds ventured offshore as the season progressed (Julian date: LRT = 5.979, P = 0.015; β = 0.012 ± 0.005), but there was no significance difference between years in the foraging range by birds offshore (GLMM testing year, accounting for Julian date; LRT = 1.782, df = 1, P = 0.182; means: 2010: 38.47±34.30 km, 2011: 34.60±21.24km, n = 1994 trips for 19 birds). However, pooling all data across the season (n = 3825 trips for 22 birds) a greater distance was reached overall during 2010 than 2011 (39.89±31.33 km, and 31.30±21.32km respectively; LRT = 13.185, df = 1, P < 0.001).

Trips increased in duration throughout the season through both breeding periods (LRT = 4.590, df = 1, P = 0.032; β = 0.0098 ± 0.0045) and for all data including periods of uncertain breeding status (LRT = 11.041, df = 1, P < 0.001; β = 0.010 ± 0.003). After accounting for this effect, trips with a marine component were slightly longer in 2010 than 2011 during breeding (9.94±12.82 hrs and 7.21±6.07 hrs respectively), however this difference was not significant (LRT = 0.231, df = 1, P = 0.631). Similarly there was no difference in trip durations between years for all data combined (LRT = 0.269, df = 1, P = 0.604; 2010: 9.63±10.73 hrs; 2011: 10.63±23.83 hrs).

Focusing just on those birds tagged in 2010 and comparing to 2011 (birds 334, 391, 395, 407), trips by these birds were significantly greater in foraging range in 2010 than in 2011 (LRT = 7.845, df = 1, P = 0.005), being twice as far offshore (2010, 41.06±34.58 km, 2011, 21.64±19.76 km) however these trips, that contained a marine component, were not longer in duration between years (LRT = 0.289, df = 1, P = 0.591).

3.1.2 Great Skua

3.1.2.1 Hoy

A total of 552 offshore trips were recorded at Hoy in 2011, of which 396 were during periods when birds had eggs and chicks, while the remaining 156 encompassed post-breeding movements or those of failed breeders. During breeding, Great Skuas at Hoy had a maximum foraging range of 138.26 km (mean 22.83±26.18 km) up to 521.64 km travelled per trip (average 57.52±70.81 km), lasting up to 64.31 hours (mean 3.67±5.03 hours). Trip statistics and foraging behaviour for Hoy are subject to further investigation.

3.1.2.2 Foula

During 2011, we recorded a total of 839 offshore trips during breeding, of which 93 were during confirmed incubation and 252 during confirmed chick-rearing phases. Similar to 2010, Great Skuas from Foula in 2011 also foraged predominantly north and west of the colony (see Fig. 5), often reaching the offshore continental shelf mid-way between Shetland and the Faroe Islands. During incubation in 2011, Great Skuas had a maximum foraging range of 180.30 km (mean 68.54±43.40 km), travelling up to 463.30 km total distance per trip (mean 164.43±105.61 km), and lasting up to 102.80 hours (mean 9.79±11.46 hours). Although only four birds were tagged in 2010, after accounting for Julian date, trips were significantly longer in duration in 2011 than 2010 during incubation (LRT = 3.824, df = 1, P=0.05; β = 0.690±0.340). The same was also true for foraging range (LRT = 5.282, df = 1, P=0.022; β = 2.665±1.125) and total distance travelled (LRT = 5.792, df = 1, P=0.016; β = 4.320±1.721). During chick-rearing in 2011, birds had a maximum foraging range of 264.70 km (mean 62.99±45.94 km), travelling up to 786.80 km total distance per trip (mean 148.98±119.90 km), lasting up to 51.46 hours, (mean 6.47±6.65 hours). Hence, trips during chick rearing were slightly shorter in distance and duration than during incubation. Failed breeders from Foula had a maximum foraging range of 357.80 km from the colony (mean 50.25±67.66 km offshore), and travelled up to 2233.00 km per trip (mean 142.89±247.94 km). During such trips, birds were not constrained to returning to the colony, and so were away for much longer time periods, up to 273.10 hours (mean 14.00±29.48 hours) (Table 7).

Table 6 Descriptive trip statistics for Lesser Black-backed Gulls at Orford Ness in 2011 for trips with an offshore component. Mean here denotes the mean maximum of all trips; foraging range is the distance from the colony for the offshore component of the trip; distance travelled and trip duration often encompassed parts of trips that ventured inland (see methods).

Stage	Year birds tagged	Bird	No. trips	Foraging range (km)		Distance travelled (km)		Trip duration (hrs)	
				Max	Mean+SD	Max	Mean+SD	Max	Mean±SD
All	2010	334	11	74.41	44.08±24.73	1432	523.62±385.86	277.1	115.13±75.53
		391	4	19.51	10.4±8.37	44.08	25±18.74	1.65	1.3±0.42
		395	6	36.34	24.94±9.55	87.81	64.1±22.79	7.7	4.34±2.12
		407	25	92.97	29.49±27.05	310.84	91.71±89.06	43.73	9.86±11.47
	2011	459	24	90.9	32.84±17.89	301.34	101.94±65.36	13.39	5.2±2.97
		460	18	39.66	25.07±8.29	133.43	77.77±23.44	15.98	10.22±2.99
		478	13	72.6	42.01±18.31	360.56	168.82±102.69	28.98	16.52±8.77
		479	26	80.16	40.38±20.21	266.25	112.64±61.22	12.53	5.9±3.55
		480	3	39.16	26.77±13.42	97.68	64.56±31.29	3.71	2.58±1.18
		481	9	49.8	26.49±12.08	128.05	76±30.06	5.59	3.12±1.3
		482	47	80.05	40.28±20.92	366.09	112.4±74.56	18.12	5.55±3.95
		483	10	21.97	12.07±5.48	50.13	27.84±10.8	2.87	1.57±0.58
		485	5	46.71	33.83±8.12	165.91	94.45±43.97	31.89	9.01±12.83
		486	52	90.18	44.78±14.89	328.16	133.76±60.42	26.82	8.08±5.42
		492	4	51.42	27.9±14.07	129.98	95.67±29.93	20.93	9.29±7.97
		493	79	124.04	43.84±21.31	416.24	125±79.17	26.25	7.5±5.59
		all	***336***	***124.04***	***37.66±20.33***	***1432***	***123.9±122.51***	***277.1***	***10.8±24.04***
Breeding	2011	459	15	90.9	35.49±19.6	301.34	103.25±64.01	10.41	5.25±2.63
		478	13	72.6	42.01±18.31	360.56	168.82±102.69	28.98	16.52±8.77
		479	12	68.56	34.09±19.2	206.24	97.69±57.98	10.58	5.06±3.1
		480	2	28.62	20.57±11.39	60.52	48±17.7	2.67	2.02±0.92
		481	9	49.8	26.49±12.87	128.05	76±30.06	5.59	3.12±1.3
		482	6	37.26	24.53±10.9	102.77	65.48±35.28	4.09	2.75±1.24
		483	6	21.97	10.96±6.18	50.13	26.12±12.45	2.87	1.55±0.68
		485	3	35.58	30.62±5.31	108.07	78.99±25.3	4.99	3.61±1.2
		486	51	90.18	45.04±14.91	328.16	133.74±61.02	26.82	8.03±5.46
		492	1	18	18±NA	56.98	56.98±NA	2.84	2.84±NA
		493	34	87.57	42.18±19.52	269.66	113.28±64.39	24.29	6.67±5.67
		all	***152***	***90.9***	***38.3±18.26***	***360.56***	***113.23±68.69***	***28.98***	***6.99±6.07***
Other	2011	459	9	45.21	28.42±11.78	274.37	99.77±71.44	13.39	5.12±3.65
		479	14	80.16	45.77±20.14	266.25	125.44±63.09	12.53	6.63±3.85
		480	1	39.16	39.16±NA	97.68	97.68±NA	3.71	3.71±NA
		482	41	80.05	42.58±21.2	366.09	119.27±76.54	18.12	5.96±4.05
		483	4	20.74	13.72±4.69	42.82	30.42±8.79	2.07	1.58±0.48
		485	2	46.71	38.64±11.42	165.91	117.63±68.28	31.89	17.12±20.89
		486	1	31.58	31.58±NA	134.94	134.94±NA	10.27	10.27±NA
		492	3	51.42	31.2±18.91	129.98	108.56±18.59	20.93	11.44±8.22
		493	45	124.04	45.09±22.34	416.24	133.86±88.41	26.25	8.14±5.51
		all	120	***124.04***	***37.13±22.86***	***1432***	***132.72±153***	***277.1***	***13.95±31.72***

Table 7 Descriptive trip statistics for Great Skuas for marine trips at Foula during 2011. Mean here denotes the mean maximum of all trips.

