BTO RESEARCH REPORT 738

Assessing movements of Lesser Black-backed Gulls using GPS tracking devices in relation to the Walney Extension and Burbo Bank Extension Offshore Wind Farms

Gary D. Clewley, Chris B. Thaxter, Elizabeth M. Humphreys, Emily S. Scragg, Katharine M. Bowgen, Willem Bouten, Elizabeth A. Masden & Niall H.K. Burton

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Assessing movements of Lesser Black-backed Gulls using GPS tracking devices in relation to the Walney Extension and Burbo Bank Extension Offshore Wind Farms

Report of work carried out by the British Trust for Ornithology[1,2] in association with the University of Amsterdam[3] and University of the Highlands and Islands[4] on behalf of Ørsted

Gary D. Clewley[2], Chris B. Thaxter[1], Elizabeth M. Humphreys[2], Emily S. Scragg[1], Katharine M. Bowgen[3], Willem Bouten[4], Elizabeth A. Masden[5] and Niall H.K. Burton[1]

[1] British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU, UK, [2] BTO Scotland, Beta Centre (Unit 15), Stirling University Innovation Park, Stirling, FK9 4NF, UK, [3] BTO Cymru, Thoday Building, Deiniol Road, Bangor, Gwynedd LL57 2UW, UK, [4] Computational Geo-Ecology, Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Sciencepark 904, 1098 XH Amsterdam, The Netherlands, [5] Centre for Energy and the Environment, Environmental Research Institute, North Highland College – University of the Highlands and Islands (UHI), Ormlie Road, Thurso, Caithness, KW14 7EE, UK

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BTO, The Nunnery, Thetford, Norfolk IP24 2PU
Tel: +44 (0)1842 750050 Email: info@bto.org
Registered Charity Number 216652 (England & Wales), SC039193 (Scotland).

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EXECUTIVE SUMMARY

1. Offshore wind farm developments form a major part of the UK government's commitment to obtain 15% of the UK's energy needs from renewable sources by 2020. However, there is concern over the potential detrimental effects that offshore developments may have on bird populations.

2. Many seabird species included as features 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. Any impacts may also vary between years as well as between construction and operational phases of wind farm developments.

3. This study investigated the movements of Lesser Black-backed Gulls (*Larus fuscus*) using bird-borne telemetry devices over four breeding seasons (2016-2019) and three non-breeding seasons in relation to the development of the Walney Extension and Burbo Bank Extension offshore wind farms in northwest England. The overall objectives of this study were to assess:

    i. Foraging ranges and foraging distributions during four breeding seasons;
    ii. Connectivity with the Walney Extension and Burbo Bank Extension (and other) offshore wind farms during four breeding seasons;
    iii. The extent of area use of the Walney Extension and Burbo Bank Extension offshore wind farms through construction into operation;
    iv. Movements during three non-breeding seasons;
    v. Behaviour within offshore wind farms and avoidance.

    This report covers objectives i-iv, with additional outputs provided as scientific papers.

4. Breeding individuals were tracked from two colonies in Cumbria, UK: South Walney, a large but declining coastal colony within the Morecambe Bay and Duddon Estuary SPA, and adjacent urban areas in Barrow-in-Furness. During 2016, 20 high temporal resolution University of Amsterdam (UvA) GPS devices were attached using permanent harnesses to adults trapped at the nest at South Walney. Data were also available for an additional 17 individuals (12 UvA devices and 5 Movetech Telemetry GPS-GSM devices) tagged under a previous project at South Walney funded by the Department for Business, Energy and Industrial Strategy (BEIS) between 2014-2016. A total of 32 Movetech devices were fitted to individuals at Barrow-in-Furness (2016 - 10, 2017 - 13, 2018 - 9), those in 2017 and 2018 using temporary harnesses, designed to fall off birds after a period of time. The return rates and productivity of tagged individuals were compared with those of an untagged control group to assess potential detrimental effects of the devices.

5. Over the 2016-2019 breeding seasons, a total of 8,128 and 3,445 complete foraging trips were recorded for 36 and 29 of the individuals tracked from the South Walney and Barrow-in-Furness colonies respectively. At South Walney, trip duration increased significantly from a mean (± SD) of 5 ± 4.9 to 7 ± 5.8 hours between the 2016 and 2019 seasons and correspondingly the mean foraging range per trip also increased significantly over time from 9.3 ± 10.2 to 14.2 ± 18.4 km. Similarly, data from Barrow-in-Furness indicated that foraging trip duration increased from 5.5 ± 5 to 7.8 ± 5.9 hours between 2016 and 2019, although this increase was not significant. Foraging ranges were also more similarly across years for birds tagged in Barrow and no significant changes over time were detected. However, significant increases in foraging range were only observed at the individual level for two of 13 individuals from South Walney tracked for at least three years.

6. The telemetry data revealed predominantly terrestrial space use, including use of landfill, agricultural and urban habitats. The maximum time spent offshore across individuals in any given year was <5% for birds from South Walney and <3% for birds from Barrow-in-Furness. Overall, 20 individuals from South Walney and 12 individuals from Barrow showed connectivity with offshore wind farms, just six (five from South Walney and one from Barrow-in-Furness) with the Walney Extension offshore wind farm and three (from South Walney) with the Burbo Bank Extension offshore wind farm. There was no significant change in the proportion of individuals showing connectivity with the offshore wind farms through the construction period.

7. Utilisation distributions were calculated using a Time-in-Area approach and identified individual and colony scale core and total home ranges. Core home ranges were significantly larger for birds from the South Walney colony than for birds from Barrow-in-Furness. At the colony scale, the core home range also increased over time for birds from South Walney, with novel locations visited during 2019; however, no significant changes to the size of the core home range were detected at the individual scale. The core home ranges of only two individuals (from South Walney) overlapped with any offshore wind farms, while across birds, total home ranges showed less than 2% overlap. Across all years, for all birds pooled together, the time spent inside offshore wind farms was <1% of the overall time budget. The maximum spatial overlap with Walney Extension in any year was 0.22% of the total home range and there was no overlap with the Burbo Bank Extension site.

8. Data were also available to assess non-breeding season movements in 2016/17, 2017/18 and 2018/19. There was considerable variation in wintering locations between individuals. All individuals (except one wintering in Morocco during the 2016/17 period) from the South Walney colony remained in Europe with a tendency to winter in Northern Europe (such as UK and France) over the course of the study. One individual was recorded travelling to Denmark during the post-breeding period but subsequently returned to the UK to winter. Although the sample size was smaller, individuals tracked from the Barrow colony were apparently more evenly spread across the various wintering destinations selected and travelled a greater maximum distance from the colony compared with birds from South Walney. There was a large amount of individual variation however, with the range for maximum distance travelled away from the colony during the non-breeding season ranging from 85 to 2370 km for birds from South Walney and from 188 to—2473 km for birds from Barrow. Individual birds tended to be consistent between years in their selected wintering site.

9. Conclusions: The majority of individuals tracked from both the South Walney and Barrow colonies made relatively limited use of the marine environment through the 2016-19 breeding seasons and less than seen during the 2014-2016 BEIS-funded study at South Walney. Birds spent less than 1% of their time within offshore wind farms, with very limited connectivity with the Walney Extension and Burbo Bank Extension sites. Given this, it was not possible to formally assess changes in the use of these areas between the pre-construction, construction and operational phases and it is difficult to infer whether their development had any detrimental effect to the colonies studied, but it is unlikely. Further, there was no evidence of broad scale changes in area use associated with the construction of these new wind farms. Nevertheless, while use of the Walney Extension and Burbo Bank Extension sites was limited, the study has provided valuable data, building on the previous BEIS project that has furthered understanding of birds' use of offshore wind farms and their potential effects on birds providing benefit to the wider offshore wind industry.

1. INTRODUCTION

1.1 Background

As part of the National Renewable Energy Action Plan, under the European Union (EU) Renewable Energy Directive (2009/28/EC), the UK government has a commitment to obtain 15% of the UK's energy needs from renewable sources by 2020 (DECC 2009). The UK also has a commitment to the Paris climate change agreement, where at the 21st Conference of Parties of the United Nations Framework Convention on Climate Change, consensus was reached to stem further increases in global temperatures to below 2°C, with concerted effort to limit increases to 1.5°C (UNFCCC 2015). Wind energy is playing a major part in achieving these national and international obligations. Currently, the UK is a global leader in the offshore wind farm industry, with 7.9 GW of generating capacity from operational sites and a further 5.7 GW under construction by the end of 2018 (The Crown Estate 2019), a marked increase from the first round of developments completed between 2003 and 2013 with a capacity of 1.2 GW. A recent report further highlighted the future potential for wind energy generation up to 2030, with a total capacity of at least 25 GW available based on current policy frameworks (Hundleby & Freeman 2017). Consequently, many further wind farms are currently under construction, consented or proposed including the latest leasing 'Round 4' announced in 2019.

There is, however, concern as to the impacts that these developments may have on wildlife. Offshore wind farms may potentially have impacts on bird populations, in particular, through a number of effects: (1) displacement from or attraction to preferred foraging sites; (2) barrier effects to migration routes or local flight paths; (3) the direct mortality associated with collision; and (4) physical habitat modifications caused by the installation of offshore wind structures, including the creation or destruction of feeding habitats (Drewitt & Langston 2006, Fox *et al.* 2006). Any potential impacts may vary between the construction and operational phases of a development as the type of disturbance and modification to the environment differs (Bergström *et al.* 2014).

This study provides an assessment of the use of two sites, the Walney Extension and Burbo Bank Extension offshore wind farms, by a species of seabird, the Lesser Black-backed Gull (*Larus fuscus*), that is considered sensitive to the risk of collision with turbines (Furness *et al.* 2013).

1.2 Focal offshore wind farms

Following applications to the Planning Inspectorate by Ørsted Walney Extension (UK) Limited and Ørsted Burbo Bank Extension (UK) Limited respectively, Development Consent Orders were granted in relation to both the Walney Extension and Burbo Bank Extension offshore wind farms off the coast of northwest England, which are the main focus of this report.

Walney Extension

Offshore construction of the Walney Extension wind farm began in 2017, encompassing an area of 149 km^2. As of 18 May 2018, the wind farm was commissioned, generating power from 87 turbines. This development greatly extended the existing operational sites off the Cumbria coast approximately doubling the wind farm area.

The relevant parties, *i.e.* the applicant (Ørsted), the Marine Management Organisation (MMO) and Natural England (the Statutory Nature Conservation Body (SNCB) responsible for the application) considered the potential for offshore ornithological monitoring of the project pre-, during, and post-construction. They concluded that, owing to the absence of significant effects on the species of bird considered in the Environmental Statement (ES) and Habitats Regulations Assessment (HRA), monitoring measures were not required to be secured by condition in the deemed marine licences for the site. However, there was agreement that there would be benefit to the wider offshore wind industry if targeted offshore ornithological research studies were undertaken.

Ørsted initially proposed that:

- Research studies should focus on Lesser Black-backed Gull, Herring Gull (*Larus argentatus)*, Pink-footed Goose (*Anser brachyrhynchus)*, and Whooper Swan (*Cygnus cygnus)*;
- Priority should be given to those species considered to be the most sensitive to potential impacts generally associated with offshore wind projects and to those of greatest conservation concern;
- Studies should be targeted to answer specific hypotheses, and have an identified end date and confirmed output(s);
- Studies should be targeted to address significant evidence gaps which are relevant to offshore wind projects;
- Ørsted is prepared to contribute funding to an independent research project rather than setting up single, developer-led projects;
- Results should be easily accessible and widely disseminated.

Burbo Bank Extension

Construction for the Burbo Bank Extension offshore wind farm began in 2016, encompassing an area of 69 km^2 with 32 8-MW turbines installed and generating power by March 2017 which extended the existing Burbo Bank site (9.9 km^2) situated in Liverpool Bay.

Ørsted provided an ES and HRA report to support the application and reached agreement with Natural England and Natural Resources Wales (the two SNCBs) on a number of issues, including likely effects on breeding and wintering birds. The Marine Licence requires monitoring of the abundance and distribution of Red-throated Diver (*Gavia stellata)* around the wind farm site and across the wider Liverpool Bay Special Protection Area (SPA).

Further to this, however, Ørsted noted that contribution to existing GPS tagging studies of Lesser Black-backed Gull would further the understanding of how this species may interact with the Burbo Bank Extension offshore wind farm (acknowledging initial concerns with regards to this project) and other offshore wind farm developments.

Following discussion with Natural England and potential contractors Ørsted (Walney Extension and Burbo Extension offshore wind farms) agreed to fund a GPS tagging study of Lesser Black-backed Gull consisting of:

- GPS tagging of adult breeding birds at the South Walney colony within the Morecambe Bay SPA, to include at least two breeding seasons with an operational project, in order to assess the species' foraging range and foraging distribution;
- Equivalent GPS tagging of adult breeding birds at nearby urban Barrow-in-Furness, to also include at least two breeding seasons with an operational project, to provide comparative information on the foraging ranges and foraging distributions of local urban breeding birds.

1.3 Telemetry to understand interactions

1.3.1 Breeding season movements

At-sea data collected from boat or aerial surveys are important tools for assessing the interaction of species with offshore wind farms during breeding (e.g. Camphuysen *et al*. 2004, Buckland *et al*. 2012). However, these methods cannot establish the origin of birds recorded during surveys, and whether the individuals observed are linked to specific breeding colonies (Thaxter *et al.* 2012). Such an understanding is necessary to assess the impacts of wind farms on feature species from breeding colony SPAs or other protected sites. Radar studies can provide tracks of individual birds near wind farms (Desholm & Kahlert 2005, Desholm *et al*. 2006, Kunz *et al*. 2007), as well as their flight heights, using marine X-band vertical marine radar (e.g. Krijgsveld *et al*. 2011). However, they are often unable to identify birds to species level, and it can be difficult to follow individuals near to the turbines due to a 'shadow' effect (Kunz *et al.* 2007, Walls *et al*. 2009). The use of telemetry devices on birds within a breeding population can help resolve these issues by providing direct data on the movements of individuals from specific sites and may therefore be valuable in refining understanding of potential wind farm impacts and in making better-informed assessments.

Generic information on species foraging ranges provided by tracking studies can be used in assessing the potential connectivity between developments and breeding populations (Thaxter *et al*. 2012). However, considerable variation in foraging movements may occur between colonies and both within and between breeding seasons. Differences in the foraging ranges and at-sea distributions of Northern Gannets *Morus bassanus* between colonies (Lewis *et al*. 2001, Hamer *et al*. 2001, Wakefield *et al.* 2013, 2015, Warwick-Evans *et al.* 2017), for example, likely reflect the effects of differences in prey availability and intra-specific competition on the distances required to find food. Furthermore, the locations of important foraging habitats, and thus seabird distributions, may be ephemeral, because of links to fluctuating habitat features such as oceanographic fronts (Daunt *et al*. 2006, Camphuysen *et al*. 2006, Skov *et al*. 2008, 2015), or anthropogenic food resources (e.g. Navarro *et al.* 2016) thus giving rise to large inter-annual variability. There also may be considerable variation in the types of marine systems in which birds forage, and in the prey species available, the capture of which may require a range of foraging tactics. Given such differences in foraging ranges and at-sea distributions between colonies, it is of great importance to collect site-specific data where wind farms are suspected to have potential impacts on nearby breeding populations. Only with such detailed data is it possible to confirm the connectivity between protected breeding bird populations and wind farms and thus reliably quantify their use of these sites and potential exposure to their effects.

1.3.2 Non-breeding season movements

Many tracking studies of seabird species have focused on understanding the movements of species during the breeding season (e.g. Votier *et al*. 2006, Soanes *et al.* 2013, Cleasby *et al.* 2015) when seabird species are readily accessible at nest sites. However, their movements and distribution may vary throughout the year (Furness 2015) and particular areas may be utilised more during the migration and over-wintering periods. To more accurately assess the potential impact of wind farm developments to a given species, there is need to collect data throughout the year to better understand the timing of any interactions and if there is any cumulative increase in risk from encountering multiple developments (e.g. Thaxter *et al.* 2019). Furthermore, for any offshore wind farm development specific assessment, data collected outside throughout the year may highlight interactions from populations not considered during breeding season studies.

A limiting factor for many previous studies for the collection of non-breeding season telemetry data has been the safe and effective long-term attachment of devices, to encompass periods of moult or remain active after individuals have left the locations where they were caught. To ensure telemetry data are representative of the movements of unmarked individuals and to maintain acceptable welfare standards it is crucial that the addition of devices does not unduly affect the fitness or behaviour of the study individuals – see Appendix A1. Most tracking of seabird species in the UK remains limited to short-term attachment methods, such as tape or glue mounting, for a period of days or weeks (Geen *et al.* 2019) but there are some groups, notably gulls, which can be safely tracked using long-term harness attachments (Thaxter *et al.* 2014a) so are currently good candidate species for non-breeding season telemetry studies.

1.3.3 Relevant GPS tracking projects of Lesser Black-backed Gulls

A number of existing British Trust for Ornithology (BTO) GPS tracking projects of Lesser Black-backed Gulls are relevant and provide wider context to this project.

Department for Business, Energy and Industrial Strategy (Department of Energy and Climate Change) funded projects

As part of their Offshore Energy Strategic Environmental Assessment (OESEA2 and OEASEA3) programmes, the Department for Business, Energy and Industrial Strategy (BEIS) (formerly the Department of Energy and Climate Change – DECC) has funded three consecutive projects that have evaluated the potential interaction of breeding seabirds with offshore wind farms.

The first project, undertaken between 2010 and 2014, looked at breeding gulls and skuas from SPAs in Suffolk and Shetland. Through a BTO-University of Amsterdam (UvA) collaboration, using GPS tracking devices with high temporal and spatial resolution, the study provided detailed information on the extent of the breeding season foraging distributions and flight heights of Lesser Black-backed Gulls from Orford Ness in the Alde-Ore SPA, and also their movements during migration and winter, so informing on potential interaction with offshore wind farm developments (Thaxter *et al.* 2012, 2014a, 2014b, 2015a, 2015b, 2019, Ross-Smith *et al.* 2016).

The second project was initiated in 2014 and extended the gull tracking work to the Skokholm and Skomer SPA in southwest Wales and to the South Walney colony within the Morecambe Bay and Duddon Estuary SPA in northwest England (Thaxter *et al.* 2018a, 2018b, 2019). The project was completed following the 2016 breeding season.

At South Walney, 25 Lesser Black-backed Gulls were fitted with UvA GPS tags in 2014, with data collection from 2014-2016 and an additional five individuals tagged using Movetech Telemetry devices in 2016. A further 24 PathTrack Nanofix GPS devices were also fitted to Herring Gulls (also a feature species of the Morecambe Bay and Duddon Estuary SPA) in 2014 under this project.

Data from South Walney were used to assess the foraging ranges and the degree of spatial overlap of gulls with the Round 1 (Barrow and Ormonde) and Round 2 (Walney 1 and 2, and West of Duddon Sands) offshore wind farms areas in proximity to South Walney (Thaxter *et al.* 2018a) as well as assess meso-avoidance behaviour within wind farm areas (Thaxter *et al.* 2018b).

Data from those Lesser Black-backed Gulls previously tagged at South Walney as part of the BEIS funded project and which still had active tags between 2016-2019 are also considered in this report.

A third project was initiated at the Forth Islands SPA in 2019, providing comparative information on the breeding season foraging distributions, flight heights and migratory and winter movements of Lesser Black-backed Gulls from colonies on the Isle of May Site of Special Scientific Interest (SSSI) and Forth Islands SSSI.

Natural England and BAE Systems funded projects

In addition to the above work, two Natural England and BAE Systems funded projects are of relevance.

Through Natural England and BAE Systems funding, the BTO deployed GPS devices to Lesser Black-backed Gulls from the Ribble & Alt Estuaries SPA between 2016 and 2019. A tracking study of Lesser Black-backed Gulls, funded by Natural England, was also undertaken at the Bowland Fells SPA between 2015 and 2018.