		No.	Foraging range (km)		Distance travelled (km)		Trip duration (hrs)	
Stage	**Bird**	**trips**	**Max**	**Mean±SD**	**Max**	**Mean±SD**	**Max**	**Mean±SD**
Incubation	415	1	71.51	71.51	168.4	168.43	13.95	13.95
	418	4	89.12	58.48±28.71	210.3	129.41±68.45	13.31	5.93±5.08
	419	6	132.5	75.21±35.6	347.3	203.46±90.63	30.07	11.87±9.4
	450	19	174.8	73.51±49.65	463.3	181.5±125.98	102.8	14.1±22.22
	451	12	86.36	26.94±24.55	197.8	71.84±60.09	9.13	4.66±2.62
	454	8	152.2	83.85±42.5	336.6	194.69±93.48	17.36	9.03±5.27
	465	17	180.3	86.83±42.77	412	195.61±98.87	23.78	10.6±5.48
	470	12	160.1	95.42±33.44	411.3	228.59±89.97	28.59	12.4±7.38
	476	11	107.2	42.66±31.9	307.1	103.92±89.88	13.44	5.82±4.13
	487	3	81.46	45.44±31.26	185.5	101.97±72.33	6.46	4.14±2.11
	all	***93***	***180.30***	***68.54±43.40***	***463.3***	***164.43±105.61***	***102.8***	***9.79±11.46***
Chick	418	1	61.49	61.49	128.8	128.82	7.15	7.15
	419	15	264.7	88.02±68.67	786.8	247.58±202.41	51.46	16.41±14.58
	450	12	177.8	65.19±49.91	559.6	173.16±160.22	27.01	6.78±7.09
	451	36	95.15	30.22±19.63	238.8	71.71±48.26	9.16	2.82±1.67
	454	31	159.6	72.86±46.23	477.4	182.17±127.05	36.05	7.67±7.08
	465	27	149	64.56±42.94	351	144.72±99.58	14.59	5.98±4.08
	470	27	192.3	95.37±45.81	488.4	220.64±120.06	24.92	9.08±5.88
	476	61	162.6	49.56±33.92	397.4	111.36±81.55	17.38	4.05±3.14
	487	45	169.3	71.35±47.62	468.5	159.61±113.34	30.85	7.17±6.01
	all	***255***	***264.7***	***62.99±45.94***	***786.8***	***148.98±119.9***	***51.46***	***6.47±6.65***
Fail	415	7	357.8	186.7±103.25	2233	854.42±741.66	273.1	114.11±104.16
	418	51	245.5	58.01±64.79	761.3	140.22±163.1	54.58	8.67±10.47
	419	55	248.6	26.67±42.71	709.6	77.59±129.97	93.5	12.46±17.07
	450	49	294.4	46.93±71.58	837.5	122.18±191.26	71.96	10.88±15.42
	487	50	294.2	52.43±61.08	1084	138.13±195.44	85.6	10.17±16.1
	all	***212***	***357.8***	***50.25±67.66***	***2233***	***142.89±247.94***	***273.1***	***14±29.48***
Unknown status	451	21	425.1	63.15±112.4	1302	173.34±351.96	139.5	14.98±33.99
	454	79	274.7	38.39±56.57	764.3	102.94±161.26	65.93	9.61±12.57
	465	79	311.4	56.88±63.46	846.6	134.44±157.7	98.68	11.48±16.96
	470	32	319	60.99±78.96	1104	173.49±256.22	111.1	14.83±24.48
	476	86	211.6	32.22±35.35	574.4	73.34±86.82	68.99	5.42±8.79
	all	***297***	***425.1***	***45.71±62.59***	***1302***	***115.33±179.08***	***139.5***	***9.84±17.07***

3.2 Connectivity with the areas of proposed and consented wind farms

3.2.1 Lesser Black-backed Gull

3.2.1.1 2011 breeding season

During breeding (up to 9 July 2011), nine out the 14 Lesser Black-backed Gulls tagged in 2011 showed overlaps with offshore wind farms. Of these nine birds, all showed connectivity with the large Round 3 East Anglia zone, five showed connectivity with Galloper extension, and three showed connectivity with the Greater Gabbard Round 2 development (Fig. 3).

After 9 July 2011, eight out 12 Lesser Black-backed Gulls tagged in 2011, for which we had data beyond this date demonstrated connectivity. Only two birds (tag numbers 483 and 484) showed no connectivity throughout the season, and three further birds (tags 492, 460 and 457) showed no connectivity before 9 July 2011. There was very little data for tag 457 to assess connectivity, as this disconnected from the system on 8 June 2011. For seven of the eight individuals exhibiting connectivity after 9 July 2011, this was with East Anglia Round 3, while four showed connectivity with Galloper extension, and four with Greater Gabbard Round 2 (Fig. 3).

Five of the eleven birds tagged in 2010 returned to Orford Ness to breed in 2011 with their tags transmitting. Another individual from 2010 (tag 388) survived until mid-May 2011 when it died after getting tangled in a fishing net. This bird had apparently decided not to return to breed in 2011, and was near Nouakchott, Mauritania at the time of its death. Its tag was recovered and returned, and the data extracted. The tag of bird 336 apparently malfunctioned not long after this individual's return to Orford Ness, and tag number 334 may have stopped working too. This bird's last contact date (29 June 2011) was not late if its breeding attempt failed and it left the area, which is not unlikely considering that this bird's nest would have been repeatedly destroyed as it was trying to breed on Sizewell Nuclear Power Station. Birds with tags 407, 395 and 391 were likely to have bred in 2011, based on GPS activity at the colony.

Of these birds tagged in 2010, two out of five recorded showed some connectivity with wind farm zones between April and August 2011. Both these individuals interacted with the East Anglia Round 3 zone and the Galloper extension, and one with Greater Gabbard Round 2.

3.2.1.2 Migration

Three of the six Lesser Black-backed Gulls tagged in 2010, for which we obtained data during migration, crossed the sites of existing or proposed wind farms on migration (Fig. 4a). These sites included the Eneco Round 3 development in the English Channel and London Array 1 and 2 for birds on outward migration, and Eneco Round 3 again on the return journey. Regardless of whether birds crossed sites, every individual flew close to wind farm zones at some point during their migration, including the Southern Array Round 3 zone in the English Channel and Gunfleet Sands and Kentish Flats in the North Sea. 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 (Fig. 4b), future offshore developments by these countries could potentially affect this species.

Of the tags fitted in 2011, it is possible that some failed before the end of the breeding season and therefore will be unable to provide future migration data. Tag 457 in particular only transmitted until 8 June 2011, at which time even birds whose eggs had failed might have attempted to re-lay (Ross-Smith, personal observations). It is therefore likely that the bird bearing tag 457 remained in the colony after 8 June 2011 with a broken tag, and no further data will be received on this individual's movements.

Figure 3 Plot of all Orford Ness data for birds tagged in 2011 for (a) likely breeding, (b) other movements during 2011 (c) all movements of birds tagged in 2011, (d) all movements in 2011 of birds tagged the year before. Blue = Round 3; orange = Rounds 1 and 2; grey = extensions.

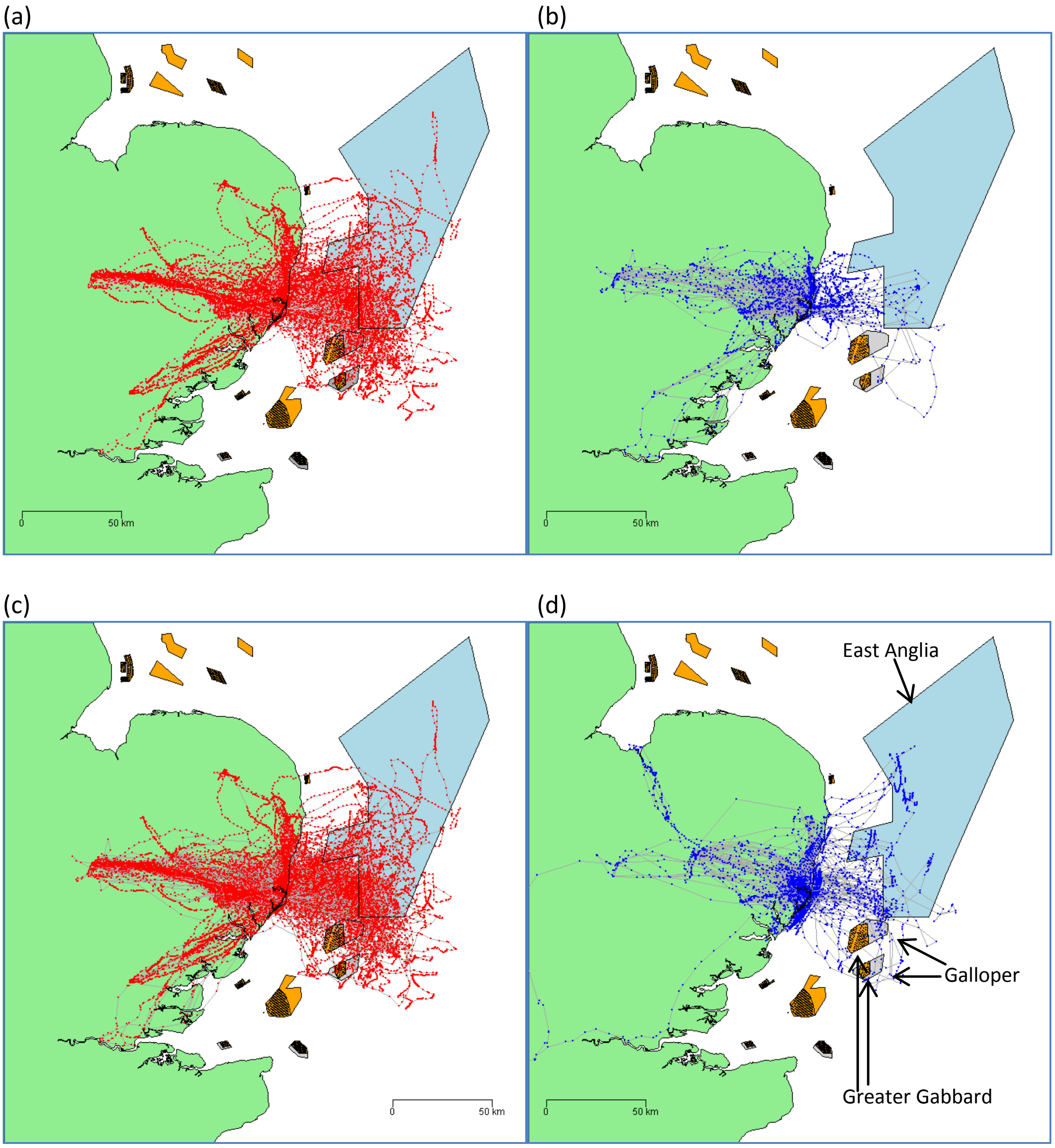
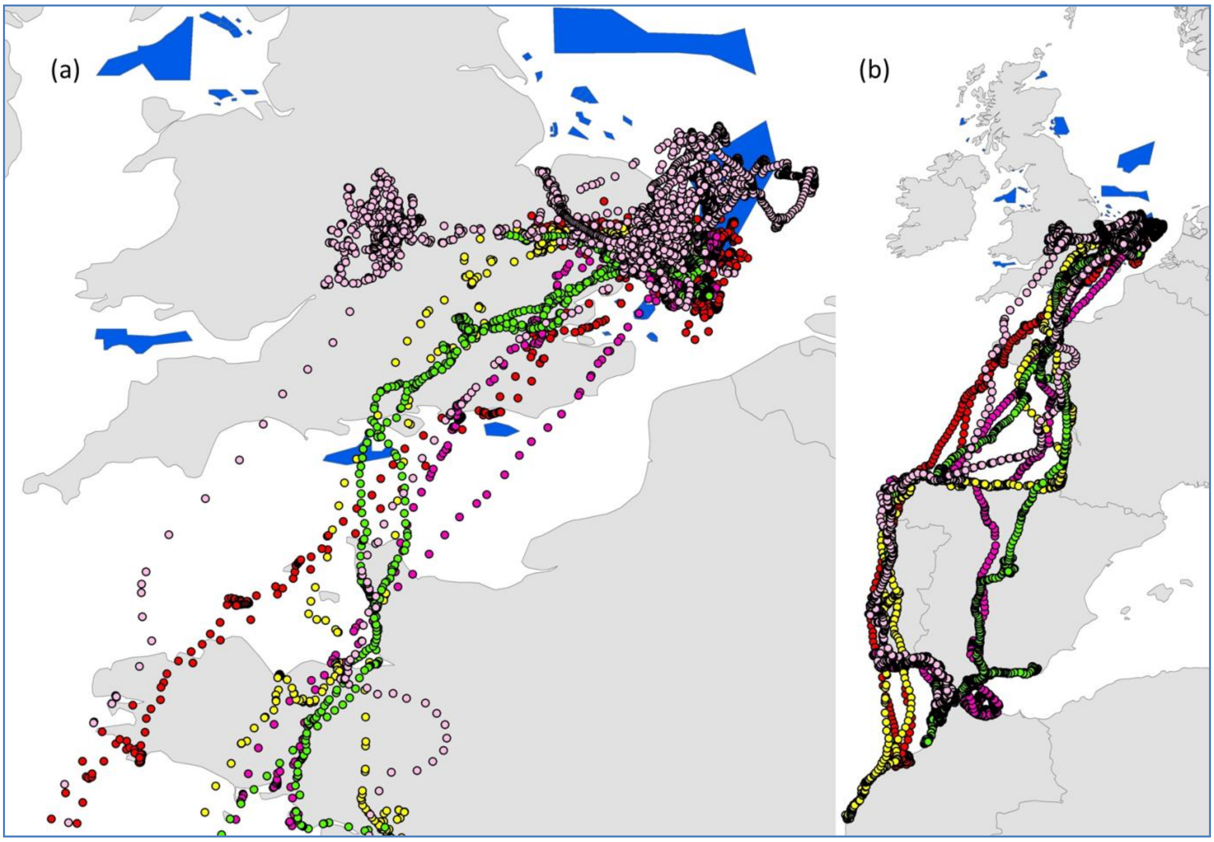


Figure 4 Flight paths of tagged Lesser Black-backed Gulls (a) leaving and returning to Orford Ness on migration between July 2010 and April 2011, and (b) their movements throughout migration and overwinter. Tracks of different individuals are shown in different colours, and UK offshore developments are shown in blue.



3.2.2 Great Skua

3.2.2.1 Foula

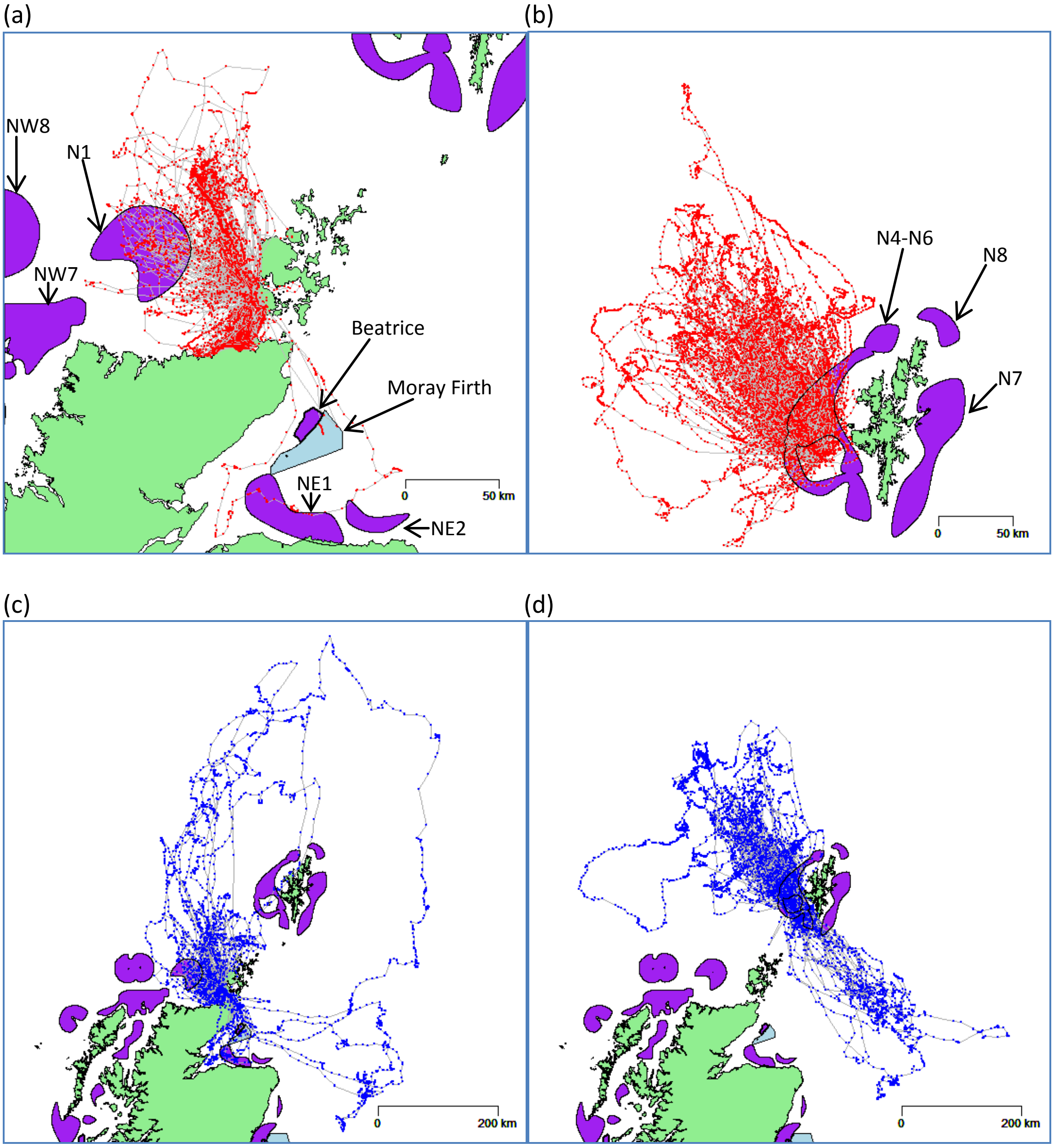
Prior to 15 July 2011, Great Skuas at Foula showed no overlaps with any Round 1, 2, 3, extensions, or Scottish Territorial Waters (STW) short-term zones. However, during this phase, all 10 birds made trips that connected with the N4-N6 STW Medium Term Option zone close to Foula (Fig. 5).

A greater area coverage by failed breeders and birds with uncertain status than breeding birds, meant that all five Great Skuas that lost eggs or chicks overlapped with N4-N6 STW zone and three birds also overlapped with the N7 STW medium-term zone. The remaining five birds all overlapped with N4-N6 after 15 July 2011, while two overlapped with N7 (Fig. 5).