Natural Environment Research Council CASE PhD studentship

Further to this study, a Natural Environment Research Council (NERC) CASE (Collaborative Awards in Science and Engineering) funded PhD studentship supervised by the University of Exeter, Natural England and BTO began in 2016 with the aim of comparing the ecology of Lesser Black-backed Gulls from SPA and non-SPA (particularly urban) colonies. This PhD draws from the data collected from the present project, as well as the BEIS and Natural England projects described above.

Natural Environment Research Council study

A further NERC project, supported by Ørsted and Natural England, has used data from the BEIS- and Ørsted-funded projects based at South Walney to develop the models used to predict collision risk as part of the assessment process to monitor and forecast avian collision risk at operational offshore wind farms.

1.4 Project Objectives

The overarching objective for the study has been to provide a comparative assessment of how Lesser Black-backed Gulls from the South Walney colony in the Morecambe Bay and Duddon Estuary SPA and from nearby urban Barrow-in-Furness interact with the Walney Extension and Burbo Bank Extension offshore wind farms through their construction and into operation, with the intention that data should be collected over at least two breeding seasons following the commencement of the operation of the Walney Extension offshore wind farm. Specific objectives have been to assess:

i. Foraging ranges and foraging distributions during four breeding seasons (2016, 2017, 2018 and 2019);
ii. Connectivity with the Walney Extension and Burbo Bank Extension (and other) offshore wind farms during four breeding seasons (2016, 2017, 2018 and 2019);
iii. The extent of area use of the Walney Extension and Burbo Bank Extension offshore wind farms through construction into operation;
iv. Movements during three non-breeding seasons (2016/17, 2017/18, 2018/19);
v. Behaviour within offshore wind farms and avoidance.

This final report provides outputs with respect to objectives (i-iv), providing details of trip statistics, connectivity, area use and spatial overlaps with the Walney Extension and Burbo Bank Extension (and other) offshore wind farms and assessments of changes in these aspects over construction periods and into their operation. A first, unpublished interim report covered the 2016 breeding season; a second, unpublished interim report covered the 2017 breeding season and movements during the 2016/17 non-breeding season. The present final report provides an overview across the whole study period, as outlined above.

Scientific papers will provide:

i. An assessment of the behaviour of gulls within offshore wind farms, building on Thaxter *et al.* (2018b) (obj. v) (Thaxter *et al.* in prep.);
ii. An assessment of avoidance, also building on Thaxter *et al.* (2018b) (obj. v) (Johnston *et al.* in prep.);
iii. An assessment of diurnal and seasonal variation over time of offshore use and overlap with wind farm areas (obj. iii) (Clewley *et al.* in prep.).

2. GENERAL METHODS

2.1 Focal species

The Lesser Black-backed Gull (the UK sub-species of which is *L. fuscus graellsii*) is a widespread species traditionally breeding at coastal colonies across Europe (Cramp & Simmons 1983). As with other large gulls, Lesser Black-backed Gulls have a generalist diet, foraging in both marine and terrestrial habitats (Götmark 1984) and commonly utilising anthropogenic food sources (Harris 1965, Camphuysen 1995). Throughout the twentieth century, the breeding populations of large gulls increased markedly largely due to increased protection and availability of novel resources such as landfill and fishery discards (Coulson 2015).

The greatest numbers of breeding Lesser Black-backed Gulls occur at just a handful of breeding colonies, which are designated SPAs (five in England, two in Scotland, two in Northern Ireland and one in Wales) (Stroud *et al*. 2016). Population declines across these colonies have been observed since 2000 (Nager & O'Hanlon 2016) and Lesser Black-backed Gulls are currently amber-listed on the current list of Birds of Conservation Concern in the UK (Eaton *et al.* 2015). However, more so than other gull species, Lesser Black-backed Gulls also colonised urban sites through the late twentieth century (Raven & Coulson 1997; Mitchell *et al.* 2004; Rock 2005) and have continued to expand their breeding range inland in recent years (Balmer *et al.* 2013). Precisely what proportion of the population now breeds at urban sites is unclear as monitoring data are incomplete and it is difficult to ascertain accurate numbers of pairs across large urban areas (Ross *et al.* 2016; Thaxter *et al.* 2017a). Individuals that do breed in urban areas have often come into conflict with humans, largely due to defensive behaviour of young (Belant 1997) and have been subject to both lethal and non-lethal management and control (Ross-Smith *et al.* 2014).

At-sea data have previously been used to investigate the species' distributions and habitat associations, for instance in the German North Sea (Schwemmer & Garthe 2008), and placement within multi-species feeding associations (Camphuysen & Webb 1999). Earlier research also focused particularly on the species' general breeding biology, diet, and kleptoparasitism (Camphuysen *et al.* 1995, Calladine 1997, Galván 2003, Kubetzki & Garthe 2003, Kim & Monaghan 2006). Previous information suggested that Lesser Black-backed Gulls regularly travel over 40 km from the colony to forage (Camphuysen *et al.* 2010) and may travel up to 180 km offshore to forage too during the breeding season (Thaxter *et al*. 2012). Given the relative proximity of offshore wind farms and development zone to the coastline, there is potential for birds to forage in these areas. Increasingly, the species has been tracked from different breeding locations across Europe, for example, in the Netherlands (Camphuysen 2011, Shamoun-Baranes *et al*. 2011, 2016, 2017), Germany (Corman & Garthe 2014, Garthe *et al.* 2016), Belgium (Baert *et al.* 2018, Stienen *et al.* 2016), Finland (Juvaste *et al.* 2017), Sweden (Isaksson *et al.* 2016) and the UK (Ross-Smith *et al.* 2016, Thaxter *et al.* 2014a, 2014b, 2015a, 2018a, 2018b, 2019).

During the non-breeding season, the extent of migration varies between and within individuals and populations (e.g. Shamoun-Baranes *et al.* 2017). Lesser Black-backed Gulls tracked from colonies in the Netherlands (sub-species *L. fuscus graellsii* and *L. fuscus intermedius*) are known to migrate initially to the UK immediately after breeding, before travelling further south to overwinter on the coasts of the Iberian Peninsula and north-west Africa (Ens *et al*. 2008, Shamoun-Baranes *et al.* 2017, Baert *et al.* 2018). Birds tracked from UK colonies also tend to winter in Iberia or north Africa, while some may travel as far south as West Africa (Wernham *et al.* 2002), but a proportion may also remain in the UK throughout the non-breeding season (Thaxter *et al.* 2018a).

2.2 Field sites

Lesser Black-backed Gulls were captured and fitted with GPS devices at two sites in Cumbria (Fig. 2.1): a mixed gull colony at South Walney (54°03'N, 3°11'W) and nearby Barrow-in-Furness, hereafter referred to as Barrow (54°07'N, 3°13'W). These sites were selected due to their proximity to the offshore wind farm areas of interest (Fig. 2.2) and availability of existing data from previous studies (see Section 1.3.3).

South Walney is owned and managed by Cumbria Wildlife Trust and forms the southern tip of Walney Island, a shingle island lying at the end of the Furness Peninsula. Both the Lesser Black-backed Gull and the Herring Gull are features of the South Walney and Piel Channel Flats SSSI, a component part of the Morecambe Bay and Duddon Estuary SPA. The SPA also supports breeding terns and internationally and nationally important populations of wintering waterbirds. The South Walney Lesser Black-backed Gull colony reduced in size from 19,487 Apparently Occupied Nests (AONs) in 1998-2002 (Mitchell *et al.* 2004) to 2,312 AONs at the start of this study in 2016 and 390 AONs by 2019 (JNCC 2020). Similarly, numbers of breeding Herring Gulls at South Walney fell from 10,129 AONs in 1998-2002 (Mitchell *et al.* 2004) to 1,156 AONs in 2016 and 1,158 AONs in 2019 (JNCC 2020).

The South Walney site comprises two sub-colonies, the 'meadow' and the 'spit' (Fig. 2.1), both of which are protected by temporary electric fencing to deter ground predators. All birds fitted with University of Amsterdam (UvA) devices were caught at the meadow sub-colony, while birds fitted with Movetech Telemetry devices were caught at the spit, see Section 2.3 for details about the different devices.

Barrow is the second largest urban area in Cumbria, connected to Walney Island by a road bridge and adjacent to but not included in the Morecambe Bay and Duddon Estuary SPA, making it a useful comparison site. Foraging gulls are ubiquitous across Barrow and several breeding colonies occur, with c. 360 AONs of Lesser Black-backed Gull recorded in 2009 (Sellers & Shackleton 2011). Permission was secured to capture gulls at two principal locations within Barrow (Fig. 2.1). The main site was an area of undeveloped ground surrounded by security fencing at Devonshire Dock where upwards to a 100 pairs of mixed gulls nest on the ground. Access to this site was arranged through BAE Systems and Associated British Ports. Devices were also deployed at Furness General Hospital where upward to 15 pairs of Lesser Black-backed Gulls nested on the flat roof. Both sites were subject to disturbance, both unintentional and intentional and eggs were removed from nests at Furness General Hospital under General License. A third site, Craven House owned by Barrow Borough Council, was also visited on several occasions but the individuals trapped were not suitable for GPS devices (under required weight) so this site is not considered in this report.

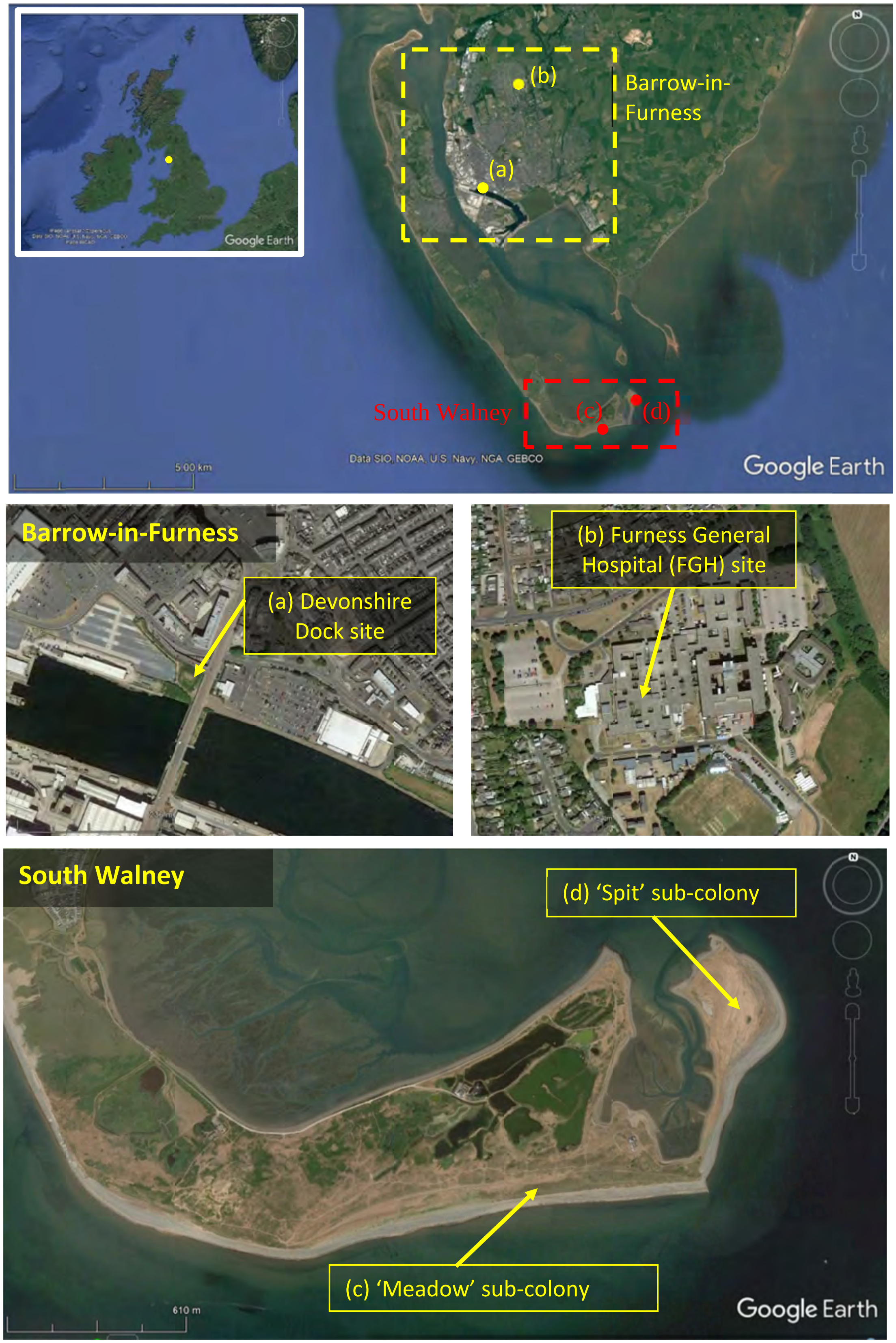


Figure 2.1 Location of the study sites at South Walney (Morecambe Bay and Duddon Sands SPA) and Barrow-in-Furness, and sub-colonies within these where tagging was undertaken.

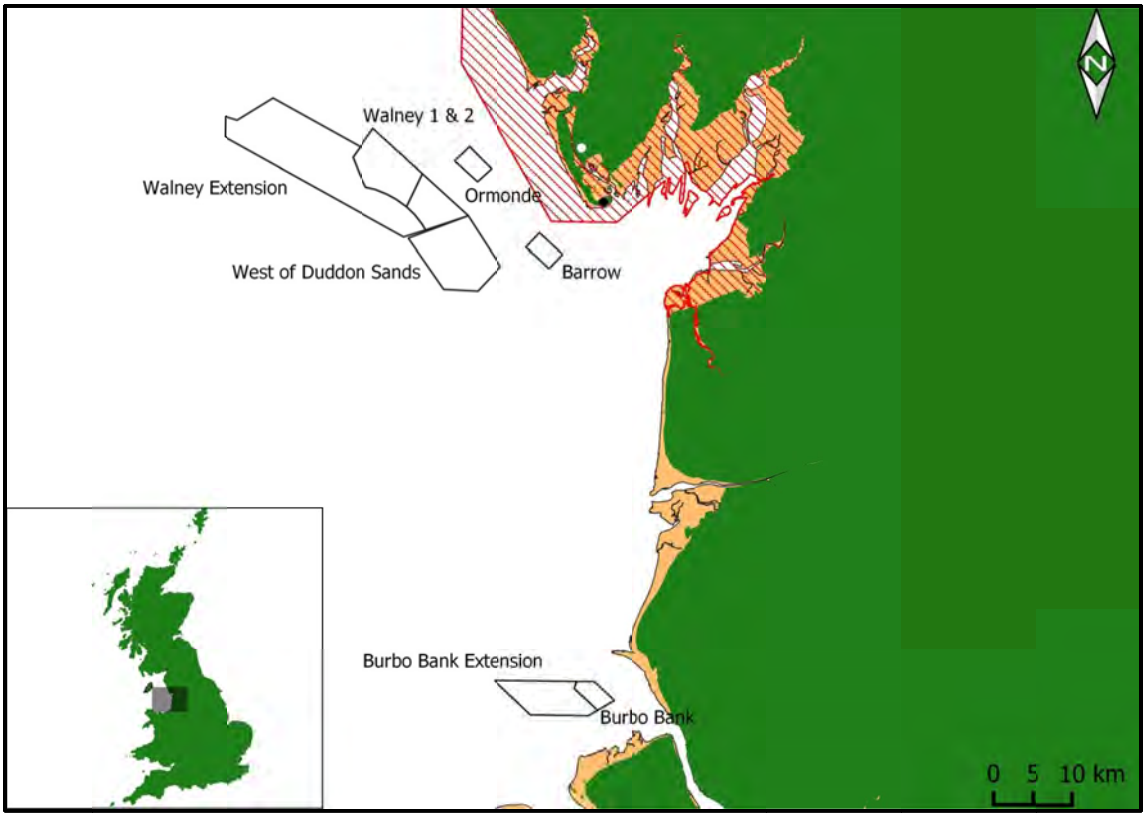


Figure 2.2 Locations of offshore wind farms considered in this study and the South Walney (black circle) and Barrow-in-Furness (white circle) Lesser Black-backed Gull breeding colonies. The red hatched area indicates the Morecambe Bay and Duddon Sands SPA.

Several wind farms located off the Morecambe Bay Estuary coastline were operational prior to the start of this study (Table 2.1), with the nearest sites being c. 9 km from the South Walney (Barrow Offshore wind farm) colony and 14 km from Barrow-in-Furness (Ormonde Offshore wind farm – see Figure 2.2), placing them well within the foraging ranges of Lesser Black-backed Gulls from these colonies (Thaxter *et al.* 2012). Of the two focal developments yet to begin construction at the start of this study, the Walney Extension site is located closer to the study colonies and was most likely to be used by gulls. However, although located at greater distance, the Burbo Bank Extension site is still within the mean (71.9 km) and mean maximum (141 km, Thaxter *et al*. 2012) breeding season foraging range for Lesser Black-backed Gulls.

Table 2.1 Timing of turbine installation activities (4C Offshore 2020) and locational information (EMODnet 2020) for the Walney Extension and Burbo Bank Extension offshore wind farms and the adjacent operational offshore wind farms.

Wind farm	First turbine installed	Last turbine installed	Fully commissioned	Distance to shore (central point) (km)	Area (km^2)	n turbines
Ormonde	Mar 2011	Aug 2011	Feb 2012	11.3	9.9	30
Barrow	Dec 2005	Jun 2006	Sep 2006	8.5	10	30
Walney 1	Jul 2010	Jan 2011	Jul 2011	17.7	27.1	51
Walney 2	Jun 2011	Sep 2011	Jun 2012	22.1	45.8	51
West of Duddon Sands	Sep 2013	Jun 2014	Oct 2014	17.9	66.8	108
Walney Extension	Aug 2017	Apr 2018	Sep 2018	29.0	149.0	87
Burbo Bank	May 2007	Jun 2007	Oct 2007	8.9	9.9	25
Burbo Bank Extension	Sep 2016	Dec 2016	Apr 2017	11.4	39.6	32

2.3 The GPS systems

2.3.1 University of Amsterdam (UvA) devices

Tags developed by UvA (model: '5CDLe') were used at the South Walney colony only, and are lightweight, solar-powered, high energy-efficient storage devices that provide the highest temporal and spatial resolution of the tags used in this study. Each tag consists of a GPS sensor, a microcontroller with a 4 Mb flash-memory, a pressure sensor, an accelerometer, a multi-cell solar panel, a battery and a battery charger. GPS tags were one of three sizes detailed below with the majority deployed being 'small' but several 'medium' and 'large' devices deployed in 2014 under the BEIS project were still transmitting data in 2016 and beyond (see Section 4):

i. 'Small' – 13.5 g (62 x 25 x 11 mm);
ii. 'Medium' – 15.5 g (62 x 31 x 13.5 mm);
iii. 'Large' – 18.5 g (62 x 31 x 13.5 mm).

All tags had similar functionality, and included a two-way wireless VHF (Very High Frequency) transceiver that communicated to a central base station. Once the tags were deployed, GPS locational data were downloaded remotely via a laptop. This communication was facilitated by external relay antennae that amplified the range of the signal (Fig. 2.3). Once tagged birds came within range of this 'network', data from the tags were automatically downloaded. Further, new sampling rate settings and communication intervals were also uploaded remotely through the network, avoiding the need for recapture of tagged birds to retrieve data. The tags also allowed measurement of short-interval GPS position fixes, up to one fix every 3 seconds (Bouten *et al*. 2013; Thaxter *et al.* 2018b). Fast-sampling data can be very useful to investigate fine-scale behaviour and have the potential to describe space use and behaviour in relation to individual turbines, as well as in relation to whole wind farms (Thaxter *et al.* 2018b). The data have been of particular value to two of the peer-reviewed papers produced as part of this project, on (i) avoidance; and (ii) the behaviour of gulls within wind farms.

UvA tags were set to record one GPS fix every five minutes during the breeding season when birds were away from the colony (ca. March to August). Whilst birds were at the colony, devices were set for fixes to be taken at 30 minute intervals in order to conserve battery power. In addition, when devices were sufficiently charged and birds were away from the nest on foraging trips, GPS sampling rates of 10 seconds were used to maximise data collection when the battery was at maximum charge under sunny conditions. For the non-breeding season (ca. September to February), GPS sampling intervals of 60-180 minutes were used when birds were within the UK, as defined by a GPS fence with lat-long coordinates: 60°N, 17°W (northwest corner) and 49°N, 4°E (southeast corner); when birds were outside the UK (i.e. when further south and likely experiencing sunnier conditions permitting faster rates), a GPS sampling rate of 30 minutes (plus five minutes fast sampling at maximum battery charge) was used.

2.3.2 Movetech Telemetry devices

These GPS devices (model: Flyway-18; 18-25 g; 50 x 26.5 x 18 mm) utilise the Global System for Mobile Communications (GSM) network to transmit data directly to an online telemetry data repository (www.movebank.org) without the need for any in situ equipment. In areas without mobile coverage, the devices continue to store GPS locations on internal memory sufficient for over 60 000 records. The devices have high efficiency solar panels to recharge the battery and have been developed by Movetech Telemetry (hereafter 'Movetech').

Movetech tags were used in preference to UvA tags for deployments within Barrow due to the potential difficulties of downloading data from tags through a base station system in a changing urban environment, where individual birds may move nesting site from year-to-year.

Movetech tags were set to record one fix every 30 minutes across the breeding season between 0800 and 2000 and 180 minutes between 2000 and 0800 overnight (to save battery power), and at a maximum rate of 30-60 minutes, dependent on solar-charging, from overwinter departure in mid-late July to breeding season return in March/April. Higher sampling rates comparable with the UvA devices were not possible as the method of data transfer using the GSM network consumes more power.

Table 2.2 outlines comparison between the two types of device used in this study.

Figure 2.3 Images of relays used as part of the University of Amsterdam (UvA) tracking system in operation at South Walney. Top left image: position of the relay at the 'meadow' gull colony; Top right image: a relay positioned at the offices of the Cumbria Wildlife Trust, where the laptop and base station were located (photo: C. Thaxter). Bottom: Image showing location and orientation of relays (yellow) and base station (blue).

Table 2.2 Summary of tag types, the information obtained using each, along with their function and means of data collection/transmission to the user.

Tag type	Type: size and dimensions of tag	Data	Fast-sampling GPS fixes	Remote data transmission	Download range	Battery	Expected Duration
University of Amsterdam	Small: 13.5 g (62 x 25 x 11 mm)	xy location, flight height, speed, acceleration	Yes	Yes	Local base station (*e.g.* 4 km)	Lithium + solar	1-5+ years
	Medium: 15.5 g (62 x 31 x 13.5 mm						
	Large: 18.5 g (62 x 31 x 13.5 mm)						
Movetech	18-25 g (18 x 50 x 26.5 mm)	xy location, flight height, speed	No	Yes	GSM mobile cellular download, no range limit	Lithium + solar	2 years +

2.4 Field methods

All trapping and ringing activities were carried out by licensed individuals holding valid BTO ringing permits and all tags and harnesses were fitted under endorsement from the Special Method Technical Panel (SMTP) of the BTO Ringing Committee.

Adult birds were caught during late incubation or the very early chick-rearing phase of the breeding season (end of May to mid-June), when they are relatively reluctant to spend time away from the nest. Only one member of a pair was tagged. Cage nest traps, of small mesh chicken wire with a funnel entrance, were placed over nests, usually several at once to reduce the number visits into the colony (Fig. 2.4). Traps were monitored by observers until a bird was captured, at which point the bird was retrieved, placed in individual cotton sacks and processed. Individual nests were targeted for a maximum of c. 30 minutes and if no adults were captured traps were moved to different areas of the colonies to reduce repeat disturbance. A small number of birds were also captured using remote release noose traps placed around the nests. All periods of inclement weather were avoided for catching to prevent unguarded eggs from becoming chilled.

Processing took place out of sight from the colony but within 100 m or less and involved fitting a numbered metal ring, unique coded colour-ring, attaching the device and recording biometrics (wing length, bill length (to feather), bill depth (at gonys), total head length, weight and moult). Bill measurements allow probable sex of an individual to be determined.

The tags were attached using a tried and tested permanent wing harness that has previously been used successfully for Lesser Black-backed Gulls (Thaxter *et al*. 2014a; Shamoun-Baranes *et al.* 2017). All harnesses were constructed from 6.35 mm tubular Teflon ribbon (Bally Ribbon Mills, Pennsylvania, USA) to minimise abrasion and included a braided nylon core for strength. Harnesses used in Barrow in 2017 and 2018 were modified to include a cotton weak-link element which will allow safe detachment of the tag, without need to recapture the bird, after an expected period of approximately 2 years. Weak-link harnesses followed the design described in Clewley *et al.* (submitted).

The time to safely fit the harness was c. 15-20 minutes and overall capture, holding and handling time was aimed to be 45 minutes or less. All individuals were observed immediately after release to ensure mobility was not impaired in any way.

Previous assessments of the potential negative effects of fitting devices using harnesses for Lesser Black-backed Gulls found no differences in productivity, return rates or nest attendance (Thaxter *et al.* 2015b). Nevertheless, site, method or year specific impacts should not be discounted and it is thus important to monitor and asses any potential impacts both with respect to the birds' welfare and as a licence requirement, and also to provide context to results.

An appraisal of the potential impacts of the tagging is provided in Appendix A1. To assess the effects of devices and harnesses, separate control birds and their nests were also monitored. Control birds were captured at the nest using the techniques described above and also fitted with colour-rings.

It was intended to recapture individuals fitted with permanent harnesses after a minimum of two years if still nesting in the colony to remove the device. Although this may have reduced sample sizes for long-term data collection, it was a licensing requirement to safeguard the birds' welfare. However, no individuals with permanent harnesses were ultimately recaptured due to poor breeding success across the entire colony and difficulty in targeting non-breeding birds.

In summary, 20 Lesser Black-backed Gulls were fitted with UvA GPS tags at the South Walney colony in 2016. Data from 17 Lesser Black-backed Gulls tagged at South Walney as part of the BEIS funded project are also considered in this report, 12 fitted with UvA GPS tags in 2014 and which still had active tags over the period of this study and five further birds fitted with Movetech GPS-GSM tags in 2016.

The mean ± SE mass of adults captured at South Walney from 2014 to 2016, i.e. including both those captured in the present study and in the previous BEIS funded study, was 824 ± 10 g (range: 640-1100 g, n = 138). The total additional weight of the UvA devices (plus harness and colour ring) was no more than 25 g (mean ± SE percentage of body mass = 2.5 ± 0.08 %) which adheres to a well-established threshold in the UK to minimise the risk of negative effects of tagging (Geen *et al.* 2019).

A further 32 Lesser Black-backed Gulls were fitted with Movetech GPS-GSM tags at colonies within urban Barrow-in-Furness, 10 in 2016, 13 in 2017 and nine in 2018 (those in 2017 and 2018 including a sample of six tags provided through funding from Natural England and replacements for tags that had worked less well in previous years).

The mean ± SE mass of adults captured at Barrow 2016-2018 was 821 ± 12.5 g (range: 670-1010 g, n = 80) and the total additional weight (device plus harness and colour ring) was no more than 31.5 g (mean ± SE percentage of body mass = 2.96 ± 0.05 %).

Table 2.3 Numbers of birds captured at the South Walney and Barrow sub-colonies during 2016-2018, that were either fitted with GPS devices ('tagged'), or simply fitted with a colour ring as 'control' birds. See Figure 2.1 for a map of the study sites.

Year	Site	Tagged	Control
2016	Walney 'meadow'	20	20
	Walney 'spit'[1]	5	5
	Barrow 'Dock'	7	8
	Barrow 'FGH'	3	2
2017	Barrow 'Dock'	12	17
	Barrow 'FGH'	1	2
2018	Barrow 'Dock'	9	10
	Barrow 'FGH'	0	0
TOTAL	Walney	25	25
	Barrow	32	39

[1] Five Movetech Telemetry devices were also fitted to Lesser Black-backed Gulls at South Walney in 2016 under BEIS project funding, data from which were also available for the present study.

Figure 2.4 Pictures of tags being deployed on Lesser Black-backed Gulls at South Walney and Barrow; top-left: nests traps being set in gull colony on Furness General Hospital rooftop; top-right: University of Amsterdam (UvA) GPS device with a Teflon wing-harness; bottom-left: UvA tag (type 'large' in Table 2.2) attached to a bird; bottom-right: Recording wing length of a bird being tagged in Barrow (photos: G. Clewley).

3. BREEDING SEASON AREA USAGE AND INTERACTIONS BETWEEN LESSER BLACK-BACKED GULLS FROM THE SOUTH WALNEY AND BARROW-IN-FURNESS COLONIES AND THE WALNEY EXTENSION AND BURBO BANK EXTENSION OFFSHORE WIND FARMS

3.1 Introduction

The movements of individual Lesser Black-backed Gulls from the South Walney and Barrow colonies were investigated over the 2016-2019 breeding seasons. Within the objectives of the overall study (Section 1.4), investigations assessed:

i. The foraging range and duration of foraging trips of individual gulls from the South Walney and Barrow colonies;
ii. Connectivity with the Walney Extension and Burbo Bank Extension (and other) offshore wind farms.
iii. The extent of area use of the Walney Extension and Burbo Bank Extension offshore wind farms through construction into operation.

3.2 Methods

3.2.1 Breeding periods and seasonal definitions

Data on bird movements and time budgets were collected during the period when birds were linked to their breeding colonies. The periodic checks of the colonies did not allow precise hatching and laying dates to be determined for individual Lesser Black-backed Gulls (while nests of individuals tagged in previous years could not always be precisely located – see Appendix A1). Further, given the widespread breeding failure at the study sites, it was not possible to define precisely when individual nesting attempts finished.

Therefore, for the purposes of this study, we included all data collected during the period when birds were linked to their breeding colonies, defined by the first and last GPS fix recorded from within the colony boundaries. This will have encompassed some considerable post-breeding movements – see results, and also Klaassen *et al.* (2012) for similar examples.

Non-breeding season periods were defined from the last GPS fix recorded in the colony until return the following year and included both migration and wintering periods.

3.2.2 Foraging trips

Foraging trips were defined by the departure and subsequent return of individuals to the colony and thus include commuting and resting behaviours as well as active foraging. As gulls may use a number of areas within the colony in addition to the nest site, e.g. loafing and bathing sites, we defined the 'colony' by a rectangular perimeter that was also used to switch the sampling rates of UvA tags when birds moved to and from this area. The same colony definition was also used for birds tagged using Movetech devices, albeit the 'fence' was not actively used in determining the sampling schedules of those tags. As such, arrival and departure was gauged through departure from and arrival to this rectangular 'perimeter fence' around the colony. For all trips, we calculated: i) trip duration (time elapsed between departure and return); ii) foraging range (the maximum point reached from the colony) and iii) the total cumulative distance travelled per trip.

Trips shorter than 30 minutes or longer than 24 hours were excluded from analyses as they were not considered likely to represent genuine foraging trips away from the colony during the periods that birds were breeding and constrained as central place foragers. For example, they may have been a result of nearby loafing behaviour, a series of GPS fixes with larger location error or more extensive post-breeding movements.

Differences in trip duration and foraging range (averaged for each individual across all trips) between years were analysed using Linear Mixed-effects Models with the ‘lme4’ R package (Bates *et al.* 2015). A continuous variable for year was included as a fixed effect and individual ID included as a random effect. Models were run for each colony separately and significance was tested comparing models with and without the year effect, reporting the Chi-squared significance of a change in deviance. Differences between colonies were analysed as above but pooling data across years and including colony identity as a categorical factor. Changes in trip duration and foraging range between years at the individual level were analysed separately for each bird using linear regression models.

Further investigations into diurnal and seasonal variation in activity and interactions with offshore wind farm areas will be detailed in a manuscript separate to this report (Clewley *et al.* in prep.).

3.2.3 Connectivity with the areas of the Walney Extension and Burbo Bank Extension and other offshore wind farms

Tracks of all birds were initially overlain onto maps showing the areas of wind farms to indicate the extent of interaction with these areas. An individual bird was concluded to show connectivity with the area of an offshore wind farm if GPS fixes from at least one trip were located within that area. We also note instances where interpolation between GPS fixes additionally suggested transit through wind farm areas.

3.2.4 Area usage

Breeding season area use analyses focused on observations during trips only and thus the areas that might have been used for foraging and other activities away from the colony.

The “time-in-area” (TIA) approach was used to quantify time spent in grid cells which, when ranked by cumulative proportion, produced estimations of utilisation distributions (UD) akin to a standard kernel density estimate (KDE) (e.g. Soanes *et al.* 2013, Thaxter *et al.* 2017b). The two methods are thus congruent, however, KDE is a point-based area approach, whereas TIA assesses the metric of relevance – i.e. time – within grid cells. Although there may be slight differences in the eventual surfaces produced, the TIA approach has been shown to perform as well as KDE methods, yet is simpler to apply and can calculate temporal and spatial utilisation in one process (Warwick-Evans *et al.* 2015).

Grid cell size can have an effect on the size of the eventual area produced under the TIA approach (Soanes *et al.* 2015); such choices always need care and attention at the outset of assessing area utilisation. Here, we used a grid cell size of 1x1 km, which was deemed most suitable for determining wider-scale area use and potential use of offshore wind farms. Areas were produced for 50%, 75%, 95% and 100% UD contours (the latter representing a full total area use, with lower contour levels presented to align with presentation in other studies, which can differ in how they define area usage: see Soanes *et al.* 2014, Thaxter *et al.* 2017b). The 50% UD is considered to represent the core range and the 95% UD the home range. Each of these UD contours was used to calculate the proportion of time spent within the areas of the Walney Extension and Burbo Bank Extension sites and other wind farms. TIA calculations used the R package ‘trip’, which provides functions for accessing and manipulating spatial data from animal tracking based on the interaction of line segments with pixels of a raster image. Although other methods for interpolating between points are available, for simplicity, here, we follow Sumner (2016) and use linear interpolation.

We also calculated the proportion of time spent away from the colony and time spent offshore by each individual, and for all birds together. These time budgets were the cumulative sum of time differences between consecutive fixes when devices were continuously active for periods outside the defined colony and offshore (defined as GPS locations outside a UK low water shape modified to exclude estuaries and mudflat areas).

Differences in the UD area sizes between years and between colonies were analysed using Linear Mixed-effects Models as described in Section 3.2.1.

All analyses were conducted using 3.6.1 (R Core Team 2019), and using custom-written functions and the R package 'trip' (Sumner 2016).

3.3 Summary of GPS data collected

Data collection periods and device performance over the 2016-2019 breeding seasons are summarised in Tables 3.1 and 3.2, for all individuals tagged during the study and also returning birds tagged as part of the BEIS funded project begun in 2014. The GPS data collected covered a wide area of northwest England (Fig. 3.1). Example plots for individuals are shown in Fig. 3.2.

Telemetry data were cleaned prior to analyses to remove any potentially erroneous data. Any incomplete or duplicate data were removed, as well as any GPS fixes obtained using three or fewer satellites which were likely to have a larger location error. Movetech devices recorded manufacturer specific metadata ('flt:switch' values) on the validity of the GPS fix obtained and only good fixes were retained for any analysis. Finally a speed filter (threshold 30m/s) was used to remove fixes considered unreliable based on calculated speed between two consecutive points.

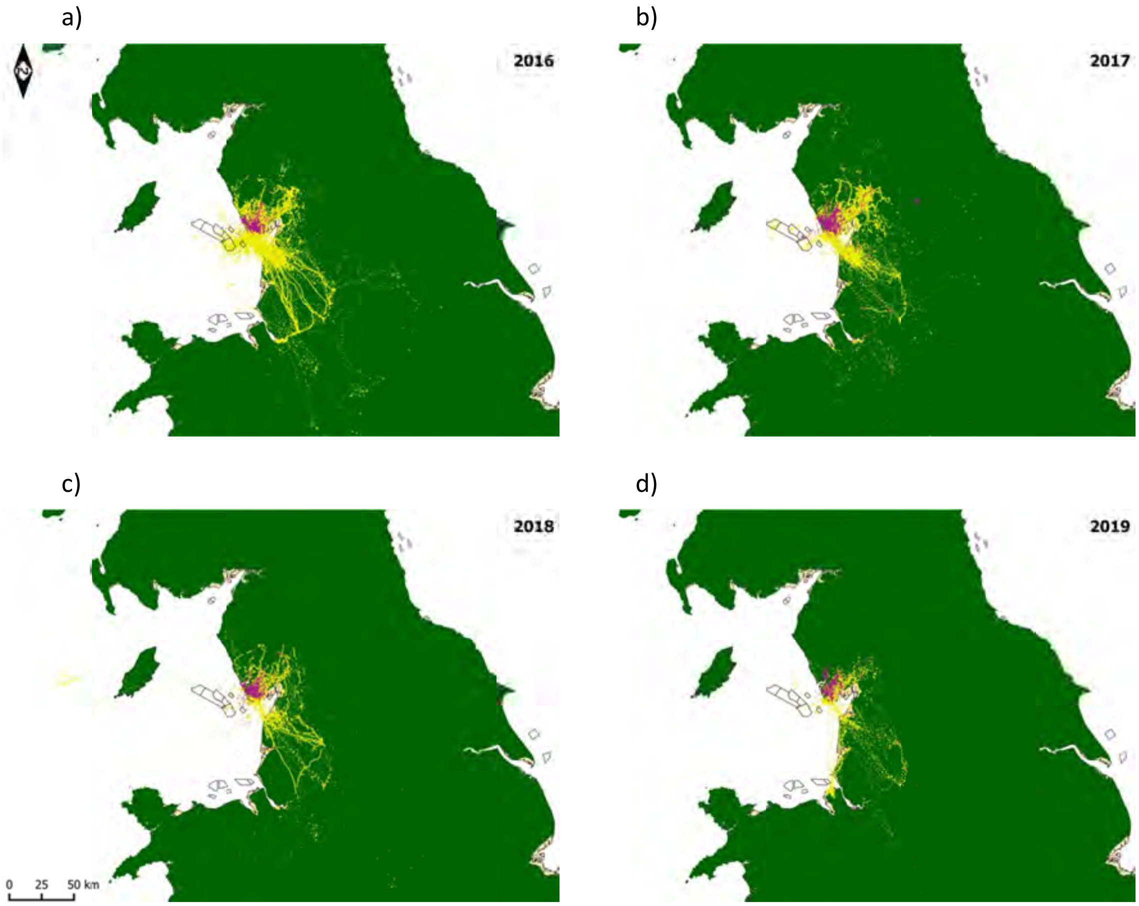


Figure 3.1 All GPS fixes recorded from tracked Lesser Black-backed Gulls breeding at South Walney (yellow) within the Morecambe Bay and Duddon Estuary SPA and Barrow-in-Furness (purple) for the 2016-2019 (a-d) breeding seasons. The numbers of individuals for which data were collected from in each year were: 2016 – 36, 7; 2017 – 23, 19; 2018 – 13, 13; 2019 – 7, 6, for each site respectively. Outlines of offshore wind farm areas of interest are show in black.

3.3.1 South Walney

All except one (5378) of the UvA devices transmitted data during the year of deployment (2016); that individual was not re-sighted in the colony after deployment in any of the study years so most likely abandoned the colony and moved outside the UvA network. For the remaining 19 devices, the mean (± SE) tracking duration was 43 ± 6.2 days with three individuals only providing data for a week or less whereas others remained associated with the colony until early August. Premature departure from the colony was expected from failed breeders but any data still collected in the local area after the bird left the UvA network was stored and downloaded if it returned the following year.