3.2.2.2 Hoy

During breeding two birds did not overlap with any zones at all, while for one bird (392) no data were downloaded. Of the remaining seven birds, six had connectivity to the STW medium-term zone N1, and one bird (409) overlapped with NE1, NE2, and the Moray Firth Round 3 zone (Fig. 5). For failed individuals at Hoy, there were adequate data for seven birds during this period, three of which showed no connectivity with any zones, three showed connectivity with N1, two with N4-N6, one with NE1, one with N8, and then two birds both showed connectivity with the Moray Firth R3 zone and the Beatrice Scottish short-term zone (Fig. 5).

Figure 5 Movements of Great Skuas in 2011 from (a) Hoy during breeding, (b) Foula during breeding, (c) Hoy during post-breeding, and (d) Foula during post-breeding; wind farm zones are shown as purple for new Scottish medium term zone, and one short-term Zone Beatrice in the Moray Firth, and blue for the Round 3 Moray Firth Zone



3.2.2.3 Migration

All tags deployed on Great Skuas in 2010 failed before the onset of migration, so no data are yet available for this species' movements outside the breeding season. We hope this will be rectified over forthcoming months when birds tagged in 2011 return to Foula and Hoy for the 2012 breeding season.

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 offshore wind farms are presented for each individual bird (kernel analysis for GPS locations of individual birds), as well as a total "population" kernel analysis (all GPS points of all birds).

3.3.1 Lesser Black-backed Gull

During breeding for birds tagged in 2011, Lesser Black-backed Gulls showed up to 32% overlap of the 95% kernel for all data with the East Anglia R3 zone (26% "foraging" overlap), and 20% overlap of the 50% KDE (25% "foraging") (Table 8, Fig. 6). However, for all birds combined, the 95% KDE showed an overlap of 16% for all birds (14% "foraging"), with no core 50% KDE overlap at all. During breeding, birds showed overlaps to a lesser degree with the Galloper extension and the Greater Gabbard Round 2 zone, with less than 2% overlaps of the 95% KDEs for all data and foraging.

For other data (after 9 July), movements were similar, albeit less offshore and with considerably less overlap with the same three wind farm zones described above during breeding (e.g. less than 2% overlap of the 95% KDE for all birds with the East Anglian Round 3 zone).

3.3.2 Great Skua

3.3.2.1 Foula

Table 9 shows the percentage overlaps of individual and total Great Skua kernels with offshore wind farm zones. For the 10 Great Skuas during breeding (up to 15 July), overlaps were recorded with the N4-N6 STW medium term option only. The maximum overlaps of any individual bird with this zone during this period was 37% of the all data 95% KDE (36% "foraging" overlap), and 58% of the all data 50% KDE (51% "foraging" overlap). The total kernel showed a 9% KDE overlap for the 95% KDE for all data (9% "foraging"), and a 31% overlap for the 50% KDE for all data (22% "foraging") (Table 9).

After 15 July, failed breeders (birds that had lost eggs or chicks) showed a population level overlap with the N4-N6 STW short term option of 6% for the 95% KDE for all data and foraging, and a 32% overlap for the 50% KDE for all data (27% foraging). Birds of unknown status showed similar area usage and overlap (Table 9, Fig. 7). Three failed breeders (birds 419, 450, and 487) also showed overlap with the N7 STW zone. Although bird 487 showed overlap of up to 11% of the 95% KDE for total and foraging area usage with this zone, the overall bird kernel showed less than 1% overlap. A similar situation was seen for birds of unknown status, with bird 454 showing the greatest overlaps with the N7 STW short term option. However, the overall bird kernel still showed an overlap of less than 1% (Table 9).

3.3.2.2 Hoy

Table 9 shows the percentage overlaps of individual and total bird kernels with offshore wind farm zones. During breeding, the greatest overlaps were seen with the N1 STW short-term option zone with a 31% overlap of the 95% KDE using all data (46% "foraging" overlap) with this zone and a 51% overlap of the 50% KDE using all data (70% "foraging" overlap) (Table 9, Fig. 8). However, the all bird kernel revealed a slightly different picture with 12% overlap for the all data 95% KDE (9% "foraging" overlap), and a 1% overlap for the 50% KDE for all data (1% "foraging" overlap). Overlaps to a much lesser degree were seen with NE1 and NE2 STW short-term option zones but this was driven by only one bird (409). Bird 471 had no overlaps during breeding with any zones.

Post-breeding (failed / fledged) birds made wider movements bringing them into contact with the Moray Firth and Beatrice Round 3 and Scottish short-term zones – seen for birds 409 and 473 (Table 9, Fig. 8). However, overlaps of the 95% and 50% KDEs for both all data and foraging were less than 1% for both these zones. Further overlaps were seen for N1, NE1, NE2, and N4-N6 (Table 9) driven by a maximum of three birds in any case, and showing less than 6% overlap of any population level KDE with these zones. Three birds (420, 467, and 471) showed no overlaps with any zone during post-breeding movements.

Figure 6 Distribution of area use for Lesser Black-backed Gulls tagged in 2011 for all foraging trips around Orford Ness for all birds (a) during breeding on a 600 s rate; (b) during breeding on a 600 s rate representing foraging and resting locations (< 4 $m.s^{-1}$); (c) during post-breeding filtered to a 1800 s rate; and (d) during post-breeding filtered to a 1800 s rate representing foraging and resting locations (< 4 $m.s^{-1}$). Rounds 1 and 2 = orange shapes, Round 3 = purple, extensions = dark grey; 95% KDE = blue; 75% KDE = yellow; 50% KDE = red.

(a) (b)

(c) (d)

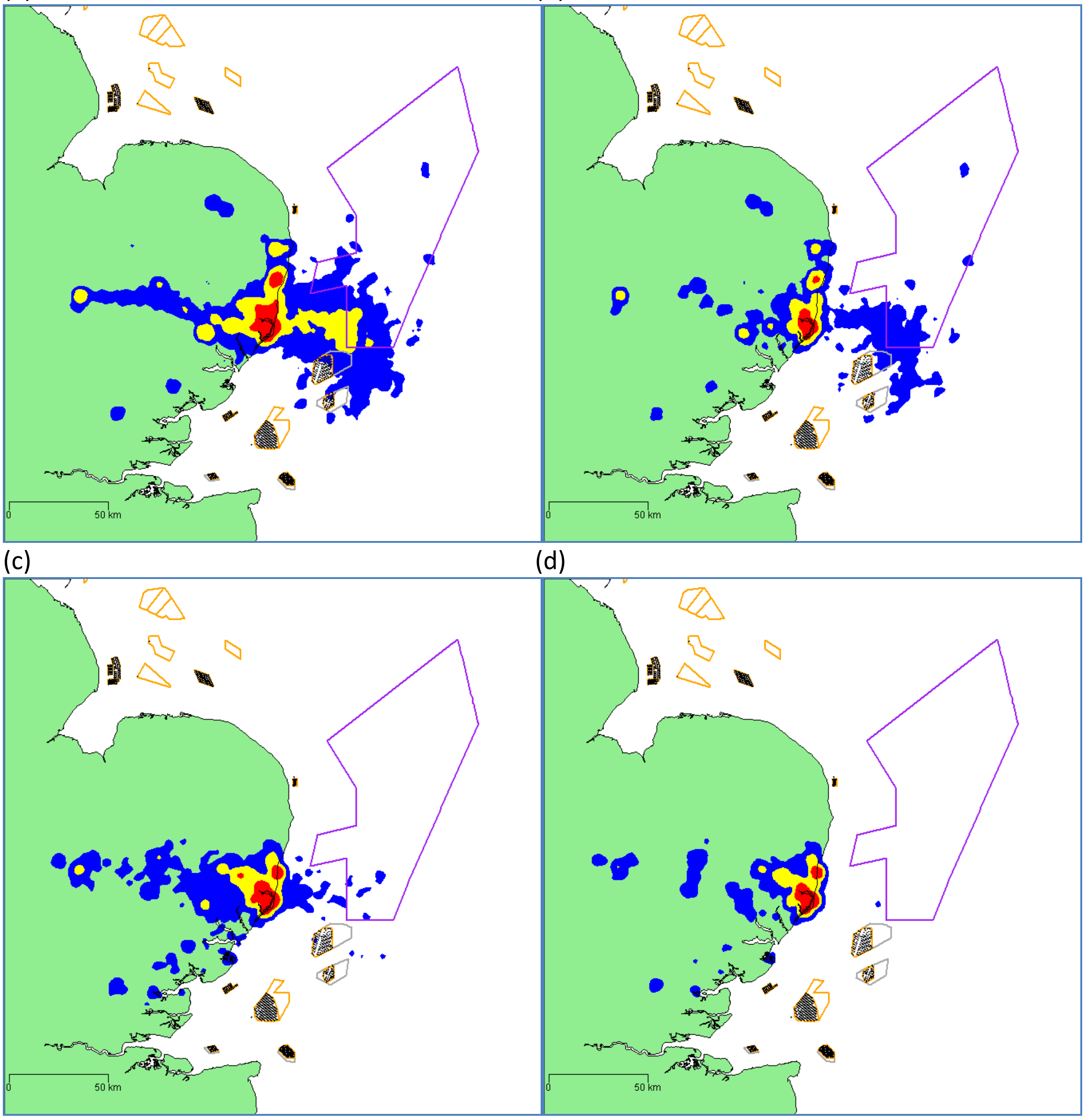


Table 8 Overlap analysis of "individual bird" and "all bird" kernels (pooled analysis) with wind farms (WF) for individual Lesser Black-backed Gulls for Orford Ness for (a) data up to 9 July 2011 (likely breeding), and (b) for data post 9 July 2011 (post-breeding) on a 600 s rate, and using a 1800 s rate. "R123" here used as shorthand for Rounds 1, 2, 3, extensions, and Scottish short-term options; only those wind farms listed are those with interactions recorded.