During subsequent years, all of the devices on returning individuals, both those tagged in 2014 during the BEIS study and those tagged in 2016, functioned well and provided data across a longer duration including pre-laying and early incubation periods. The mean tracking duration for birds returning to the study site between 20017 and 2019 was 100 ± 4.5 days (n = 55), with data collection typically starting around mid-March.

There was a reduction in the data received across each year of the study, which was expected due to a decline in tag performance over time, but which was likely also to be a result of poor breeding success in the colony. The sample of individuals was adequate to be representative of colony level space use in 2016 and 2017 (Thaxter *et al.* 2017b), although the smaller effective sample sizes in 2018 (n = 11 plus 2 with partial data) and 2019 (n = 7) do introduce more uncertainty.

3.3.2 Barrow

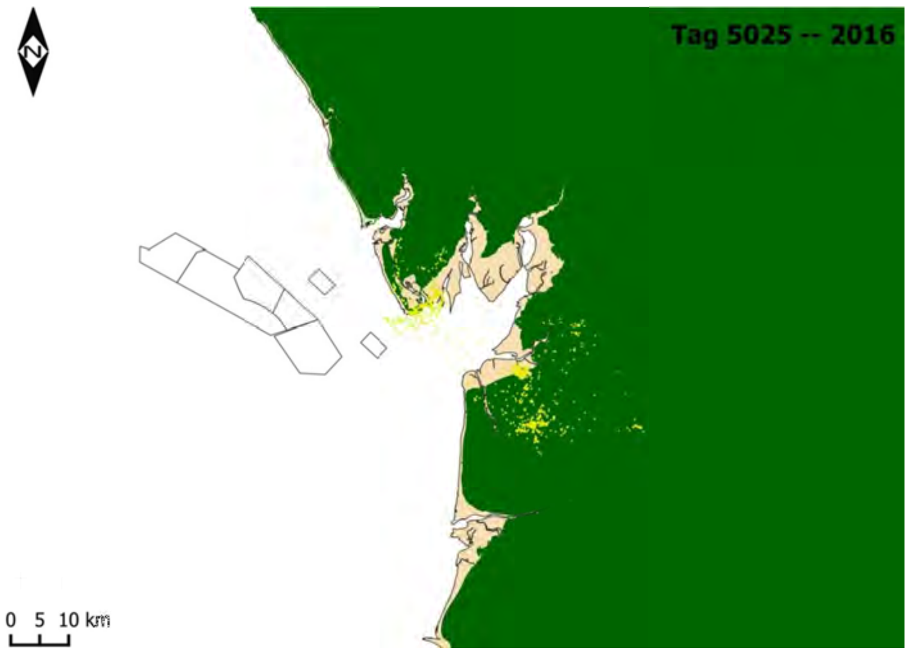
It was anticipated that the quantity of data as well as ability to collect high temporal resolution GPS fixes would be lower for Movetech devices deployed in Barrow as outlined in Section 2.3.2. However, Movetech device performance varied more than the UvA devices and data quality was too poor to be effectively used or intermittent for a greater proportion of individuals than expected. This was particularly an issue in 2016 and 2017 where six and five devices respectively provided poor data from the 10 and 13 deployed. Some of the deployments in 2017 were to replace those that did not function correctly in 2016. Device performance was improved during 2018 and as with UvA devices, data from the smaller sample of birds returning in subsequent years was generally good.

Device deployments in Barrow were staggered across years in this study, largely due to limitations in the availability of suitable nesting pairs and site access. Additionally, as a requirement of ongoing SMTP permission to fit devices using harnesses, from 2017, temporary weak-link harnesses were deployed and unfortunately these failed earlier than anticipated resulting in birds returning without devices in 2018. The harnesses used on later deployments during 2018 were reinforced and performed well with over half those individuals returning and transmitting data the following year.

The combination of variable device performance and smaller annual sample sizes means the data collected from Lesser Black-backed Gulls breeding in Barrow were less robust for assessing changes in space use between years, although they do provide robust characterisation of space use for study period as a whole.

The average tracking durations for devices deployed in Barrow were similar to those from South Walney with a mean of 42 ± 4.9 days (n = 32) for the first year of deployment and 91 ± 11.7 days (n = 16) for individuals returning in subsequent years.

a)



b)

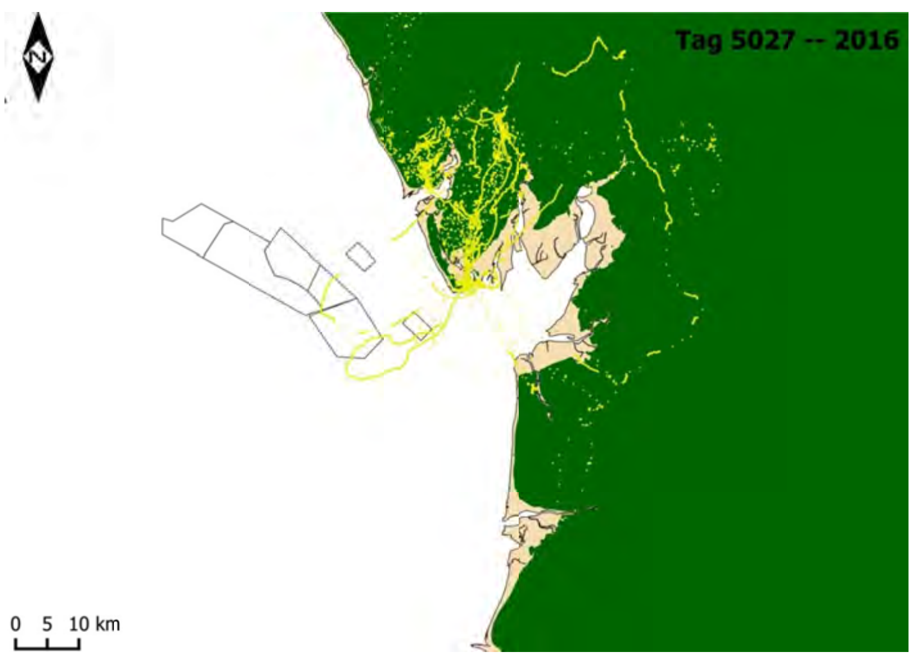


Figure 3.2 Example of cleaned GPS data collected from two individual Lesser Black-backed Gulls, a) ID 5025 and b) ID 5027, tracked from South Walney within the Morecambe Bay and Duddon Estuary SPA for the 2016 breeding season. Outlines of offshore wind farm areas of interest are show in black.

Table 3.1 Summary of breeding season data collected for Lesser Black-backed Gulls fitted with GPS tags at South Walney for the 2016-2019 breeding seasons. Data came from two separate projects funded by Ørsted and BEIS (see text) and from both University of Amsterdam (UvA) and Movetech (MT) tags. Tag IDs shown are referred to throughout the report. Birds were tagged at two 'sub-colonies', the 'meadow' and the 'spit' that, although geographically separate, are still within the South Walney Nature Reserve and the Morecambe Bay and Duddon Estuary Special Protection Area. Some tags did not provide continuous data throughout the period of study – the total 'useable' continuous spans of data are also provided. The number of GPS fixes reported is after cleaning of data to remove erroneous points.

					2016			2017			2018			2019		
Project	**Tag type**	**Sub colony**	**Tag Deployed**	**Tag ID**	**Start date**	**Data duration days (usable days)**	**GPS fixes**	**Start date**	**Data duration days (usable days)**	**GPS fixes**	**Start date**	**Data duration days (usable days)**	**GPS fixes**	**Start date**	**Data duration days (usable days)**	**GPS fixes**
Ørsted	UvA	Meadow	2016	5358	17/05	7 (2)	449									
Ørsted	UvA	Meadow	2016	5360	17/05	43	26068	30/03	64	12813	06/04	79 (58)	15099	30/04	43 (33)	2996
Ørsted	UvA	Meadow	2016	5362	17/05	78	25352									
Ørsted	UvA	Meadow	2016	5363	17/05	78 (74)	9893	28/03	89	22849						
Ørsted	UvA	Meadow	2016	5365	17/05	71 (70)	16694	06/04	72	21683						
Ørsted	UvA	Meadow	2016	5366	17/05	70	41673	11/03	67	6660						
Ørsted	UvA	Meadow	2016	5367	18/05	73 (67)	9995	08/03	149	12695	07/03	115 (110)	11405			
Ørsted	UvA	Meadow	2016	5368	18/05	4	3871									
Ørsted	UvA	Meadow	2016	5371	18/05	19	15443									
Ørsted	UvA	Meadow	2016	5375	01/06	5	3442							19/03	79	9545
Ørsted	UvA	Meadow	2016	5376	01/06	62	12951	19/03	116	12513						
Ørsted	UvA	Meadow	2016	5377	02/06	48	10585	10/03	134	23358	16/03	99 (94)	13614	19/03	97 (94)	8735
Ørsted	UvA	Meadow	2016	5378[1]	02/06	0	0									
Ørsted	UvA	Meadow	2016	5379	01/06	61	11042	07/03	166	25481	16/03	69	5324	15/03	97	9932
Ørsted	UvA	Meadow	2016	5380	01/06	22	12801									
Ørsted	UvA	Meadow	2016	5381	01/06	9	7840									
Ørsted	UvA	Meadow	2016	5382	02/06	49	9738	06/03	93 (51)	2684	22/04	35	3878	09/04	73 (32)	1164
Ørsted	UvA	Meadow	2016	5383	02/06	58	29272									

Ørsted	UvA	Meadow	2016	5385	01/06	39	12247									
Ørsted	UvA	Meadow	2016	5386	02/06	14	3701									
BEIS	MT	Spit	2016	202	18/05	92	2922	01/04	115	4012	03/04	115	3997			
BEIS	MT	Spit	2016	220	18/05	52 (47)	1019	17/04	51	878						
BEIS	MT	Spit	2016	253	18/05	25 (22)	289									
BEIS	MT	Spit	2016	254	18/05	65 (64)	1121	21/03	119	1880	01/04	124	1811	06/04	76	1185
BEIS	MT	Spit	2016	278	18/05	62 (33)	399	31/03	114 (109)	474						
BEIS	UvA	Meadow	2014	503	05/03	133 (124)	8143	24/03	94	11132	06/04	71 (62)	11300			
BEIS	UvA	Meadow	2014	504	26/02	149	13458	08/03	109 (98)	6953	11/03	30	183			
BEIS	UvA	Meadow	2014	506	13/02	166	11498	04/03	136	5515	22/02	118	2989	16/04	58	6792
BEIS	UvA	Meadow	2014	4032	26/03	122 (105)	27645	14/03	127	53754	15/03	82	12881			
BEIS	UvA	Meadow	2014	4034	01/04	112	25287									
BEIS	UvA	Meadow	2014	5023	29/03	116 (31)	2098	09/03	125	10060	10/03	124 (122)	12879			
BEIS	UvA	Meadow	2014	5024	19/02	148	12594	07/03	89 (58)	3731	12/03	25 (22)	205			
BEIS	UvA	Meadow	2014	5025	02/04	85 (49)	3902									
BEIS	UvA	Meadow	2014	5026	10/04	79 (73)	9891	28/03	94 (92)	9121						
BEIS	UvA	Meadow	2014	5027	28/04	114 (68)	28681	04/03	44	2351						
BEIS	UvA	Meadow	2014	5029	25/03	117	16363	14/03	83	12259						
BEIS	UvA	Meadow	2014	5033	08/03	146	7756	09/03	135	18053						
				Mean	02/05	70 (63)	11787	17/03	104 (100)	12213	21/03	84 (81)	7351	03/04	75 (67)	5764

[1] Excluded from all analyses.

Table 3.2 Summary of breeding season data collected for Lesser Black-backed Gulls fitted with GPS tags at Barrow-in-Furness for the 2016-2019 breeding seasons. All data came from the Ørsted funded project and from Movetech GPS devices. Tag IDs are referred to throughout the report. Birds were tagged at 'sub-colony' sites of Devonshire Dock and Furness General Hospital (FGH). Some tags did not provide continuous data throughout the period of study – the total 'useable' continuous spans of data are also provided. The number of GPS fixes reported is after cleaning of data to remove erroneous points.

					2016			2017			2018			2019		
Project	**Tag type**	**Sub colony**	**Tag Deployed**	**Tag ID**	**Start date**	**Data duration days (usable days)**	**GPS fixes**	**Start date**	**Data duration days (usable days)**	**GPS fixes**	**Start date**	**Data duration days (usable days)**	**GPS fixes**	**Start date**	**Data duration days (usable days)**	**GPS fixes**
Ørsted	MT	Dock	2016	208	13/06	85	2687	13/05	37	1220	01/05	42	1222			
Ørsted	MT	Dock	2016	225	13/06	126 (123)	2605	01/04	196 (194)	6349	17/04	57	1752			
Ørsted	MT	Dock	2016	456[1]	13/06	0	0									
Ørsted	MT	Dock	2016	471	15/06	49 (27)	242	21/02	42 (25)	118						
Ørsted	MT	Dock	2016	486	15/06	49 (24)	121	09/03	139 (112)	562						
Ørsted	MT	Dock	2016	488[1]	13/06	114 (1)	22									
Ørsted	MT	Dock	2016	492	13/06	42	407	28/03	90 (87)	804	02/04	75 (64)	726	28/03	78 (63)	594
Ørsted	MT	FGH	2016	204	10/06	54 (22)	391	28/04	125	2978	18/04	132 (130)	3001			
Ørsted	MT	FGH	2016	276	10/06	63 (16)	1247									
Ørsted	MT	FGH	2016	472[1]	07/06	6	46									
Ørsted	MT	Dock	2017	687				30/05	90	1329						
Ørsted	MT	Dock	2017	707				30/05	59	869						
Ørsted	MT	Dock	2017	708				23/06	41 (24)	160						
Ørsted	MT	Dock	2017	711				14/06	40 (18)	146						
Ørsted	MT	Dock	2017	717				14/06	21 (14)	133						
Ørsted	MT	Dock	2017	718				12/06	26 (24)	293						
Ørsted	MT	Dock	2017	725				15/06	43	550						
Ørsted	MT	Dock	2017	727				30/05	64	863						

Ørsted	MT	Dock	2017	729				31/05	33	461						
Ørsted	MT	Dock	2017	742				15/06	16 (13)	163						
Ørsted	MT	Dock	2017	744				30/05	50	599						
Ørsted	MT	Dock	2017	777				15/06	40	513						
Ørsted	MT	FGH	2017	715				01/06	52	556						
Ørsted	MT	Dock	2018	851							14/06	63	999	03/03	74 (29)	487
Ørsted	MT	Dock	2018	863							14/06	48	374			
Ørsted	MT	Dock	2018	868							14/06	43	416	16/03	135 (114)	1211
Ørsted	MT	Dock	2018	885							22/05	59 (57)	437			
Ørsted	MT	Dock	2018	914							12/06	51 (23)	191			
Ørsted	MT	Dock	2018	916							07/06	74	1023	25/04	120	1633
Ørsted	MT	Dock	2018	918							07/06	28	269			
Ørsted	MT	Dock	2018	919							07/06	70	719	28/03	101	1222
Ørsted	MT	Dock	2018	920							11/06	58 (56)	534	23/02	158 (154)	1588
				Mean	12/06	59 (37)	777	17/05	63 (58)	982	23/05	62 (58)	897	20/03	111 (97)	1123

[1] Excluded from all analyses.

3.4 Results

3.4.1 Foraging trips

Colony scale

Over the 2016-2019 breeding seasons, a total of 8,128 and 3,445 complete foraging trips were recorded for 36 and 29 of the individuals tracked from the South Walney and Barrow colonies respectively (Table 3.3). At South Walney, trip duration increased significantly (β = 0.74, χ^2_1 = 14.44, *P* < 0.001) from a mean (± SD) of 5 ± 4.9 to 7.0 ± 5.8 hours between the 2016 and 2019 seasons and correspondingly the mean foraging range per trip also increased significantly over time (β = 1.24, χ^2_1 = 6.25, *P* =0.012) from 9.3 ± 10.2 to 14.2 ± 18.4 km. Similarly, data from Barrow indicate foraging trip duration increased from 5.5 ± 5.0 to 7.8 ± 5.9 hours between 2016 and 2019, although this increase was not significant (β = -0.50, χ^2_1 = 2.99, *P* = 0.084). Foraging ranges were also more similarly across years for birds tagged in Barrow and no significant changes over time were detected (β = -0.35, χ^2_1 = 1.65, *P* = 0.199) (Table 3.3).

Overall during the course of the study, compared with data from Barrow, individuals tracked from South Walney were shown to leave the colony on trips for significantly shorter periods (β = -2.63, χ^2_1 = 21.47, *P* <0.001) but travel significantly greater distances (β = 4.30, χ^2_1 = 13.89, *P* <0.001). However, in making comparisons across years at the colony level, it should be noted the number of individuals with data available in each year at each colony varied. Foraging trip statistics for each individual in each year are detailed in Appendix A2.

Table 3.3 Foraging trip summaries for Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA and Barrow-in-Furness during the 2016-2019 breeding seasons. Trips were defined as continuous periods spent away from the breeding site and trips longer than 24 hours and shorter than 30 minutes were excluded from summaries. Any incomplete trips where the data collection was truncated were also excluded.

Colony	Year	N birds	N complete trips (incomplete)	Trip duration (hrs) mean ± SD (max)	Foraging range (km) mean ± SD (max)	Total distance per trip (km) mean ± SD (max)
South Walney	2016	36	3905 (36)	5.0 ± 4.9 (23.9)	9.3 ± 10.2 (87.5)	22.2 ± 27.6 (287.8)
	2017	23	2612 (15)	6.5 ± 5.5 (23.9)	10.4 ± 10.4 (83.8)	25.0 ± 26.9 (213.7)
	2018	13	1112 (11)	6.4 ± 5.1 (23.9)	10.3 ± 11.9 (86.7)	23.6 ± 28.4 (191.8)
	2019	7	499 (4)	7.0 ± 5.8 (22.2)	14.2 ± 18.4 (89.1)	31.8 ± 41.9 (227.9)
Barrow	2016	5	481 (28)	5.5 ± 5.0 (23.9)	5.1 ± 5.2 (42.8)	12.0 ± 14.4 (131.6)
	2017	18	1359 (20)	6.8 ± 5.5 (23.9)	4.7 ± 6.7 (91.1)	10.7 ± 15.6 (207.0)
	2018	13	857 (15)	7.6 ± 5.8 (23.9)	6.2 ± 8.1 (88.0)	13.0 ± 17.6 (183.4)
	2019	6	748 (16)	7.8 ± 5.9 (23.9)	5.9 ± 7.1 (93.2)	12.1 ± 15.7 (206.2)

Individual scale

Data were collected from a total of 13 individuals from South Walney for at least three consecutive years (Table 3.4). Despite significant overall increases in foraging trip duration and range for the colony as a whole over the study period, no significant individual changes over time were detected for trip duration. Only two of 13 birds showed a significant increase in foraging range, both these individuals almost exclusively visited terrestrial habitats during the study.

Table 3.4 Trends in foraging trip duration (a) and range (b) for individual Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA for at least three consecutive years during between 2016-2019. Trips were defined as continuous periods spent away from the breeding site and trips longer than 24 hours and shorter than 30 minutes were excluded from summaries. Any incomplete trips where the data collection was truncated were excluded and the sample size for trips per individual in each year is shown in parentheses after trip duration values. Significant trends over time are highlighted in bold.

a. Trip duration ± SE (hrs);

	Walney Extension Phase				
	Pre-construction	**Construction**		**Operational**	
Tag ID	**2016**	**2017**	**2018**	**2019**	**Trend**
202	5.5 ± 3.9 (114)	7.2 ± 4.7 (95)	7.3 ± 4.9 (107)		β = 0.90, $F_{1,1}$ = 3.80, *P* = 0.301
254	6.9 ± 6 (67)	8.9 ± 5.2 (117)	7 ± 3.7 (118)	8.5 ± 4.7 (83)	β = 0.29, $F_{1,2}$ = 0.31, *P* = 0.636
503	5 ± 5 (134)	6.4 ± 4.4 (82)	5.7 ± 5.2 (90)		β = 0.35, $F_{1,1}$ = 0.33, *P* = 0.667
504	8.7 ± 6.8 (167)	7.4 ± 6.1 (112)	13.5 ± 6.7 (11)		β = 2.40, $F_{1,1}$ = 1.26, *P* = 0.463
506	6.5 ± 5.2 (240)	6.4 ± 5.1(131)	6.3 ± 5 (100)	6.5 ± 6.1 (63)	β = -0.01, $F_{1,2}$ = 0.04 , *P* = 0.865
4032	7.2 ± 6.4 (113)	8.4 ± 7.6 (88)	7.6 ± 5.7 (92)		β = 0.20, $F_{1,1}$ = 0.12, *P* = 0.788
5023	7.2 ± 5.9 (55)	7.8 ± 6 (150)	7.4 ± 5.6 (164)		β = 0.10, $F_{1,1}$ = 0.12, *P* = 0.788
5024	4 ± 4 (320)	4.9 ± 4.3 (139)	9.2 ± 5.1 (15)		β = 2.60, $F_{1,1}$ = 7.02, *P* = 0.230
5360	4 ± 3.7 (72)	3.9 ± 4.2 (36)	2 ± 1.4 (87)	4.8 ± 5.6 (54)	β = 0.05, $F_{1,2}$ = 0.01, *P* = 0.946
5367	2.6 ± 2.8 (194)	4.5 ± 4.1 (216)	5.2 ± 4.6 (135)		β = 1.30, $F_{1,1}$ = 14.08, *P* = 0.166
5377	7.2 ± 5.5 (53)	8.2 ± 5.5 (61)	6.7 ± 5 (54)	10.8 ± 6.1 (42)	β = 0.93, $F_{1,2}$ = 1.52, *P* = 0.343
5379	7.3 ± 6.6 (158)	7.3 ± 6.4 (287)	6.4 ± 4.9 (113)	7.3 ± 5.6 (167)	β = -0.09, $F_{1,2}$ = 0.14, *P* = 0.742
5382	4.7 ± 6 (73)	6.6 ± 5.4 (31)	6.2 ± 4.4 (26)	8.1 ± 5.5 (39)	β = 0.98, $F_{1,2}$ = 9.08, *P* = 0.095

b. Foraging range ± SE (km).

	Walney Extension Phase				
	Pre-construction	**Construction**		**Operational**	
Tag ID	**2016**	**2017**	**2018**	**2019**	**Trend**
202	9.8 ± 11.2	7.6 ± 6.8	9.2 ± 8.3		β = -0.30, $F_{1.1}$ = 0.07, *P* = 0.830
254	15.3 ± 11.1	23.9 ± 22.1	15.4 ± 17.3	28.1 ± 24.4	β = 2.99, $F_{1,2}$ = 1.15, *P* = 0.395
503	6.5 ± 7	8.4 ± 6.7	7.8 ± 7.8		β = 0.65, $F_{1.1}$ = 0.81, *P* = 0.533
504	8.9 ± 9.9	7.5 ± 9.5	13.9 ± 13.5		β = 2.50, $F_{1.1}$ = 1.23, *P* = 0.467
506	9.6 ± 8.9	9.6 ± 7.9	9 ± 13	11.4 ± 13.9	β = 0.48, $F_{1,2}$ = 1.10, *P* = 0.404
4032	13.8 ± 12.3	14.6 ± 13.7	12.3 ± 11.5		β = -0.75, $F_{1.1}$ = 0.70, *P* = 0.556
5023	10.3 ± 9.5	9.2 ± 7.9	9.5 ± 8.8		β = -0.40, $F_{1.1}$ = 0.98, *P* = 0.503
5024	**6.6 ± 5.7**	**8.9 ± 7.6**	**11 ± 6.6**		**β = 2.20, $F_{1.1}$ = 1452, *P* = 0.017**
5360	15.2 ± 18	9.6 ± 8.5	9.5 ± 11.5	19.8 ± 31.1	β = 1.37, $F_{1,2}$ = 0.29, *P* = 0.643
5367	5.5 ± 8.5	8.8 ± 13.9	9.9 ± 15.1		β = 2.20, $F_{1.1}$ = 12, *P* = 0.179
5377	18.8 ± 11.6	16.7 ± 10.7	12.8 ± 10.5	19.4 ± 10.4	β = -0.21, $F_{1,2}$ = 0.02, *P* = 0.909
5379	6.9 ± 3.2	7.8 ± 5.4	7.5 ± 5.8	7.1 ± 5.9	β = 0.03, $F_{1,2}$ = 0.02, *P* = 0.904
5382	**9.9 ± 12.3**	**13 ± 13.3**	**14.9 ± 16.6**	**16.1 ± 14.4**	**β = 2.05, $F_{1,2}$ = 45.93, *P* = 0.021**

3.4.2 Connectivity with the areas of the Walney Extension and Burbo Bank Extension and other offshore wind farms

Overall, 20 of the 37 individuals tracked from South Walney and 12 of the 32 individuals from Barrow showed connectivity (at least one trip) with any offshore wind farms over the whole study. In total, six individuals (five from South Walney and one from Barrow) showed connectivity with the Walney Extension offshore wind farm and three from South Walney with the Burbo Bank Extension offshore wind farm (Table 3.5).

A greater number of individuals from South Walney than from Barrow connected with at least one offshore wind farm, although as a proportion of the total sample tracked across all years this difference was not significant (Fisher's Exact Test, P = 0.562). Similarly, the proportion of tracked individuals from South Walney connecting with offshore wind farms did not change significantly between years (Fisher's Exact Test, P = 0.898) nor the proportion connecting with the Walney Extension (Fisher's Exact Test, P = 0.653). Connectivity, however, was significantly different between years for birds tracked from Barrow (Fisher's Exact Test, P = 0.012), with relatively few individuals connecting with wind farms in 2017, relatively more during 2018, but none in 2019. However, only one individual from Barrow connected with the Walney Extension offshore wind farm.

Table 3.5 Connectivity between Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA and Barrow-in-Furness during the 2016-19 breeding seasons and offshore wind farms. Connectivity is here defined as GPS fixes lying within wind farm polygons during at least one trip away from the colony. The total number of different individuals from the annual sample connecting with at least one wind farm area is also presented.

			N individuals connecting with offshore wind farm areas							
Colony	**Year**	**N birds**	**Barrow**	**Ormonde**	**Walney 1**	**Walney 2**	**West of Duddon Sands**	**Walney Extension**	**Burbo Bank Extension**	**Total**
South Walney	2016	36	14	7	8	3	13	5	2	15
	2017	23	7	3	2	1	2	1		7
	2018	13	4	2	2		3	1	1	5
	2019	7	2	1	1	1	2	1	1	3
Barrow	2016	7	1	1		2				3
	2017	19	2	1	1		2			3
	2018	13	3	4	3	2	5	1		8
	2019	6								0

3.4.3 Area usage

Colony Scale

Colony level UDs (cumulative across all birds) for Lesser Black-backed Gulls tracked from both the South Walney (Fig. 3.3) and Barrow (Fig. 3.4) colonies indicate that birds predominantly used terrestrial areas when on trips away from the colony during the breeding season. Individual UDs are shown in Appendix A3. Over the course of the entire study, the individual 50% UD (core area) and 95% UD (home range) areas were significantly larger for birds from South Walney compared with those from Barrow (50% UD: $\beta = 10.64$, $\chi^2_1 = 8.40$, $P = 0.004$; 95% UD: $\beta = 164.22$, $\chi^2_1 = 7.29$, $P = 0.007$). Habitats most frequently visited within the core 50% UD for individuals from South Walney included agricultural land on the Furness Peninsula and landfill sites across Morecambe Bay (Fig. 3.5). Habitats visited by individuals from Barrow were similar but an apparently greater use was made of urban areas. A wider variety of overall habitat use was recorded for individuals from South Walney but this could be expected given the larger sample size and that individual birds tended to be consistent in their habitat preference.

The percentage of time spent offshore was <5% for all years of the study (Table 3.6) and <2% in the first three years. Individual time budgets are shown in Appendix A4. The UDs for each colony indicate very limited offshore use for birds breeding in Barrow compared with those from South Walney.

The tracking data from South Walney suggest that over time, 50% UD areas (Appendix A5) significantly increased ($\beta = 3.94$, $\chi^2_1 = 4.95$, $P = 0.026$), with the greatest area utilised in 2018. However, there was no significant increase in the area for the 95% UD ($\beta = 55.29$, $\chi^2_1 = 3.70$, $P = 0.054$). There were no significant differences detected in the area of the 50% UD ($\beta = 0.02$, $\chi^2_1 = 0.02$, $P = 0.894$) or the 95% UD ($\beta = 21.93$, $\chi^2_1 = 1.53$, $P = 0.216$) over time for birds tracked from Barrow.

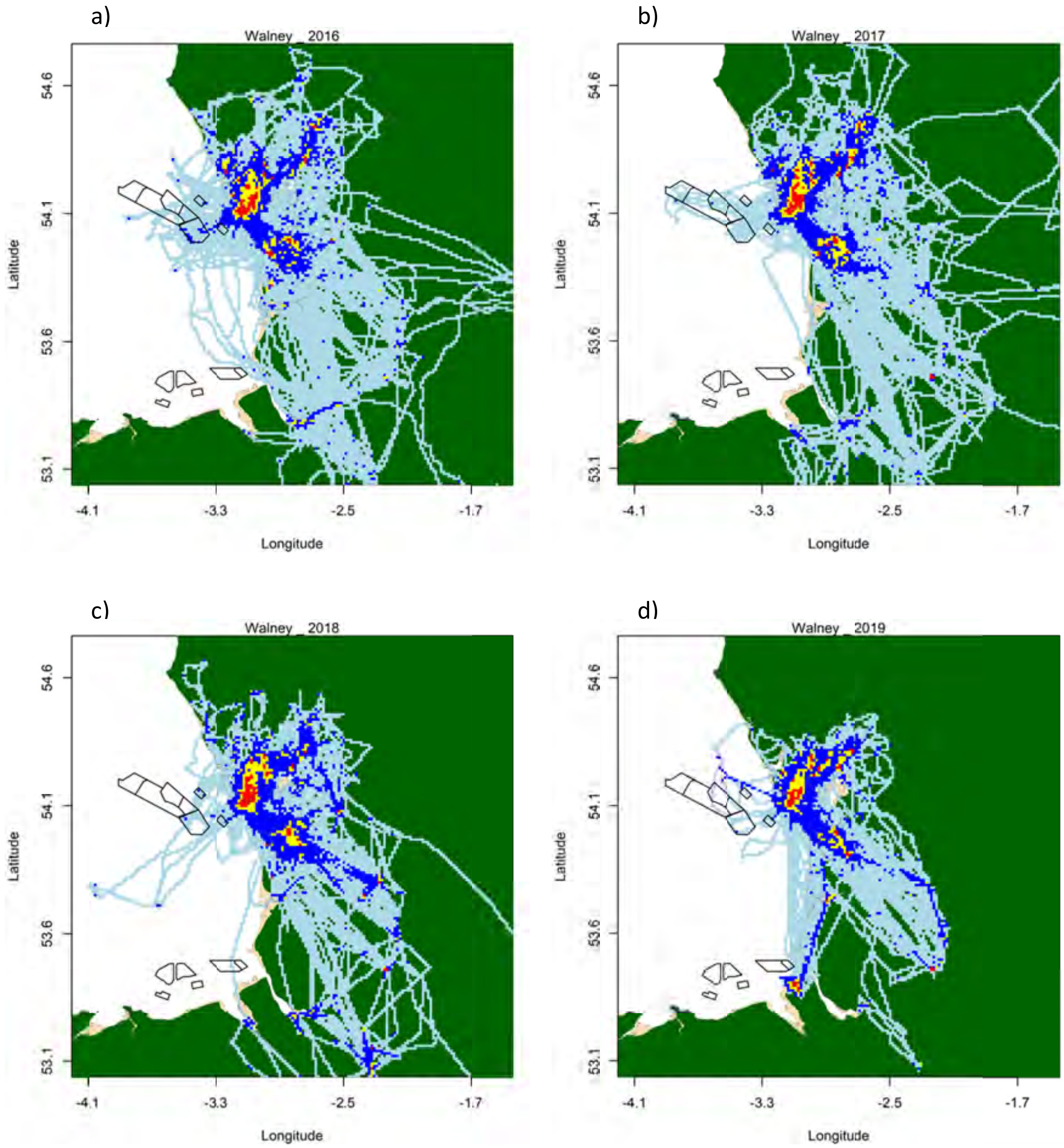


Figure 3.3 Utilisation distributions calculated using a Time-In-Area approach for all Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA during the 2016-2019 breeding seasons (a-d) (n = 36, 23, 13, 7 birds respectively). Light blue = 100% UD, dark blue = 95% US, yellow = 75% UD, red = 50% UD.

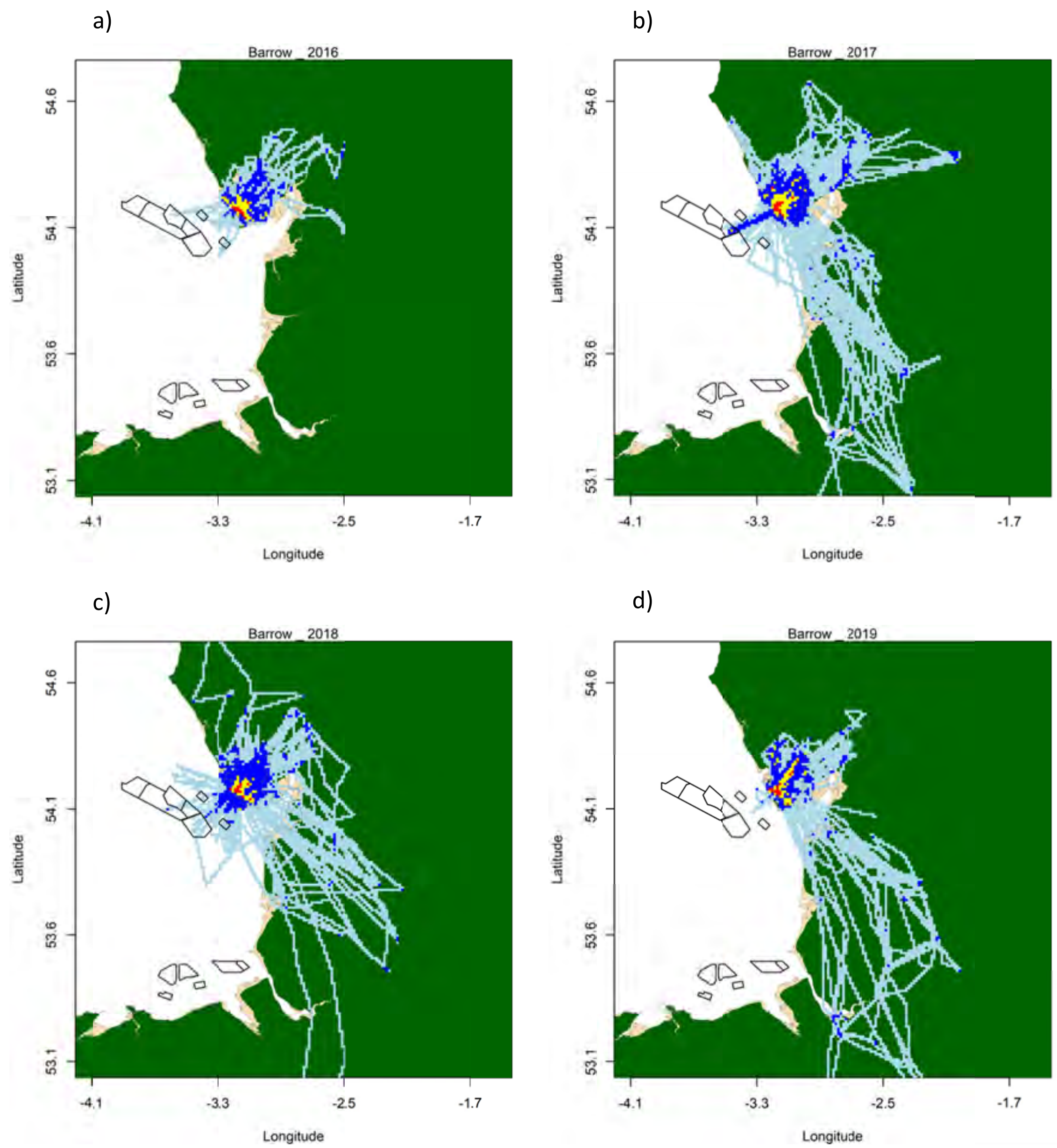


Figure 3.4 Utilisation distributions calculated using a Time-In-Area approach for all Lesser Black-backed Gulls tracked from Barrow-in-Furness during the 2016-2019 breeding seasons (a-d) (n = 7, 19, 13, 6 birds respectively). Light blue = 100% UD, dark blue = 95% US, yellow = 75% UD, red = 50% UD.

Figure 3.5 Satellite imagery showing examples of typical land use types from within the core 50% utilisation distribution of tracked Lesser Black-backed Gulls breeding at South Walney (yellow) or Barrow (purple) between 2016-2019. Habitats visited include agricultural (top left and bottom right), landfill (top right), urban (bottom left) and intertidal (bottom right). Imagery © 2020 Google.

Table 3.6 Time budgets of birds tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA and Barrow-in-Furness during the 2016-2019 breeding seasons. Offshore is defined as further than 1 km from mean high water line and outside the mouth of any estuary.

Colony	Year	N birds	Combined continuous tracking duration (days)	Time away from nest (%)	Time offshore (%)
South Walney	2016	36	2519	56.1	1.5
	2017	23	2278.4	67.7	0.9
	2018	13	1041.8	64.0	0.8
	2019	7	469.9	73.3	4.8
Barrow	2016	7	350.3	52.7	2.8
	2017	19	1082.9	69.9	1.9
	2018	13	755.1	63.3	1.9
	2019	6	580.1	63.4	0.2

Individual scale

Although the average area of the 50% UD across all individuals tracked from South Walney increased significantly over the duration of the study, a similar increase was not apparent at the individual level where data were available for multiple years. None of the 13 individuals with multi-year data from South Walney showed significant changes in their core area over time (Table 3.7) suggesting that changes to average individual home ranges were a result of difference between individuals in different years and not changes in individual behaviour.

Table 3.7 Summary of core (50%) utilisation distribution areas using a Time-In-Area approach for individual Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA with consecutive years of data.

	Walney Extension Phase				
	Pre-construction	**Construction**		**Operational**	
Tag ID	**2016**	**2017**	**2018**	**2019**	**Trend**
202	11	15	23		β = 6.00, $F_{1,1}$ = 27, *P* = 0.121
254	36	79	43	27	β = -6.30, $F_{1,2}$ = 0.29, *P* = 0.643
503	22	51	32		β = 5.00, $F_{1,1}$ = 0.13, *P* = 0.778
504	22	41	55		β = 16.50, $F_{1,1}$ = 130.7, *P* = 0.056
506	53	38	38	72	β = 5.70, $F_{1,2}$ = 0.53, *P* = 0.544
4032	61	39	72		β = 5.50, $F_{1,1}$ = 0.12, *P* = 0.788
5023	22	19	36		β = 7.00, $F_{1,1}$ = 1.47, *P* = 0.439
5024	26	23	29		β = 1.50, $F_{1,1}$ = 0.33, *P* = 0.667
5360	10	2	1	4	β = -1.90, $F_{1,2}$ = 1.18, *P* = 0.392
5367	6	30	20		β = 7.00, $F_{1,1}$ = 0.51, *P* = 0.606
5377	64	20	20	29	β = -10.50, $F_{1,2}$ = 1.44, *P* = 0.353
5379	3	10	38	14	β = 6.10, $F_{1,2}$ = 0.73, *P* = 0.482
5382	12	6	23	35	β = 8.60, $F_{1,2}$ = 6.15, *P* = 0.131

Overlaps of utilisation distributions with offshore wind farms

Mean UDs and the percentage overlap of these with offshore wind farms are shown in Table 3.8. As expected the greatest overlap occurred with operational sites in closer proximity to the colonies. Averaged across all individuals, there was no overlap between the 50% UD, i.e. the core area, and offshore wind farms. For birds from both colonies, less than 2% of the 95% UD home range area, typically representative of total home range, overlapped with offshore wind farms. There was some variation between years in the amount of overlap with offshore wind farms, with the greatest degree of overlap occurring during 2016 for birds from South Walney and during 2017 for birds from Barrow.