(a)			KDE overlap (%)			KDE foraging overlap (%)		
Stage	**WF name**	**Bird**	**50**	**75**	**95**	**50**	**75**	**95**
Breeding	East Anglia	459			10.99			
		478		3.12	6.31		2.37	4.74
		479		23.36	16.24			26.03
		480			0.49			
		482	16.10	17.17	25.67		8.24	23.85
		485			1.03			
		486	19.35	12.26	14.93	19.25	18.74	16.06
		492			2.79			
		493	20.16	28.50	32.91	25.32	29.52	25.98
		All bird		***9.09***	***15.77***			***13.81***
	Galloper extension	459			0.23			
		478			0.18			
		479		0.02	3.74			5.70
		482		1.10	2.72			0.73
		486	5.56	4.68	2.94	0.07	3.99	2.94
		493		1.99	1.82		1.36	2.44
		All bird			***1.89***			***1.97***
	Greater Gabbard	479			0.20			
		482			1.67			0.04
		486		0.24	2.76		<0.01	1.17
		493			0.47			0.15
		All bird			***0.60***			
	no overlap: 457, 460, 481, 483, 484							

(b)			KDE overlap (%)			KDE foraging overlap (%)		
Stage	**WF name**	**Bird**	**50**	**75**	**95**	**50**	**75**	**95**
Other data	East Anglia	482		0.59	17.30			8.82
		493			6.31			3.32
		All bird			***1.84***			
	Galloper extension	482			1.89			0.08
		All bird			***0.11***			
	Greater Gabbard	482			2.21			2.63
		All bird			***0.12***			
	no overlap: 459, 460, 479, 480, 481, 483, 484, 485, 486							
	no data past 9 July: 457, 492, 478							

Figure 7 Distribution of area use of Great Skuas (using LSCV) for all foraging trips around Foula for all birds (a) during breeding on a 600s rate (h = 2636 m); (b) during breeding on a 600 s rate representing foraging and resting locations (< 4 $m.s^{-1}$) (h = 2566 m); (c) during post-breeding filtered to a 1800 s rate (h = 3394 m); and (d) during post-breeding filtered to a 1800 s rate representing foraging and resting locations (< 4 $m.s^{-1}$) (h = 3741 m). Also shown are Scottish medium term development areas (light blue) and Round 3 zones and extensions (orange); 95% KDE = blue; 75% KDE = yellow; 50% KDE = red.

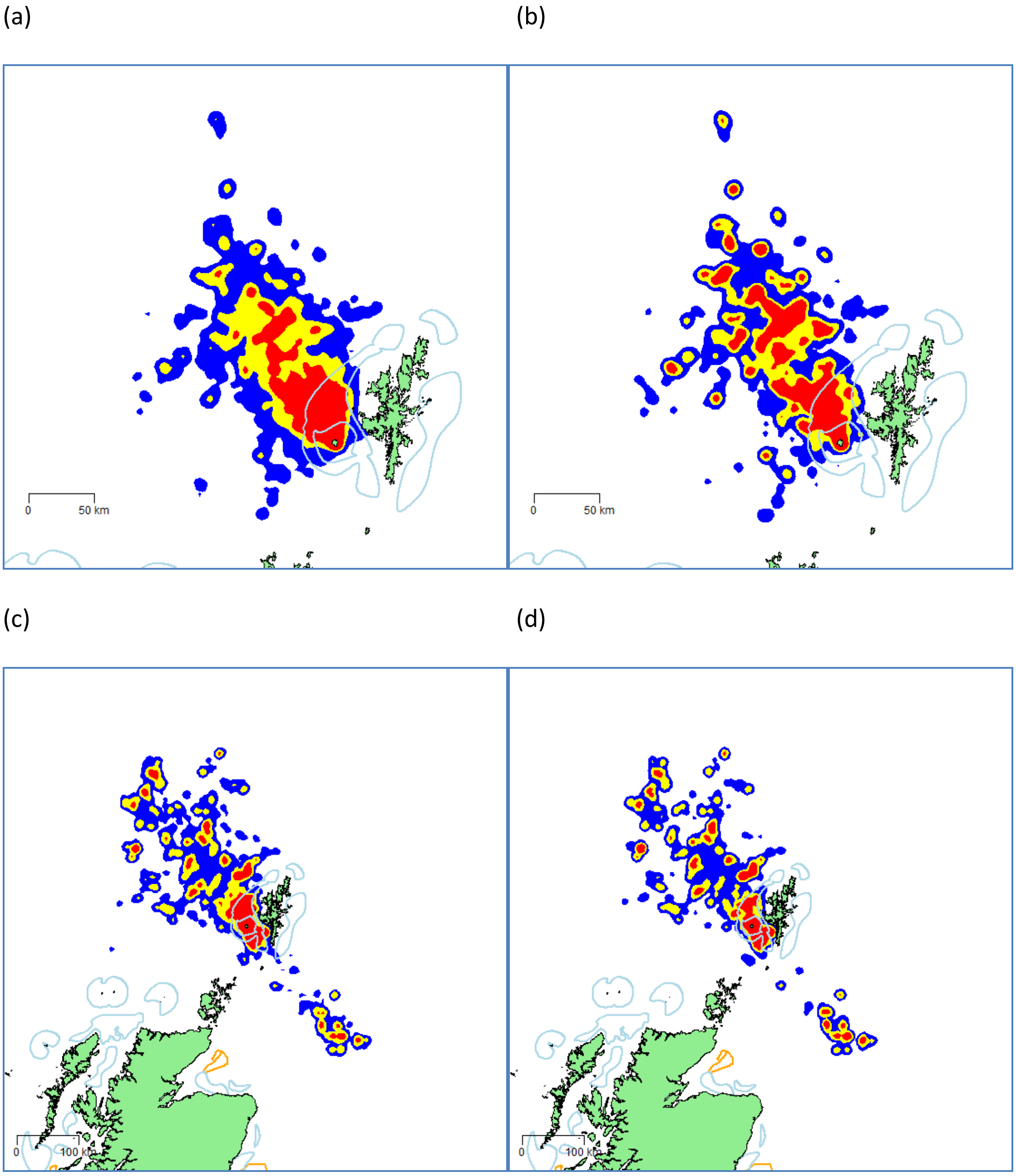
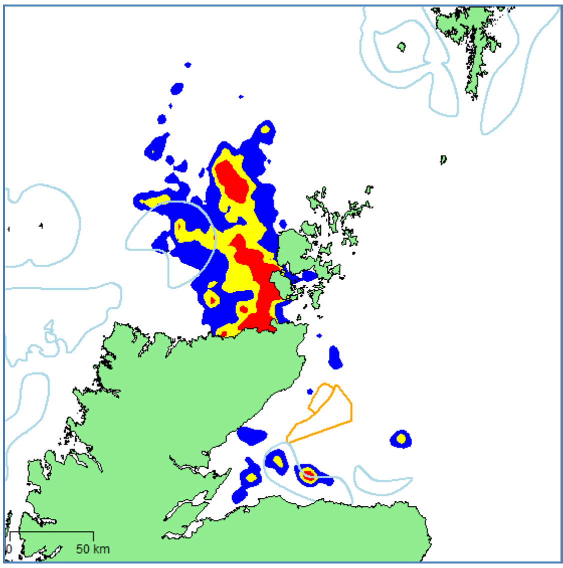
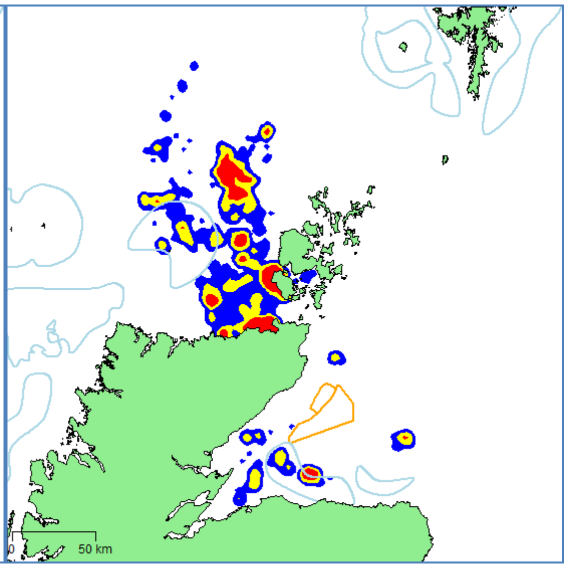


Figure 8 Distribution of area use of Great Skuas (using LSCV) for all foraging trips around Hoy for all birds (a) during breeding on a 600 s rate (h = 1923 m); (b) during breeding on a 600 s rate representing foraging and resting locations (< 4 m.s^{-1}) (h = 1814 m); (c) during post-breeding filtered to a 1800 s rate (h = 5563 m); and (d) during post-breeding filtered to a 1800 s rate representing foraging and resting locations (< 4 m.s^{-1}) (h = 5954 m). Also shown are Scottish medium term development areas (light blue) and Round 3 zones and extensions (orange); 95% KDE = blue; 75% KDE = yellow; 50% KDE = red.

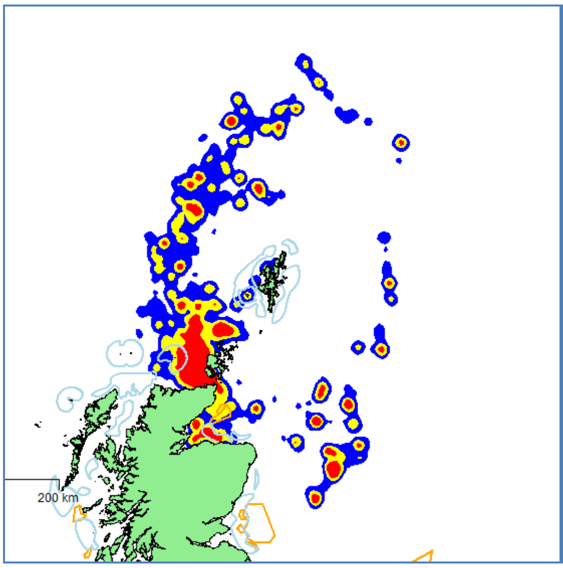
(a)



(b)



(c)



(d)

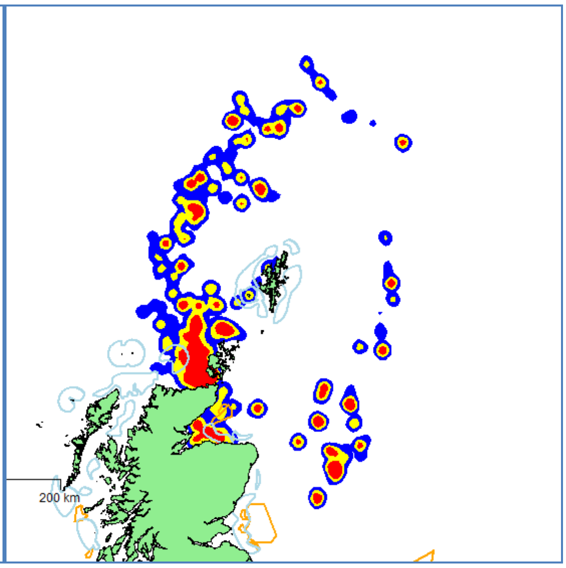


Table 9 Overlap analysis of all bird kernels with wind farms for individual Great Skuas for (a) Foula and (b) Hoy during breeding on 600 s rate, and post-breeding using an 1800 s rate.

(a)			KDE overlap (%)			KDE foraging overlap (%)		
Stage	**WF name**	**Bird**	**50**	**75**	**95**	**50**	**75**	**95**
Breeding	N4-N6	418	30.47	32.85	30.85		20.33	30.57
		419	25.83	19.54	16.68	8.71	13.05	13.63
		450	29.07	18.54	11.95	29.22	22.78	16.99
		451	58.15	52.52	37.01	51.34	47.22	35.71
		454	29.84	23.27	13.48	18.75	18.88	14.17
		465	15.23	14.29	10.88	5.44	7.15	9.40
		470	24.48	17.08	11.67	1.28	2.16	6.68
		476	51.65	31.80	17.03	37.33	31.48	20.70
		487	25.75	18.84	15.30	11.03	13.76	12.33
		All bird	***30.63***	***16.48***	***9.49***	***22.38***	***15.21***	***9.18***
Failed breeding	N4-N6	415		0.04	2.39			0.74
		418	21.09	21.69	14.60	2.03	18.06	17.95
		419	27.31	38.71	30.68	26.37	38.10	31.99
		450	14.14	18.01	11.41	3.03	9.16	13.74
		All bird	***32.34***	***13.54***	***6.00***	***27.45***	***14.21***	***6.37***
Unknown		451	12.17	13.67	9.79	8.57	10.77	9.97
		454	18.22	30.86	16.07	12.18	20.38	17.79
		465	11.63	13.46	11.21	1.92	4.93	10.73
		470	17.87	16.19	9.60	8.69	14.83	12.22
		476	40.08	40.13	26.12	33.57	37.73	29.37
		All bird	***35.50***	***14.85***	***6.23***	***32.23***	***15.48***	***6.97***
Failed breeding	N7	415						
		418						
		419			0.10			
		450			0.63			0.39
		487	28.19	17.39	11.42	7.82	17.73	10.99
		All bird	***0.00***	***0.00***	***0.08***	***0.00***	***0.00***	***0.07***
Unknown		451						0.02
		454	1.59	1.41	0.75	0.00	1.72	1.12
		465			0.02			0.03
		470			0.02			
		476			0.94			
		All bird	***0.01***	***0.42***	***0.43***	***0.00***	***0.36***	***0.33***

Table 9 cont.

(b)			KDE overlap (%)			KDE foraging overlap (%)		
Stage	WF name	Bird	50	75	95	50	75	95
Breeding	N1	400	51.28	40.95	30.59	70.17	60.01	46.37
		420	3.75	3.26	5.66	3.19	3.15	2.67
		448	0.97	1.71	2.89		4.42	7.98
		467		1.89	11.44			2.62
		473	20.45	24.28	28.89	32.91	30.93	29.31
		475	19.56	23.32	24.32	50.39	42.87	33.86
		All bird	***0.54***	***6.93***	***12.25***	***1.47***	***5.34***	***9.28***
	NE1	409	19.62	15.70	11.11	24.23	19.06	15.31
		All bird	***0.89***	***1.44***	***2.96***	***4.28***	***3.91***	***2.71***
	NE2	409			0.39			
		All bird			***0.05***			
	No overlap:	471						
Post-Breeding (failed / fledged)	Beatrice Scottish	409		1.42	1.17	0.61	0.65	0.86
		473		0.07	0.20		0.11	0.25
		All bird		***0.40***	***0.15***		***0.25***	***0.18***
	Moray Firth R3	409		3.12	4.97		0.84	3.94
		473		0.48	0.50			0.58
		All bird		***0.91***	***0.60***		***0.25***	***0.68***
	N1	400	1.43	1.87	2.49		0.67	1.67
		448	5.53	6.29	6.35	6.36	6.88	6.80
		473	2.01	3.21	2.21	0.02	2.00	1.60
		All bird	***5.54***	***3.66***	***1.92***	***3.28***	***3.39***	***1.91***
	N4-N6	448		0.23	0.52	0.05	0.49	0.58
		473		0.03	0.38			0.35
		All bird		***0.09***	***0.40***		***0.14***	***0.32***
	NE1	409	27.00	16.13	10.48	33.03	22.03	15.37
		All bird	***4.46***	***2.47***	***1.04***	***5.22***	***2.77***	***1.27***
	NE2	409						0.06
		All bird			***0.06***			***0.06***
	No overlap	420						
		467						
		471						

3.4 Time budgets

3.4.1 Lesser Black-backed Gull

Lesser Black-backed Gulls spent between 0% (tags 457, 460, 483, 484 and 492) and 11.8% (tag 493) of their time away from Orford Ness in wind farm zones between tagging and 9 July 2011 (Table 10a). When terrestrial movements are discounted, gulls' presence in wind farms accounted for between 0% and 27.4% (tag 493) of their time offshore (Table 10a). After 9 July 2011, birds spent between 0% and 9.5% (tag 493) of their time outside the colony in wind farm zones, which amounted to between 0% and 15% (tag 482) of their time offshore (Table 10b).

Perhaps unsurprisingly, the wind farm 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. During breeding, the largest amount of overlap for any bird (tag 493) with this wind farm was 18.4% time offshore and 7.9% total time including time at the nest (Table 10a). As in 2010, birds also showed temporal overlap with Greater Gabbard Round 2 Zone and the Galloper extension. For other movements during the 2011 season (unknown status), the maximum time spent in the East Anglia Round 3 Zone was 12.4% of offshore time and 9.3% total time budget for tag 493 (Table 10b). There was again temporal overlap with Greater Gabbard Round 2 and Galloper extension.

Five individuals did not visit wind farm zones at all before 9 July 2011, while seven did not visit these zones after this date. For certain birds, the amount of time spent in the wind farm varied across the season. For example, bird 486 spent 11.6% of its time in wind farms before 9 July 2011, but 0% of its time in these zones after this date. Indeed, this bird did not venture offshore at all after 9 July 2011. Other individuals were more consistent. Across all birds, the time spent in wind farm zones only represented a total of 3.8% of time spent offshore and 1.6% of the total time away from the colony.