Overlap with the Walney Extension offshore wind farm was <0.05% and <1% for the 95% and 100% UDs respectively for individuals tracked from the South Walney colony over each of the four years of the study. Only one bird from Barrow connected with the Walney Extension area (Table 3.5) resulting in a maximum overlap with the 95% UD of 0.22% in 2018. Only birds from tracked from South Walney showed any overlap with the Burbo Bank Extension area, albeit marginally, with a maximum of 0.07% of the 100% UD area during 2018 and 2019. The overall time spent inside any of the wind farm areas throughout the study was <1% of total tracking time in each of the four study years. Given the relatively limited use of the Walney Extension and Burbo Bank Extension offshore wind farms, it was not possible to undertake formal assessment of changes in the use of these sites over time, through their construction and into operation.
While use of the Walney Extension and Burbo Bank Extension sites was limited, the combined data on interactions with the wind farms local to the breeding colonies from this and the previous BEIS

study have proved extremely valuable in furthering understanding of the potential effects of offshore wind farms. Analysis of the macro-scale and meso-scale responses of Lesser Black-backed Gulls to offshore wind farms is reported in Johnston *et al.* (in prep.) and their behaviour within them in Thaxter *et al.* (in prep.).

Table 3.8 Summary of utilisation distribution analyses using a Time-In-Area approach for all Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA and Barrow-in-Furness during the 2016-2019 breeding seasons. Included are mean UD sizes and the percentage spatial and temporal overlap of the 100% UD (full area use), 95% (home range) and 50% UD (core area) with offshore wind farms areas.

					Overlaps with each UD (%)																							
Spatial		**UD area (km^2)**			**Barrow**			**Ormonde**			**Walney 1**			**Walney 2**			**West of Duddon Sands**			**Walney Extension**			**Burbo Bank Extension**			**Total**		
Colony	**Year (n)**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**
Walney	2016 (36)	68	1381	9496		0.08	0.11		0.08	0.10			0.27			0.19		1.00	0.70			0.28			0.01		1.44	1.66
	2017 (23)	83	1410	10972			0.07			0.05			0.15		0.07	0.35			0.53		<0.01	0.69					0.76	1.85
	2018 (13)	80	1644	7190		0.06	0.13		0.12	0.13			0.07					0.08	0.56		0.02	0.02			0.07		0.27	0.99
	2019 (7)	60	1134	4521		0.02	0.16			0.11			0.24			0.19		0.09	0.65			0.27			0.07		0.38	1.70
Barrow	2016 (7)	12	263	982			0.70			0.61						0.88											0	2.19
	2017 (19)	16	506	4087			0.15			0.02		1.66	0.38					0.01	0.12								1.67	0.67
	2018 (13)	13	457	4762		0.04	0.19			0.12			0.22			0.15			0.70		0.22	0.15					0.19	1.53
	2019 (6)	16	343	3175																							0	0
Temporal		**Combined time in UD (days)**																										
Colony	**Year**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**	**50**	**95**	**100**
Walney	2016	706	1343	1413		0.01	0.03		0.04	0.05			0.01			<0.0		0.17	0.27			<0.01			<0.01		0.22	0.37
	2017	769	1466	1543			0.01			<0.0			<0.0		0.01	0.02			0.04		<0.01	0.04					0.04	0.11
	2018	333	633	667		0.01	0.02		0.01	0.01			<0.0					0.01	0.04		<0.01	<0.01			<0.01		0.03	0.08
	2019	172	327	344		<0.01	0.01			<0.0			0.01			0.01		0.01	0.05			<0.01			<0.01		0.02	0.09
Barrow	2016	90	175	185			<0.01			0.01						0.02											0	0.03
	2017	375	719	757			<0.01			<0.0		0.57	0.56					<0.0	0.01								0.57	0.57
	2018	232	454	478		<0.01	0.03			0.01			0.02			0.01			0.07		0.01	0.04					0.04	0.17
	2019	184	350	368																							0	0

4. SUMMARY OF NON-BREEDING SEASON MOVEMENTS

A summary of the non-breeding season movements is presented for Lesser Black-backed Gulls tracked from the South Walney (Fig. 4.1) and Barrow (Fig. 4.2) colonies. All individuals which downloaded or transmitted data in each breeding season also provided useable data for the preceding non-breeding period allowing calculation of basic migration statistics (Table 4.1). Data were also available from several individuals (South Walney – IDs 4034, 5362, 220 & 278; Barrow – IDs 471 & 863) which did not contribute data to the subsequent breeding period due to relocation away from the study area or potential device failure, increasing non-breeding sample sizes. Individual data summaries are presented in Appendix A6.

Consistent with findings from previous tracking studies in the UK (Thaxter *et al.* 2018b), there was variation in the main wintering location selected. All individuals (except one wintering in Morocco during the 2016/17 period) from the South Walney colony remained in Europe with a tendency to winter in Northern Europe (such as UK and France) over the course of the study. One individual (ID 5024) was recorded travelling to Denmark (Fig. 4.1b) during the post-breeding period but subsequently returned to the UK to winter. Although the sample size was smaller, individuals tracked from the Barrow colony were apparently more evenly spread across the various wintering destinations selected and travelled a greater maximum distance from the colonies compared with birds from South Walney (Table 4.1). There was a large amount of individual variation, however, with the range for maximum distance travelled away from the colony during the non-breeding season ranging 85 to 2370 km for birds from South Walney and from 188 to 2473 km for birds from Barrow (Appendix A6). Individual birds tended to be consistent between years in their selected wintering site.

On migration and during winter, tracked Lesser Black-backed Gulls tended to use similar habitats to the breeding season. Landfill sites appear important and preferred for many individuals throughout the species winter range. Particularly in Southern Europe and North Africa some individuals appeared to rely heavily on coastal foraging and associated with towns and areas linked with fishing.

Initially during the study, the sampling rate for the devices was set to record locations every hour during the non-breeding season. However, in many cases and especially for those individuals which wintered in Northern Europe where the solar conditions were less adequate for recharging the batteries this rate could not be continuously sustained. As a result there are frequent data gaps in the non-breeding season data where devices were not recording location, often for days at a time but occasionally longer gaps. Only one individual (ID 486) was excluded from summaries as the data were too intermittent and sparse to allow interpretation of the main wintering destination.

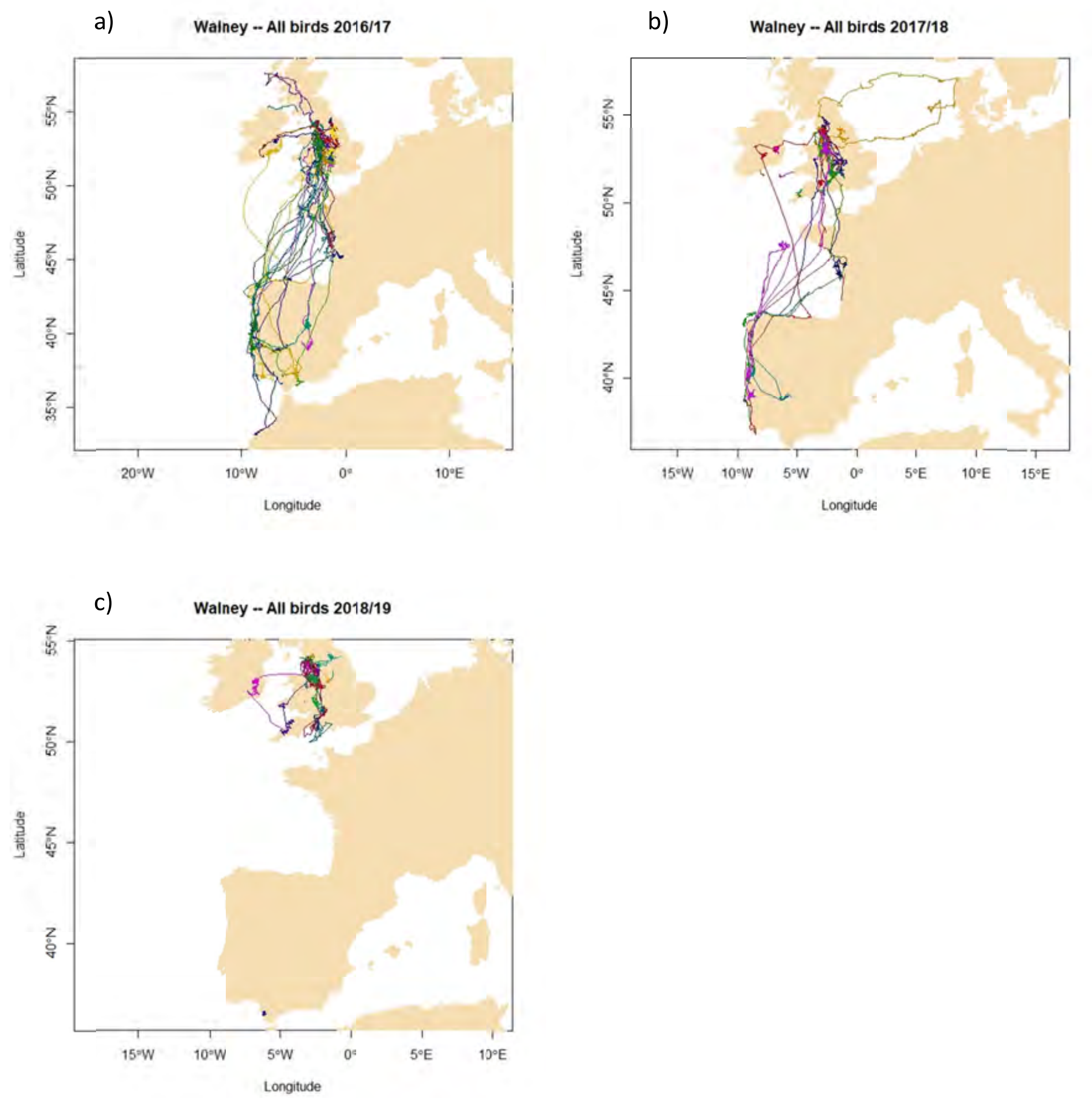


Figure 4.1 Non-breeding season movements for Lesser Black-backed Gulls tracked from South Walney in the Morecambe Bay and Duddon Estuary SPA in (a) 2016/17, (b) 2017/18 and (c) 2018/19 (a-c). Different individuals are shown in different colours (randomly allocated each year).

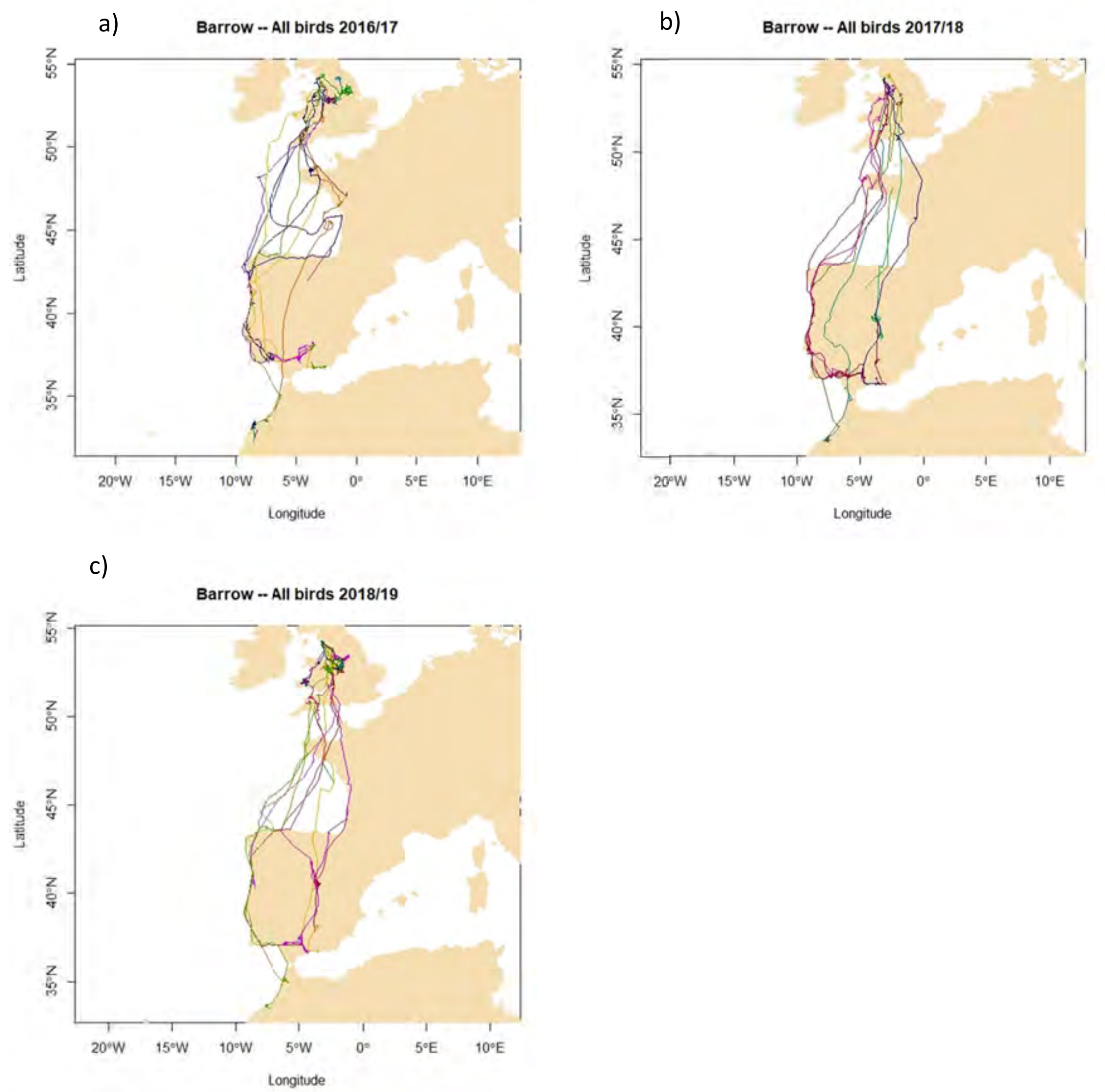


Figure 4.2 Non-breeding season movements for Lesser Black-backed Gulls tracked from Barrow-in-Furness in (a) 2016/17, (b) 2017/18 and (c) 2018/19. Different individuals are shown in different colours (randomly allocated each year).

Table 4.1 Summary of non-breeding movements of Lesser Black-backed Gulls tracked from South Walney and Barrow-in-Furness colonies between 2016 and 2019. All values are mean ± SE.

								Main winter destination		
Period	**N**	**Mean departure date**	**Mean return date**	**Data duration (days)**	**Data gaps (days)**	**Maximum distance (km)**	**Total distance (km)**	**North Europe**	**South Europe**	**North Africa**
South Walney										
2016/17	25	01/08	09/03	220.1 ± 9.0	54.9 ± 9.9	1065.6 ± 157.6	8987.6 ± 966.3	13	11	1
2017/18	15	08/07	27/02	234.3 ± 11.2	70.9 ± 16.6	878.7 ± 178.1	7300.6 ± 946.9	10	5	0
2018/19	7	06/07	03/04	270.4 ± 7.5	191.6 ± 24.4	499.4 ± 233.4	6026.6 ± 1187.4	6	1	0
Barrow										
2016/17	6	20/08	02/04	225.2 ± 13.4	60.7 ± 22.5	1797.6 ± 282.1	8507.7 ± 1383.6	1	3	2
2017/18	5	23/08	28/03	216.3 ± 38.1	41.9 ± 15.2	1997.2 ± 77.2	8855.6 ± 1771.4	0	4	1
2018/19	7	11/08	20/03	157.8 ± 16.6	63.1 ± 12.9	1392.9 ± 299.0	8397.1 ± 1223.0	4	2	1

5. DISCUSSION

5.1 Foraging trips and area use

Lesser Black-backed Gulls are known to forage up to 180 km offshore during the breeding season (Thaxter *et al*. 2012) and previous studies from the South Walney colony report annual mean foraging ranges between 11-14 km (Thaxter *et al.* 2018b). This is consistent with the additional foraging range data collected during the present study where means for individuals from South Walney were from 9.3 and 14.2 km between 2016 and 2019. This increase in mean foraging range across all individuals was significant over time, as was a corresponding increase in the mean trip duration. However, when the movements of individuals with multiple years of data were tested separately, only two showed increases in foraging range over time. Consequently, it is possible that annual variation at the colony scale may have been the result of the sample of individuals varying between years rather than changes to individual behaviour.

Foraging ranges can be colony specific. Thaxter *et al.* (2018b), for example, reported an annual mean range of up to 32 km for Lesser Black-backed Gulls breeding offshore island of Skokholm in Wales, which require longer commuting flights to reach suitable terrestrial foraging areas. Urban breeding birds from Barrow in the present study, although very close to South Walney geographically, had significantly smaller foraging ranges with a maximum annual mean of 6.2 km recorded in 2018. Birds from Barrow made apparently greater use of the proximate anthropogenic areas, as has been shown for birds from other urban breeding colonies (Spelt *et al.* 2019), rather than commuting to foraging areas further afield as birds from South Walney tended to.

There should also be some caution when comparing foraging ranges recorded from telemetry data between years as movements may vary over the breeding season (Klaassen *et al.* 2012, Thaxter *et al.* 2015a) and as the data collection periods in years subsequent to deployments, which were made during late incubation, also included pre-breeding periods. This issue was partially addressed in this study with the inclusion of the additional data from birds previously tagged at South Walney in the BEIS funded study birds.

The core home ranges for both colonies indicated predominantly terrestrial foraging through the breeding season, which has been reported for other coastal colonies as well (Garthe *et al.* 2016). The overall time spent offshore was <5% across all years and was highest in 2016 for individuals from Barrow and in 2019 for individuals from South Walney. Landfill sites have historically been an extremely important foraging resource for gulls from South Walney (Sibly & McCleery 1983) and continue to be (Thaxter *et al.* 2018b). However, changes in waste management practices, including closure of a large landfill site at Fleetwood prior to the 2017 breeding season exploited by birds from the colonies, may have affected movements. Langley *et al.* (in prep.) reported how the foraging ranges and trip durations of birds from colonies at both South Walney and the Ribble Estuary increased between 2016 and 2017 following landfill closures. There was further evidence of novel site use in this study with birds from South Walney utilising areas of the Wirral during 2019 which had not been previously visited. This may thus have been a factor in the increased time spent offshore in 2019.

5.2 Connectivity and overlaps with wind farm areas

Overall, there was very little direct overlap between the individuals tracked from the South Walney and Barrow colonies and either the Walney Extension or Burbo Bank Extension wind farm areas. Less than 0.05% of the total tracking time across all individuals was spent inside either of the extension areas and less than 1% in any given year within any operational wind farm. As such we did not attempt to formally assess changes in the specific use of these areas between the pre-construction, construction and operational phases but instead assessed whether there may have been wider changes in the use of offshore areas and offshore wind farms over this period as a possible consequence of the developments.