3.4.2 Great Skua

3.4.2.1 Foula

All Great Skuas from Foula spent some of their time in proposed wind farm zones during breeding. The amount of time spent in these zones ranged from 2.8% (tag 415) to 10.7% (tag 476) of birds' total time away from the colony, or 5.7% (tag 415) to 33.8% (tag 451) of their total time offshore (Table 11a). After breeding, birds spent between 1.4% (tag 415) and 12.6% (tag 419) of their time in wind farm zones, which accounted for 1.6% (tag 415) to 26.8% (tag 476) of the time these birds spent offshore (Table 11b).

The greatest degree of overlap for offshore foraging trips was with the Scottish N4-N6 STW medium-term option, which is unsurprising given its proximity to the colony. During breeding, some birds spent over one third of their time in this zone (e.g. bird 450, Table 11a), and nearly 11% of their total time budget (e.g. bird 476, Table 11a). Across all birds during breeding, a total of 21.6% of time was spent offshore was in this zone with 7.1% of their total time budgets. No birds spent time in Round 1, 2, 3, extensions or Scottish short-term options. Post-breeding and unknown birds showed similar temporal overlaps (Table 11b), the largest extent of which was again with the N4-N6 STW medium-term option (up to 26.5% offshore time, 12.6% total time). However, owing to wider scale movements (e.g. Fig. 5), Great Skuas also overlapped with the N7 zone, although to a much lesser degree (Table 11b).

3.4.2.1 Hoy

All but two Great Skuas from Hoy spent some of their time in proposed wind farm zones during breeding. Birds spent between 0% (tags 471 and 472) and 5.7% (tag 400) of their time away of the colony in wind farm zones, amounting to between 0% (tags 471 and 472) and 33.4% (tag 400) of their time offshore. They also spent up to 33.4% offshore time and 5.7% (tag 400 in both cases) total time budgets in the N1 STW medium-term option (Table 11a). However bird 409 also spent time in NE1, NE2, and the Moray Firth Round 3 zone (Table 11a). Post-breeding, birds visited N1, N4-N6, N8, NE1, Beatrice Scottish short-term, and the Moray Firth Round 3 Zone. The total time spent in Scottish medium-term option zone was 4.7% time offshore and 2.7% total time budgets (Table 11b). Great Skuas spent between 0% and 13.9% (tag 409) of their time in wind farm zones after breeding, accounting for between 0% and 22.3% (tag 409) of the time they spent offshore (Table 11b). Three Great Skuas (tags 420, 467 and 471) from Hoy did not visit wind farm zones at all post-breeding (Table 11b).

Table 10 Time spent by Lesser Black-backed Gulls during (a) breeding until 9 July 2011 (2011 tagged birds) and (b) other movements of unknown status including post-breeding (after 9 July 2011 for birds tagged in 2011, and 2010 tagged birds for entire 2011 season), in offshore wind farm (WF) zones. Time is expressed in relation to the offshore movements of birds away from the nest and overall time budget of the bird (including time at the nest).

(a)

Bird	WF name	Time budget (hrs)			Time in WF (%)		No. trips	
		Time in WF	Away from nest	Total time	Offshore movements	All time	N trips in WF	Total trips
459	East Anglia	10.2	315	691	3.2	1.5	5	87
	Galloper ext	1.6	315	691	0.5	0.2	2	87
493	East Anglia	49.6	269.4	627.6	18.4	7.9	20	61
	Galloper ext	23.2	269.4	627.6	8.6	3.7	4	61
	Gr Gabbard	1.1	269.4	627.6	0.4	0.2	2	61
479	East Anglia	5.5	238.1	724.5	2.3	0.8	6	94
	Galloper ext	4.8	238.1	724.5	2	0.7	2	94
	Gr Gabbard	0.3	238.1	724.5	0.1	0	1	94
486	East Anglia	72.8	600.4	1178.4	12.1	6.2	29	108
	Galloper ext	53.5	600.4	1178.4	8.9	4.5	16	108
	Gr Gabbard	10.4	600.4	1178.4	1.7	0.9	12	108
485	East Anglia	1.3	207.5	603.6	0.6	0.2	1	62
481	East Anglia	1.7	506.9	1177.6	0.3	0.1	1	198
482	East Anglia	0.1	108.1	627.3	0.1	0	1	66
478	East Anglia	20.4	864.1	1645.4	2.4	1.2	7	148
	Galloper ext	4.9	864.1	1645.4	0.6	0.3	2	148
480	East Anglia	0.1	343	724.4	0	0	1	64
484	None	0	238.7	727.4	0	0	0	82
483	None	0	260.4	624.1	0	0	0	67
492	None	0	212.3	626.8	0	0	0	56
460	None	0	36.1	68	0	0	0	7
457	None	0	108.3	423.3	0	0	0	48
Total	**Round 1,2,3**	**161.7**	**4199.8**	**10046.2**	**3.8**	**1.6**	**70**	**1100**

Table 10 cont.

(b)

Year tagged	Bird	WF name	Time budget (hrs)			Time in WF (%)		No. trips	
			Time in WF	Away from nest	Total time	Offshore movements	All time	N trips in WF	Total trips
2011	481	None	0	19	22.3	0	0	0	204
	483	None	0	387.4	1015.9	0	0	0	217
	484	None	0	671.9	908.8	0	0	0	231
	486	None	0	395.9	451.1	0	0	0	162
	459	East Anglia	4.3	568.2	831.4	0.8	0.5	3	185
	493	East Anglia	94.8	761.3	1018.8	12.4	9.3	28	222
		Galloper ext	2.1	761.3	1018.8	0.3	0.2	1	222
		Gr Gabbard	0.3	761.3	1018.8	0	0	1	222
	479	East Anglia	22	508.1	887	4.3	2.5	10	250
		Galloper ext	7	508.1	887	1.4	0.8	3	250
		Gr Gabbard	0.4	508.1	887	0.1	0	2	250
	485	Galloper ext	0.1	542.8	854.1	0	0	1	133
		Gr Gabbard	0.7	542.8	854.1	0.1	0.1	1	133
	492	East Anglia	3.8	237.9	321.5	1.6	1.2	1	83
	480	East Anglia	0.6	583.3	911.4	0.1	0.1	1	195
	482	East Anglia	54.9	531.4	1004.4	10.3	5.5	26	206
		Galloper ext	18	531.4	1004.4	3.4	1.8	9	206
		Gr Gabbard	7	531.4	1004.4	1.3	0.7	7	206
	460	East Anglia	0.8	722.8	1572.2	0.1	0.1	3	169
2010	334	East Anglia	49.2	1778.2	1796.2	2.8	2.7	6	21
		Galloper ext	55.9	1778.2	1796.2	3.1	3.1	3	21
		Gr Gabbard	2.1	1778.2	1796.2	0.1	0.1	2	21
	407	East Anglia	42.3	2075.8	3101.2	2	1.4	8	241
		Galloper ext	2.3	2075.8	3101.2	0.1	0.1	1	241
	395	None	0	1326.3	2636	0	0	0	283
	336	None	0	33.7	39.6	0	0	0	2
	391	None	0	1166.9	2826.9	0	0	0	405
	Total	**Round 1,2,3**	**369.4**	**12311**	**20198.9**	**3**	**1.8**	**120**	**5399**

Table 11 Time spent by Great Skuas during (a) breeding and (b) post-breeding (failed, fledged) in 2011 in offshore wind farm (WF) zones in relation to the offshore movements of birds away from the nest and overall time budget of the bird (including time at the nest).

(a)

Colony	Bird	WF name	Time budget (hrs)			Time in WF (%)		No. trips	
			Time in WF (hrs)	Away from nest	Total time	Offshore movements	All time	N trips in WF	Total offshore trips
Foula	415	N4-N6	0.8	14.0	28.9	5.7	2.8	1	2
	470	N4-N6	58.0	387.4	984.1	15.0	5.9	38	58
	465	N4-N6	69.2	341.5	982.1	20.3	7.0	44	69
	451	N4-N6	53.2	157.4	981.8	33.8	5.4	48	67
	450	N4-N6	61.4	322.3	874.7	19.0	7.0	30	53
	418	N4-N6	11.2	38.5	287.4	29.1	3.9	6	15
	454	N4-N6	63.4	289.4	916.8	21.9	6.9	38	86
	476	N4-N6	99.9	311.0	937.2	32.1	10.7	72	88
	419	N4-N6	52.3	317.4	654.5	16.5	8.0	21	29
	487	N4-N6	69.2	311.3	963.4	22.2	7.2	45	71
	Total	**Round 1,2,3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
		Scot Med term	**538.6**	**2490.1**	**7610.7**	**21.6**	**7.1**	**343.0**	**538.0**
Hoy	471	None	0.0	614.3	1559.1	0.0	0.0	0	183
	472	None	0.0	4.2	40.6	0.0	0.0	0	6
	473	N1	10.5	47.2	316.5	22.3	3.3	4	18
	448	N1	2.4	37.7	310.8	6.4	0.8	2	18
	420	N1	1.8	68.0	296.0	2.6	0.6	2	24
	409	NE1	6.3	126.4	460.7	5.0	1.4	1	36
		NE2	0.1	126.4	460.7	0.1	0.0	1	36
		Moray Firth R3	1.6	126.4	460.7	1.3	0.4	1	36
	475	N1	6.9	46.2	342.0	15.0	2.0	3	24
	467	N1	32.9	686.4	1538.8	4.8	2.1	11	165
	400	N1	26.1	78.0	458.5	33.4	5.7	12	32
	Total	**Round 1,2,3**	**1.6**	**126.4**	**460.7**	**1.3**	**0.4**	**1**	**36**
		Scot Med term	**87.1**	**1708.4**	**5323.0**	**5.1**	**1.6**	**36**	**542**

Table 11 cont.