The numbers of individuals which connected with wind farms in the area were relatively stable across years for birds tracked from South Walney. Except a slight drop in 2017 (30%), c. 40% of the individuals tracked visited the offshore wind farms at least once each breeding season between 2016 and 2019. There was more variation for individuals tracked from Barrow (although sample sizes were smaller), with only 16% of individuals visiting offshore wind farms in 2017, up to 62% in 2018 but none at all in 2019 (Fig. 3.5). However, even for those individuals which connected with the offshore wind farm areas, actual utilisation appeared to be low in this study. There was considerable variation in the spatial and temporal overlaps of individual's home ranges with offshore wind farms (Appendix A5). The core home ranges (50% UDs) of only two individuals from South Walney overlapped with offshore wind farms, while across birds, total home ranges (95% UDs) showed less than 2% overlap with offshore wind farms. These values are lower than recorded during the 2014-2016 BEIS study when there was a 6% overlap in total home ranges (95% UDs) across all individuals and a maximum of 14% in 2014 (Thaxter *et al.* 2018b) (although some caution is needed as the methodology used to calculate home ranges differs). However, reduced overlaps with offshore wind farms of less than 1% in 2015 and 2016 are consistent with the findings of this report.

It is possible that the long-term deployment of devices had an impact to the birds' behaviour over the study resulting in reduced offshore use. However, the pattern of high overlap with offshore wind farms during the year of deployment and reduced overlap in subsequent breeding seasons seen in the BEIS study was not observed for the new sample of birds tagged in this study during 2016 and overlap with offshore wind farms was low throughout. The more obvious difference between 2014 and 2015-2019 was a change in overall productivity at the South Walney colony. From 2015 wide scale chick failure was recorded at South Walney (Thaxter *et al.* 2018b) and low productivity continued throughout the present study. Lesser Black-backed Gulls from coastal sites traditionally forage offshore more during chick provisioning (Camphuysen 1995, Thaxter *et al.* 2015a) and consequently offshore use may be reduced in years when breeding success is poor.

5.3 Non-breeding season movements

Migration strategies recorded between 2016 and 2019 varied between individuals. The majority of individuals from South Walney remained in Northern Europe (notably France and the UK) during the non-breeding season but with others migrating to Iberia and one individual going as far as Morocco. Some movements south only occurred after extended periods in the UK in the post-breeding period and use of various stopover locations, whereas other movements to wintering sites were more direct. Although the samples were not balanced, on average, birds tracked from Barrow migrated further south during winter and a greater proportion were recorded in Southern Europe or Morocco

At a species scale, variation in migration strategy and behavioural plasticity can be advantageous, allowing responses to changes in environmental conditions, such as novel food sources (Shamoun-Baranes *et al.* 2017). However, individuals tended to be very consistent in their selection of wintering locations and migration strategies. Differences in migration strategy may consequently have impacts on populations, should pressures differ between wintering areas. Thaxter *et al.* (2019) assessed the vulnerability of Lesser Black-backed Gulls to collision with wind farms through the year using data for birds tracked from several UK colonies, including South Walney, and highlighted high levels of vulnerability to collision not just in the breeding season, but also in staging and wintering areas in southern and north western Spain.

5.4 Conclusions

The majority of Lesser Black-backed Gulls tracked from the South Walney and Barrow colonies made relatively limited use of the offshore environment during the 2016-2019 breeding seasons and less use than previous shown by birds tracked during the BEIS-funded study in 2014. This may reflect decrease breeding success at the colonies since 2015, as Lesser Black-backed Gulls tend to use offshore areas more during the chick-rearing period. Changes in waste management practices, including closure of a large landfill site at Fleetwood prior to the 2017 breeding season, conversely may have increased ranging subsequent behaviour and thus relative offshore use. The study highlighted the importance of considering data from multiple years to capture between year variation in breeding success and resource availability.

Reflecting the relatively limited use of offshore areas, overall use of offshore wind farms was also relatively low and less than seen during the 2014-2016 BEIS-funded study. Given the very limited connectivity with the Walney Extension and Burbo Bank Extension sites, it was not possible to formally assess changes in the specific use of these areas between the pre-construction, construction and operational phases and it is difficult to infer whether their development had any detrimental effect to the colonies studied, but it is unlikely. Further, there was no evidence of broad scale changes in area use associated with the construction of these new wind farms

While use of the Walney Extension and Burbo Bank Extension sites was limited, the combined data on interactions with the wind farms local to the breeding colonies from this and the previous BEIS study have proved extremely valuable in furthering understanding of the potential effects of offshore wind farms providing benefit to the wider offshore wind industry. Analysis of the macro-scale and meso-scale responses of Lesser Black-backed Gulls to offshore wind farms is reported in Johnston *et al.* (in prep.) and their behaviour within them in Thaxter *et al.* (in prep.).

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APPENDIX A1 ASSESSMENT OF THE POTENTIAL EFFECTS OF THE GPS DEVICES AND HARNESS ATTACHMENT

A1.1 Introduction

The use of telemetry devices, bio-logging, is commonplace in wildlife research for studying the movement, behaviour, and physiology of animals (Murray & Fuller 2000; Ropert-Coudert *et al.* 2009). However, in any such study, it is important to be able to determine whether the attachment of devices has any deleterious effects, both for the welfare of the individuals marked and to ensure that it is known that the behaviour of the individuals has not been affected and thus that robust scientific conclusions can be drawn from the study. Such monitoring should also help to highlight where there are issues for future studies and to enable improvements to be made to the design and attachment of devices.

The DECC (BEIS) funded project examining the interaction between Lesser Black-backed Gulls from the Alde-Ore SPA and Great Skuas from the Foula SPA and Hoy SPA provided an assessment of the potential effects of devices and harnesses through comparison with separate untagged control birds and their nests. Comparison was made between: (1) territory attendance; (2) breeding success; and (3) over-winter survival. No significant differences were found with respect to any of these parameters for Lesser Black-backed Gulls and thus it was concluded that the devices and harnesses used were suitable for the species across the temporal scales they were utilised. In contrast, for Great Skua, there was strong evidence that the devices and harnesses used in 2011 led to reduced over-winter survival. The particular devices and harnesses used were thus suitable for Lesser Black-backed Gull across the year, but were not suitable for Great Skua during the non-breeding season. The results of this evaluation are summarised in Thaxter *et al.* (2015), in order to help direct future bio-logging research and conservation for both species.

The potential effects of fitting devices using harnesses to Lesser Black-backed Gulls were further assessed at additional sites, including South Walney (24 individuals) and Skomer Island (25 individuals) for UvA devices deployed in 2014 under a subsequent BEIS funded project. No significant differences were found between tagged and control groups for return rates and propensity to breed in subsequent years or breeding success in 2014 (Thaxter *et al.* 2018) confirming findings from Thaxter *et al.* 2015).

The effects of tagging may, however, manifest differently at different locations and in different years, particularly if there are constraints on resources or poor conditions. Therefore, it is good practice, as well as an agreed requirement of the SMTP endorsement for this project, to continue to assess any potential effects. Here, we assess the potential effects of tagging of Lesser Black-backed Gulls at South Walney and Barrow between 2016 and 2019 though comparison of the return rates and breeding success of birds fitted with GPS devices attached with harnesses and matched untagged control cohorts.

A1.2 Methods

A1.2.1 Productivity

Nests of tagged and control gulls were monitored through the 2016-2019 breeding seasons through periodic visits to the colonies. Nests were marked with uniquely numbered markers at time of capture and GPS position recorded to allow accurate relocation. In years subsequent to marking, colour ringed individuals were watched back to determine nest location, though this was not possible for all individuals due to the terrain and the need to avoid additional disturbance.

Visits were made to assess the contents of nests approximately every 3-10 days depending on the site, with more frequent visits made to the colony at South Walney as access was more limited at the Barrow dock colony. Nests at the FGH roof site were controlled (eggs removed) under General License so are not included in productivity comparisons.

We followed methodology in Thaxter *et al.* (2018a) to compare the breeding productivity of tagged and control Lesser Black-backed Gulls, principally considering the clutch size and hatching success for each nest. Chicks of ground nesting gulls tend to be highly mobile as they get older and therefore it is very difficult to assign chicks within colonies to particular nests/pairs with confidence and results of likely fledging should be treated with caution. Late season visits were also made to the colonies to ascertain an overall view of colony success in each year.

A1.2.2 Overwinter return (apparent survival) rates

To assess potential device and harness effects on overwinter survival, the return rates of both tagged and control birds marked in 2016 to their breeding colonies in 2017-2019 were monitored. Visual searches for colour-ringed birds using a telescope and digital camera were made during c. 10 regular visits to the colonies throughout April-June, with additional ad hoc records available from site managers and field staff undertaken during catching and ringing activities.

Overwinter return rates only represent ‘apparent’ survival, as birds may move to other sites between years or not be re-sighted. Adult Lesser Black-backed Gulls can skip breeding in certain years (Calladine & Harris 1997) which will reduce the apparent survival rate estimate until the bird is re-sighted again subsequently as a breeder.

Return rates were compared between groups at each site separately using Generalised Linear Mixed-effects Models with a binomial error structure in the ‘lme4’ R package (Bates *et al.* 2015) including tagged or control group as a fixed effect and year and individual as random effects. Significance was assessed by comparing models with and without the tag group factor, reporting the chi-squared significance of a change in deviance.

All analyses were carried out using R 3.6.1 (R Core Team 2019).

A1.3 Results

A1.3.1 Productivity

Unfortunately productivity monitoring during this project was severely impacted by widespread colony failure and access limitations to urban sites, consequently, the data collected were not sufficient for a comprehensive comparison between tagged and control cohorts.

During 2016, when devices were deployed at South Walney, follow up monitoring visits to marked nests in the ‘meadow’ colony area revealed widespread chick mortality and missing eggs for the vast majority of nests and no breeding attempts were confirmed to be active within a few weeks after marking. Despite a perimeter electric fence around the colony, evidence from the site wardens suggests mammalian predation was the principle cause of failure during 2016. The ‘spit’ colony area of South Walney was more successful during 2016 with some chicks fledging but high apparent levels of chick mortality were still observed.

In all subsequent years after tagging at South Walney, no successful breeding attempts were recorded among tagged or control birds. In 2017, despite extensive searches, only two tagged birds were confirmed to have active nests (birds 5358 and 5371), one of which (5371) had relocated to the 'spit' colony area. Both these birds laid full clutches but were later found to have failed at the egg stage. A single individual from the control cohort was found with an active nest during 2017 and similarly had moved to the 'spit', abandoning the 'meadow' site; this nest also failed before hatching. A further five and three tagged and control birds respectively, were observed back at the site and displaying territorial behaviour, but unfortunately, no active nesting attempts with eggs were confirmed for these individuals. One of these territorial tagged birds (5380) had also switched to the 'spit'. Widespread colony failure was observed in the 'meadow' site in each year after tagging with no chicks known to have fledged from any nests. Predation, both mammalian and avian (notably Raven *Corvus corax*), was apparent again in 2017 and by 2018 overall nesting attempts in the 'meadow' area were reduced to less than 100. The 'spit' colony contained the vast majority of the sites breeding pairs – 2,312 in 2016 and 390 by 2019 (JNCC 2020) – and some, limited successful fledging was observed (searches for chicks nearing fledging age in early July yielded counts of less than 50 birds). Hatching success appeared to be good but widespread chick mortality was also observed on the 'spit' from 2017. The cause of mortality at the 'spit' was less clear, with predation not considered as likely as at the 'meadow'; however, frequent cannibalism was observed from other gulls, suggesting limited resource availability.

At Barrow, 10 of the 32 devices were deployed in 2016 across two sites, however, at both sites nest removal management was being undertaken by contractors under General License and site access was limited, therefore productivity monitoring was not carried out after tagging.

In subsequent years, tagging was focussed at the Barrow dock colony, which was not subject to nest control and so breeding attempts were able to proceed to a natural conclusion. Nest monitoring during the year of marking indicated that the hatch rates of tagged birds were greater than those of control birds in both 2017 and 2018 (Table A1.1). However, these comparisons should be considered more a reflection of initial group success rather than as a positive effect of tagging as in many cases, the capture and tagging event occurred already as full clutches were just about to hatch or with small chicks. Unfortunately, as at South Walney, locating nesting attempts of marked individuals in subsequent years proved difficult due to limited access to the site and less suitable terrain for observations. A total of five subsequent nesting attempts were followed for tagged birds and none for control birds. In both 2017 and 2019 overall colony productivity appeared to be low with very high rates of chick mortality or loss on nest monitoring visits. The cause of failure was not apparent. In 2018, breeding attempts were more successful with four tagged individuals (birds 208 and 225 from the 2016 cohort and birds 718 and 727 from the 2017 cohort) hatching chicks. It was not possible to confirm if these chicks survived to fledging but recently fledged chicks were apparent in the colony in July.

Table A1.1 Summary of productivity monitoring data collected from GPS tagged and untagged control Lesser Black-backed Gulls breeding at South Walney and Barrow between 2016-2019.

			2016		2017		2018		2019	
Colony	**Year marked**	**Group**	**Clutch size (n)**	**Hatch rate**	**Clutch size (n)**	**Hatch rate**	**Clutch size (n)**	**Hatch rate**	**Clutch size (n)**	**Hatch rate**
Barrow	2016[1]	Tagged	-	-	-	-	2.5 ± 0.35 (2)	0.58 ± 0.06	-	-
		Control	-	-	-	-	-	-	-	-
	2017	Tagged	-	-	2.66 ± 0.18 (12)	0.32 ± 0.24	3 ± 0 (2)	0.83 ± 0.35	3 (1)	-
		Control	-	-	2.76 ± 0.13 (17)	0.14 ± 0.06	-	-	-	-
	2018	Tagged	-	-	-	-	3 ± 0 (7)	0.57 ± 0.11	-	-
		Control	-	-	-	-	2.82 ± 0.17 (11)	0.52 ± 0.1	-	-
Walney	2016	Tagged	3 ± 0 (25)	0.2 ± 0.14 (25)	3 ± 0 (2)	0	-	-	-	-
		Control	3 ± 0 (25)	0.26 ± 0.14 (25)	3 (1)	0	-	-	-	-

[1] Nests in Barrow in 2016 were controlled (eggs removed) under General License so data on hatch rates are not included.

A1.3.2 Overwinter return (apparent survival) rates

A summary of the return rates, as indicative of over-winter survival, of tagged and control birds is shown in Table A1.2. Of the 25 birds tagged in 2016 at South Walney, 10 were visually seen back at the colony in 2017 (40%). A further six tagged birds were seen overwinter, but then not seen back at the colony (5362, 5367, 5368, 5378, 5386, all UvA and 278, Movetech); however, four of these (5367, 5379, 5386 and 278) were recorded on the GPS or GPS-GSM tracking systems during the 2017 breeding season as were others bringing the total confirmed returned individuals in 2017 to 17 (68%).

Resighting rates of tagged birds from South Walney based on reading of colour rings alone were greater than those of controls in 2017, equal in 2018 and lower in 2019 (Table A1.2). There was no significant difference in resighting rates between either tagged or control group across all years (χ^2_1 = 0.031, P = 0.861). Thus, there was no evidence that the harnesses and devices caused deleterious effects on individual survival.

Only one individual tagged in 2016 with a UvA device under this project was reported dead in subsequent years – ID 5385 from South Walney, which was reported freshly dead in Spain in March 2019. An individual tagged in Barrow (ID 851) potentially also died during 2019 with a period of stationary GPS locations recorded for seven days, however, this bird was fitted with a weak-link harness and it was not possible to confirm whether this was a case of mortality or harness drop-off. There were no reports of dead control birds from this study.

Resighting rates for birds tagged at Barrow were the same or higher than control groups (Table A1.2). Overall apparent return rates from visual resightings were low (less than 50%) for individuals marked in 2016 and 2017, but, as for South Walney, data retrieved from tagged birds breeding at the site in subsequent years indicates that not all returning birds were resighted. In contrast, 78% of the 2018 tagged cohort were seen in 2019, with GPS data suggesting that no additional birds returned. Across years, as at South Walney, there was no significant difference in the resighting rates of tagged and control birds at Barrow (χ^2_1 = 1.987, P = 0.159).

Table A1.2 Summary of overwinter return (apparent minimum survival) rates of Lesser Black-backed Gulls marked at South Walney and Barrow-in-Furness, based on (i) observations of colour-ringed birds, and (ii) additional records obtained through the tracking systems (GPS and GPS-GSM).

				2017		2018		2019	
Colony	**Year marked**	**Group**	**n**	**No. re-sighted (%)**	**No. re-sighted or recorded by GPS (%)**	**No. re-sighted (%)**	**No. re-sighted or recorded by GPS (%)**	**No. re-sighted (%)**	**No. re-sighted or recorded by GPS (%)**
Barrow	2016	Tagged	10	2 (20%)	6 (60%)	3 (30%)	4 (40%)	2 (20%)	3 (30%)
		Control	10	2 (20%)	-	3 (30%)	-	1 (10%)	-
	2017	Tagged	13	-	-	6 (46%)	6 (46%)	5 (38%)	5 (38%)
		Control	19	-	-	5 (26%)	-	4 (21%)	-
	2018	Tagged	9	-	-	-	-	7 (78%)	7 (78%)
		Control	11	-	-	-	-	6 (56%)	-
South Walney	2016	Tagged	25[1]	10 (40%)	17 (68%)	4 (16%)	6 (24%)	1 (4%)	5 (20%)
		Control	25	8 (32%)	-	4 (16%)	-	2 (8%)	-

[1] Five Movetech Telemetry devices were also fitted to Lesser Black-backed Gulls at South Walney in 2016 under BEIS project funding, data from which were also available for the present study.

A1.4 Conclusions

Despite incomplete productivity monitoring during this study, there was no apparent evidence that tagged individuals were likely to be more adversely affected by nest failure and there was also no difference in the return rates of tagged and control birds to either colony. These findings broadly agree with previous studies, such as those for Lesser Black-backed Gulls from the Alde-Ore SPA (Thaxter *et al.* 2014b), and at Skokholm and South Walney (Thaxter *et al.* 2018). It is reasonable then to conclude that data collected from the GPS devices are representative of normal behaviours.

Using data collected from resightings combined with GPS device transmissions, a minimum of 17 (68%) of the tagged birds were confirmed to return to the South Walney colony one year after tagging and 6 (24%) after two years. However, these rates are lower than those for the BEIS study cohort tagged in 2014, which were 79% and 63% after one and two years respectively (Thaxter *et al*. 2018). This may be expected since the overall number of breeding pairs in the colony has declined over the study but along with widespread failure in breeding attempts potentially masking detrimental effects of fitting devices, undetected impacts should not be discounted.

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APPENDIX A2 INDIVIDUAL FORAGING TRIP SUMMARIES FOR LESSER BLACK-BACKED GULLS TRACKED FROM SOUTH WALNEY IN THE MORECAMBE BAY AND DUDDON ESTUARY SPA AND BARROW-IN-FURNESS DURING THE 2016-2019 BREEDING SEASONS.

Trips were defined as continuous periods spent away from the breeding site and trips longer than 24 hours and shorter than 30 minutes were excluded from summaries. Any incomplete trips where the data collection was truncated were also excluded.

a. South Walney.