(b)

Colony	Bird	WF Name	Time budget (hrs)			Time in WF (%)		No. trips	
			Time in WF (hrs)	Away from nest	Total time	Offshore movements	All time	N trips in WF	Total offshore trips
Foula	415	N4-N6	12.8	798.8	901.5	1.6	1.4	7	30
	470[u]	N4-N6	56.4	481.2	795.2	11.7	7.1	33	105
		N7	0.3	481.2	795.2	0.1	0.0	1	105
	465[u]	N4-N6	114.6	906.9	1555.6	12.6	7.4	79	172
	451[u]	N4-N6	29.2	314.6	738.6	9.3	4.0	21	95
	450	N4-N6	66.7	560.3	1158.9	11.9	5.8	50	123
		N7	1.5	560.3	1158.9	0.3	0.1	3	123
	418	N4-N6	68.6	434.6	1461.2	15.8	4.7	50	97
		N7	0.5	434.6	1461.2	0.1	0.0	2	97
	419	N4-N6	157.8	685.5	1253.2	23.0	12.6	55	101
		N7	0.2	685.5	1253.2	0.0	0.0	1	101
	454[u]	N4-N6	118.4	778.5	1408.1	15.2	8.4	80	206
		N7	5.4	778.5	1408.1	0.7	0.4	2	206
	476[u]	N4-N6	123.3	465.8	1015.5	26.5	12.1	86	197
		N7	1.3	465.8	1015.5	0.3	0.1	3	197
	487	N4-N6	80.2	526.3	951.1	15.2	8.4	51	135
	Total	**Round 1,2,3**	**0.0**	**5952.4**	**11238.7**	**0.0**	**0.0**	**0**	**1261**
		Scot Med term	**837.3**	**5952.4**	**11238.7**	**14.1**	**7.5**	**512**	**1261**
Hoy	473	N1	16.8	924.8	1379.2	1.8	1.2	9	128
		N4-N6	1.5	924.8	1379.2	0.2	0.1	1	128
		Beatrice Scottish	1.2	924.8	1379.2	0.1	0.1	2	128
		Moray Firth R3	2.1	924.8	1379.2	0.2	0.2	2	128
	448	N1	35.1	751.5	1451.2	4.7	2.4	12	109
		N4-N6	1.1	751.5	1451.2	0.1	0.1	1	109
		N8	0.1	751.5	1451.2	0.0	0.0	1	109
	409	NE1	61.1	334.0	537.0	18.3	11.4	7	71
		Beatrice Scottish	2.0	334.0	537.0	0.6	0.4	5	71
		Moray Firth R3	11.4	334.0	537.0	3.4	2.1	8	71
	400	N1	4.7	235.5	409.6	2.0	1.1	2	47
	420	None	0.0	69.7	285.9	0.0	0.0	0	45
	467	None	0.0	103.4	119.3	0.0	0.0	0	173
	471	None	0.0	152.6	217.4	0.0	0.0	0	208
	Total	**Round 1,2,3**	**16.7**	**2571.6**	**4399.6**	**0.7**	**0.4**	**30.0**	**781.0**
		Scot Med term	**120.3**	**2571.6**	**4399.6**	**4.7**	**2.7**	**30**	**781**

[u] Unknown status after 15 July 2011.

3.5 Flight heights

As explained in Thaxter *et al*. (2011), there are sources of error associated with the accuracy and precision of our altitude measurements for both Lesser Black-backed Gulls and Great Skuas. The tags' manufacturers at the University of Amsterdam are currently updating the software for extracting and analysing these data accounting for such error (Bouten & Shamoun-Baranes, personal communication). We have therefore decided not to pursue flight height analyses in this report, but a discussion of the approaches that will be taken can be found in section 2.7.4.

4. DISCUSSION

4.1 Overview

The 2011 field season was far more successful than that of 2010 (Thaxter *et al.* 2011), in that a greater number of both Lesser Black-backed Gulls and Great Skuas were tagged and a higher proportion of birds retained their tags (because of a more effective tagging protocol). We were therefore able to collect a greater amount of data than in 2010, especially for Great Skuas. The 2011 breeding season was also better than 2010 in terms of productivity for both species (when many nests failed at the egg stage and very few or no chicks fledged), so data obtained during the breeding months in 2011 are more likely to be reflective of normal breeding behaviour than those gathered in 2010.

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

4.2 Lesser Black-backed Gulls

As in 2010, the results show that Lesser Black-backed Gulls from Orford Ness visited areas of proposed and existing wind farms throughout the breeding season. Information downloaded at the start of the season from birds tagged in 2010 that returned to breed in 2011, showed that Lesser Black-backed Gulls also interacted with sites of proposed and existing wind farms on passage. The data reveal a degree of intraspecific variation in the amount of spatial and temporal overlap between each individual and wind farms. This 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; Delhay *et al.* 2001; Grieg *et al.* 1985; McCleery & Sibley 1986; Pierotti & Annett 1987; Skórka & Wójcik 2008).

Preliminary attempts to analyse birds' behaviour at different stages of the season suggests that the way in which birds use the marine environment (including offshore wind farm zones) varies during breeding. The results of the time budget analysis, for example, indicate that birds on average spent a greater amount of their time in wind farm zones when engaged in incubation and chick-rearing than later in the breeding season, when chicks were relatively independent and/or fledged. However, for some individuals the opposite was true. In general, Lesser Black-backed Gulls made trips that were longer in duration and farther from the colony as the season progressed. Birds whose chicks had fledged or whose nests had failed made the longest trips (in terms or time and distance) before departing from Orford Ness for wintering grounds.

4.3 Great Skuas

Our findings for Great Skuas were similar to those with Lesser Black-backed Gulls. Thaxter *et al.* (2011) suggested no spatial or temporal overlap between Great Skuas and offshore wind farms during the breeding season. However, since this report was produced, the Scottish Government has set out medium-term plans for offshore renewable energy developments, most of which include a wind component, and several of which are in close proximity to Foula and Hoy. Analysis of Great Skuas' movements in 2011 therefore showed substantial spatial and temporal overlap with many of these newly proposed zones, especially for birds on Foula, as a development zone essentially surrounds the island.

As with Lesser Black-backed Gulls, there was marked variation between individuals in terms of areas of sea visited during foraging, and therefore the amount of time spent in, and likelihood of spatial overlap with, offshore wind farm zones. There was again a tendency for individuals from both sites to cover greater distances as the breeding season progressed. However, this did not necessarily translate into longer time periods spent away from the nest; on Foula, although foraging range and distance travelled per trip increased with the transition from incubation to chick rearing, the mean and mean maximum trip duration fell at this point.

As tags did not last beyond the breeding season in 2010, we do not yet have any information on whether Great Skuas interact with offshore wind farms during migration. We hope that data on migration will be obtained from those Great Skuas tagged in 2011 as they return in 2012.

4.4 Effects of wind farms on gulls and skuas

The implications of these results for Lesser Black-backed Gulls or Great Skuas are not yet clear. Gulls were observed using areas of extant wind farms, suggesting that not all birds are displaced by their development. However, we have not yet undertaken a comprehensive analysis of flight altitude (section 2.7.4), the study of which will inform the collision risk of both species during the breeding season and on passage. We have also not investigated gulls' movements in relation to the position of individual turbines.

It would also be valuable to define birds' behaviours in existing and proposed wind farm zones, so that diving, floating and other movements can be characterised. This would help to show whether birds are using wind farm area for foraging, for example, suggesting the importance of these sites to SPA features. We hope to be able to define such behaviours over forthcoming months using data for the tags' accelerometers and software being developed by the University of Amsterdam (Bouten, personal communication). This software also allows different types of flight, i.e. flapping and soaring, to be distinguished (Shamoun-Baranes *et al.* submitted). Birds may fly through a wind farm at turbine altitude with no apparently adverse effects. However, if individuals change their flight patterns from soaring to flapping, for example, this may suggest an otherwise hidden seabird-wind farm interaction in terms of flight energetics.

4.5 Concluding comments

The data presented here build on those described Thaxter *et al.* (2011) and further show the value of GPS tagging studies in assessing both connectivity and potential interactions between SPA features and offshore wind farms. Although we now have data from two breeding seasons and one overwintering period (for gulls), we shall be better equipped to address this project's aims after the 2011/12 and 2012/13 non-breeding and 2012 breeding seasons. At this time, we should have a clearer picture of non-breeding movements and how these species interact with wind farms within and outside the breeding season. This question is particularly important for Great Skuas, for which we do not yet have non-breeding season data.

Following the 2011/12 and 2012/13 non-breeding and 2012 breeding seasons, all data will be comprehensively analysed to examine how these SPA feature species and offshore wind farms interact at different times of the year (including at different points in the breeding season). We hope to relate our findings to characteristics of individual birds, for example sex and breeding status, as well as to environmental variables such as weather data (Kemp *et al.* 2011). These analyses will incorporate flight altitudes and accelerometer data, allowing us to comprehensively fulfil of the aims and objectives of this project.

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