Year	Tag ID	N complete trips (incomplete)	Trip duration (hrs) mean ± SD (max)	Foraging range (km) mean ± SD (max)	Total distance per trip (km) mean ± SD (max)
2016	202	114	5.5±3.9 (0.6-20.6)	9.8±11.2 (0.3-79.7)	20.9±25.4 (0.5-193.1)
	220	47 (1)	9.2±7.7 (0.5-23.3)	16.9±15.7 (0.2-42.9)	37.6±36.1 (0.2-109.4)
	253	36	5.8±4.5 (1-21.2)	9.4±6.3 (1.8-23.1)	19.9±14.1 (3.7-50.8)
	254	67 (3)	6.9±6 (0.5-23)	15.3±11.1 (0.2-77.6)	34.1±27 (0.5-178.3)
	278	20 (6)	9.5±8.6 (0.5-23.9)	6.8±1.7 (4.7-9.4)	13.8±4.7 (5.6-22.8)
	4032	113	7.2±6.4 (0.6-23)	13.8±12.3 (0.4-42.3)	36.6±37.7 (0.2-157)
	4034	215	4±3.8 (0.5-21)	6.1±6.8 (0.4-39.2)	13.4±17.5 (0-92.6)
	5023	55 (6)	7.2±5.9 (1-23.4)	10.3±9.5 (0.9-41.1)	28.4±28.6 (0.2-136.9)
	5024	320	4±4 (0.5-21.6)	6.6±5.7 (0.4-39.2)	15.3±14.5 (0.1-91.4)
	5025	65 (9)	5.1±5.5 (0.6-22.7)	5.9±7.1 (0.5-33.4)	15.5±22.6 (0.2-110.6)
	5026	74 (2)	5.9±5.1 (0.6-23.3)	16.7±12.2 (1-50.8)	40.5±33.6 (0.3-145.5)
	5027	98	4.6±4.6 (0.5-23.7)	9.8±9.4 (0.4-45.3)	25.8±32.3 (0.3-193.1)
	5029	220	5.1±5.1 (0.5-23.4)	8±6.6 (0.4-37.8)	20.9±18.9 (0.2-93.5)
	503	134 (5)	5±5 (0.5-23.5)	6.5±7 (0.3-30.6)	15.5±18 (0.2-75.1)
	5033	320	4.7±3.1 (0.5-23.9)	9.1±8.8 (1-87.5)	18.5±20.4 (0.3-203.9)
	504	167	8.7±6.8 (0.6-22.8)	8.9±9.9 (0.3-44.5)	23.7±27.5 (0-138.3)
	506	240	6.5±5.2 (0.5-23.9)	9.6±8.9 (0.3-55.4)	23.8±23.7 (0.1-126.9)
	5358	9 (2)	2.7±5.8 (0.6-18)	1.6±0.4 (1.1-2.1)	1.7±1.2 (0.6-3.9)
	5360	72	4±3.7 (0.7-20.2)	15.2±18 (1.7-87)	38.7±49.6 (0.8-287.8)
	5362	144	3.9±3.6 (0.5-22.5)	11.6±9.6 (1.2-34.3)	26±23.5 (0-84.6)
	5363	184 (1)	4.3±4 (0.5-21.6)	5.5±4.1 (0.4-20.2)	12.3±11.8 (0.2-70.8)
	5365	120	4.6±4.6 (0.5-20.5)	7.5±6.8 (0.4-35.8)	18.9±19.9 (0.2-104.9)
	5366	108	6.3±5.2 (0.5-22.8)	23.2±24.4 (0.5-85.3)	61.6±63.1 (0.3-245.3)
	5367	194 (1)	2.6±2.8 (0.5-14)	5.5±8.5 (1.1-82.7)	10.8±20.4 (0.1-208.7)
	5368	7	1.9±2.7 (0.6-8)	4±2.1 (1.1-8.3)	6.1±2.9 (0.2-9.2)
	5371	41	3.4±1.8 (0.6-8)	11.9±4.9 (0.5-20.3)	29.2±15 (0.7-57.6)
	5375	10	2±1.5 (0.6-4.1)	2.5±0.1 (2.4-2.8)	5.3±1 (4.1-7.3)
	5376	148	3±3.6 (0.5-23.1)	7.1±5.6 (0.4-23.5)	17.2±15.4 (0.1-93.9)
	5377	53	7.2±5.5 (0.5-21.4)	18.8±11.6 (1.7-48.2)	54.1±43.5 (0.2-184.1)
	5379	158	7.3±6.6 (0.5-22.5)	6.9±3.2 (0.4-19.1)	17.4±9.8 (0.2-48.9)
	5380	17	7.5±5.8 (1-17.9)	20.9±24.3 (0.4-80.3)	56.5±66.1 (0.2-216)
	5381	15	4.5±4.4 (0.5-14.7)	9.6±8.6 (1.1-20.1)	24.4±23.5 (1.6-58.5)
	5382	73	4.7±6 (0.5-23.7)	9.9±12.3 (0.4-39.7)	24.3±33.8 (0.2-126.1)
	5383	148	2.8±2.2 (0.5-10)	7.2±4.7 (1.3-19.5)	15.4±12.7 (0.7-49.1)
	5385	56	5±4.8 (0.5-21.5)	15.3±13.2 (0.4-31.7)	36.7±32.6 (0-113.2)
	5386	43	2.8±1.8 (0.6-7.4)	4.5±3.1 (1.4-15.4)	9.3±9.1 (0-40.8)
2017	202	95	7.2±4.7 (1.1-21.1)	7.6±6.8 (0.2-29.9)	17.2±16.1 (0.2-78.9)

	220	32	9.6±6.3 (2-23.2)	18.8±9.6 (3.7-42.8)	41.5±24 (7.1-103.1)
	254	117	8.9±5.2 (2-22.2)	23.9±22.1 (0.2-80)	48.8±46.9 (0.1-187.2)
	278	61 (2)	11.9±5.3 (1.5-22.2)	6.9±2.3 (2-14)	12.4±5.6 (2-27.7)
	4032	88	8.4±7.6 (0.5-23.9)	14.6±13.7 (0.4-49.9)	38±39.1 (0.2-140.5)
	5023	150 (1)	7.8±6 (0.5-23.6)	9.2±7.9 (0.9-40.5)	26.9±25.4 (0.6-117.4)
	5024	139 (9)	4.9±4.3 (0.5-23.9)	8.9±7.6 (0.4-33.5)	20.9±19.4 (0.3-103.9)
	5026	54	8.5±6.3 (0.7-21.2)	21±17.2 (1.2-48.2)	52.7±50.3 (0.5-176.9)
	5027	1	12.5 (12.5-12.5)	31.9±NA (31.9-31.9)	65.4±NA (65.4-65.4)
	5029	197	4.8±4.7 (0.6-23.1)	8.5±5.7 (0.5-28.4)	20.9±17.4 (0.3-85.9)
	503	82	6.4±4.4 (0.9-18.7)	8.4±6.7 (0.3-30.5)	21.3±19.6 (0.1-88.1)
	5033	199	5.7±4.1 (0.7-23.9)	10.3±7 (1-41.2)	21.1±16.7 (0.5-121.3)
	504	112 (2)	7.4±6.1 (0.5-22.8)	7.5±9.5 (0.4-62.2)	20.5±25.6 (0-150.5)
	506	131	6.4±5.1 (0.5-23.9)	9.6±7.9 (0.3-29.1)	22.6±18.7 (0.4-78.2)
	5360	36	3.9±4.2 (0.6-19.5)	9.6±8.5 (1.7-35.8)	23.3±20.8 (0.4-87.3)
	5363	190	5.9±5 (0.5-22.3)	8.4±6.3 (0.4-49.6)	21.8±21.3 (0.3-167.9)
	5365	100	4.7±3.8 (0.5-20.1)	9.1±8.2 (0.4-34.2)	22.6±22.5 (0.1-100.6)
	5366	50	6.4±6.2 (0.6-23.2)	9±10.6 (0.8-37.4)	24±29.9 (1.2-114.3)
	5367	216	4.5±4.1 (0.6-20.3)	8.8±13.9 (1-83.8)	19.1±34.7 (0-213.7)
	5376	183	5.5±5.3 (0.6-23.1)	12.1±5.8 (0.8-41.6)	28.9±19.6 (0.5-110.2)
	5377	61	8.2±5.5 (0.7-21)	16.7±10.7 (1.2-47.7)	45.9±33.2 (0.3-131.2)
	5379	287	7.3±6.4 (0.5-22.9)	7.8±5.4 (0.5-39.9)	20.2±16.6 (0-106.1)
	5382	31 (1)	6.6±5.4 (1-23.1)	13±13.3 (0.4-38.3)	30.2±34.1 (0.7-113.2)
2018	202	107	7.3±4.9 (0.5-23.9)	9.2±8.3 (0.3-37.7)	21.1±18.7 (0.4-107.8)
	254	118	7±3.7 (2-22.2)	15.4±17.3 (0.2-80)	30.8±37.9 (0.2-172.9)
	4032	92	7.6±5.7 (0.5-23.9)	12.3±11.5 (0.5-42.9)	28.5±28.9 (0.2-124.7)
	5023	164 (1)	7.4±5.6 (0.6-23.4)	9.5±8.8 (1.7-42)	25.4±25.2 (0-123.8)
	5024	15 (1)	9.2±5.1 (3.3-20.1)	11±6.6 (1.1-22.2)	23.4±14.8 (0.2-54.2)
	503	90 (6)	5.7±5.2 (0.6-23)	7.8±7.8 (0.3-47.5)	21.3±26.6 (0.3-189.6)
	504	11	13.5±6.7 (3-22.5)	13.9±13.5 (1-52.1)	25.1±26.9 (2-103.5)
	506	100	6.3±5 (0.5-21.2)	9±13 (0.3-80.3)	16.9±24.2 (0-162.6)
	5360	87 (1)	2±1.4 (0.6-7.5)	9.5±11.5 (1.2-86.7)	22.6±28 (0.1-181)
	5367	135 (1)	5.2±4.6 (0.6-21.1)	9.9±15.1 (1-66)	20.9±34.8 (0-191.8)
	5377	54 (1)	6.7±5 (1.3-21.2)	12.8±10.5 (1.5-53.2)	31.6±26.8 (0.5-115.3)
	5379	113	6.4±4.9 (0.6-23.1)	7.5±5.8 (0.5-28.3)	16.7±15.2 (0.3-67.3)
	5382	26	6.2±4.4 (0.6-18.1)	14.9±16.6 (0.4-59.2)	38.5±48.7 (0.4-159)
2019	254	83	8.5±4.7 (2-20.2)	28.1±24.4 (0.2-80)	56.9±52.7 (0.2-184)
	506	63	6.5±6.1 (0.6-22.2)	11.4±13.9 (0.3-87.6)	28.8±37.6 (0.1-211.9)
	5360	54 (2)	4.8±5.6 (0.5-22.1)	19.8±31.1 (1.3-89.1)	43.3±70.6 (0.2-227.9)
	5375	51	2.8±4.7 (0.5-21.2)	6.5±12 (0.2-73.3)	10.5±25.1 (0-157.6)
	5377	42 (1)	10.8±6.1 (0.7-21.1)	19.4±10.4 (1.4-48.2)	52.1±32.4 (0.5-142.4)
	5379	167	7.3±5.6 (0.5-22.1)	7.1±5.9 (0.7-37.5)	17.4±15.6 (0.2-76.4)

b. Barrow.

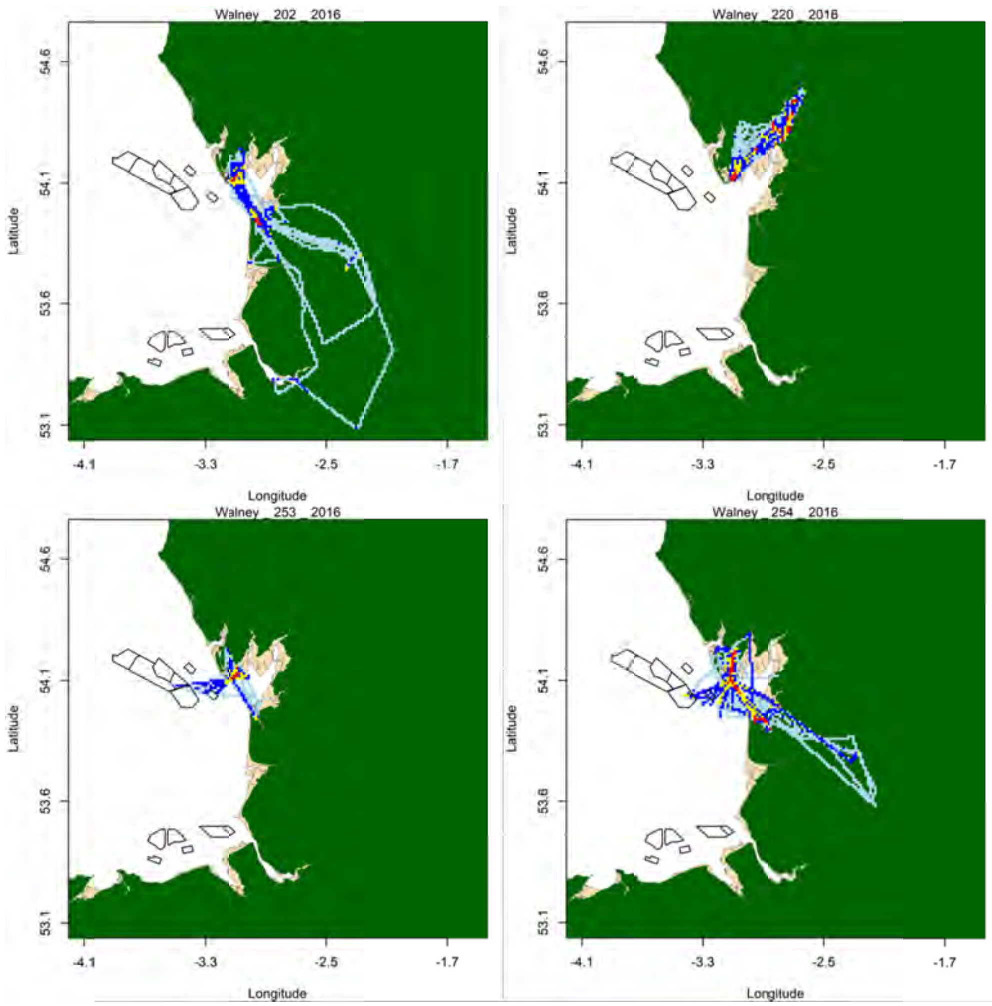
Year	Tag ID	N complete trips (incomplete)	Trip duration (hrs) mean ± SD (max)	Foraging range (km) mean ± SD (max)	Total distance per trip (km) mean ± SD (max)
2016	204	17	6.8±6 (1-22.3)	2.1±1.3 (0.2-3.8)	7.9±8.9 (0.3-26.8)
	208	240	5.2±4.2 (0.5-20.9)	6.4±4.5 (0.1-32.1)	15.5±14.9 (0.2-131.6)
	225	177	4.6±4.7 (0.5-23.9)	2.6±3.5 (0.1-25.9)	5.4±7.8 (0.3-55)
	276	0 (2)	NA	NA	NA
	471	11	8.9±7.8 (0.5-22.8)	9.5±6.2 (0.2-17.6)	20±15.9 (0.4-41.5)
	486	0 (6)	NA	NA	NA
	492	36	10.1±7.2 (0.6-23.9)	9.5±9.3 (0.3-42.8)	20.6±22.1 (0.3-97.6)
2017	204	256	7.2±5.6 (0.5-23.9)	2.3±2.1 (0.2-14.5)	6.1±6.2 (0.3-41)
	208	68	6.7±6 (0.5-22)	4.7±2 (0.3-11.8)	11±5.4 (0.4-21.2)
	225	411	4.5±4.1 (0.5-23.9)	2.7±5.3 (0.1-90.4)	6.2±11.8 (0.1-187.4)
	471	0 (2)	NA	NA	NA
	486	15 (5)	12.4±5 (6-21.4)	8.9±4.7 (0.7-14.2)	18.5±11.9 (0.8-42.2)
	492	55 (1)	8.7±5.5 (1.1-22.2)	7.7±9.1 (0.3-37.8)	16.4±19.7 (0.2-78.4)
	687	67	8.4±5.6 (1-23.5)	7.8±5.2 (0.1-21.9)	17.7±14 (0-60.3)
	707	73	8.2±5.9 (1-22.3)	9±15.6 (0.1-91.1)	22.7±38 (0.2-207)
	708	17 (3)	11.4±7.6 (1-22.9)	2.9±2.9 (0.1-10.3)	5.8±6.2 (0.2-22.5)
	711	14 (5)	7.3±5 (1-16.4)	3.1±3 (0.4-9.1)	7.5±8.3 (0.5-27.2)
	715	78	6.9±4.7 (1-18.8)	2.7±4.1 (0.2-31.4)	5.9±9 (0.1-63.6)
	717	12 (2)	10.7±5.4 (3-20.6)	8.8±5.6 (1.8-14.9)	18.4±12.5 (3.6-39.3)
	718	34 (1)	7.3±5.2 (1-19.8)	4.2±2 (0.3-10.5)	8.7±5 (0.3-23.6)
	725	44	8.9±6.8 (1-23.6)	11.2±10.6 (0-61.5)	23.9±24.8 (0-129.4)
	727	36	10.2±6.7 (1-23.9)	6.5±6 (1.5-21)	15±15.9 (1.5-53)
	729	47	7.7±5.4 (1-23.8)	8.7±7.4 (0.3-33.1)	21±18.5 (0.3-76)
	742	15 (1)	10.5±6.7 (3.1-22.7)	8.1±4 (0.8-14)	18.1±8.8 (1.6-30.7)
	744	83	7±4.9 (1-21.2)	7.2±3 (0.3-13.8)	13.4±7.4 (0.5-30.3)
	777	34	7.5±5.2 (1-20.3)	7.3±6.5 (0-19.8)	14.6±14.4 (0-51.4)
2018	204	4	7.5±4.8 (0.5-11.2)	2.3±1.3 (0.5-3.4)	7.7±6.8 (0.5-16.9)
	208	90	3.7±3.3 (0.5-18.9)	4.8±2.7 (0.1-12.7)	11±8 (0.2-44.1)
	225	143	4.3±3.1 (0.5-16.2)	2.3±3.1 (0.1-13.8)	5.1±6.8 (0.2-32.4)
	492	73 (2)	7.7±5.8 (1.1-22.1)	6.9±5.4 (0.3-25.9)	14.7±13.1 (0.6-62.2)
	851	96	7.2±4.4 (1-21.3)	9.1±12.6 (0.2-86.9)	19.1±26.1 (0.4-175.5)
	863	47	12.1±5.6 (1.1-23.7)	3.8±4.5 (0.6-30.2)	7.8±8 (1.3-50.3)
	868	51	10.3±6.4 (1-21.7)	4.6±5.6 (0.1-25.5)	9.9±12.3 (0.2-54.6)
	885	71 (1)	11.6±7 (1-23.8)	9.1±14.3 (0.1-88)	19.8±31.8 (0.2-183.4)
	914	30 (11)	7.5±7.2 (1-23.9)	4±4.4 (0.1-21.4)	7±8.5 (0.1-43.4)
	916	130	7.2±4.7 (1-22.6)	6.3±9.1 (0.1-40.1)	12.8±18.9 (0.3-88.1)
	918	24	9.9±6.6 (2-23.9)	11.1±7.6 (0.1-26.2)	23.9±18.7 (0.1-69.5)
	919	29	11.9±7 (2-23.9)	7.2±3 (1.3-16.1)	15.8±10.9 (2.5-55.2)
	920	69 (1)	8.4±5.5 (1-20.7)	9.4±5.6 (0.2-23)	19±12.1 (0.4-46.7)
2019	492	81 (4)	6.9±5.3 (1.1-23)	7.4±7.9 (0.2-42.5)	14.8±16.5 (0.3-81.3)
	851	25	5.9±4.6 (1-18.3)	10.5±24.2 (0.2-93.2)	22.4±52.7 (0.3-206.2)
	868	159 (10)	6.8±5.5 (1-23.2)	2.6±1.7 (0.1-15.3)	4.8±4 (0.1-30.7)
	916	233	7.5±5.6 (1-23.8)	2.9±4.3 (0.2-35.3)	6.3±9.7 (0.1-89.9)
	919	85	9.1±6.4 (1-23.8)	9.4±4.4 (0.2-20.5)	20.1±13.1 (0.2-61.5)
	920	165 (2)	9.4±6.4 (1-23.9)	10.1±5 (0.1-20.3)	20.4±11.4 (0.1-57.6)

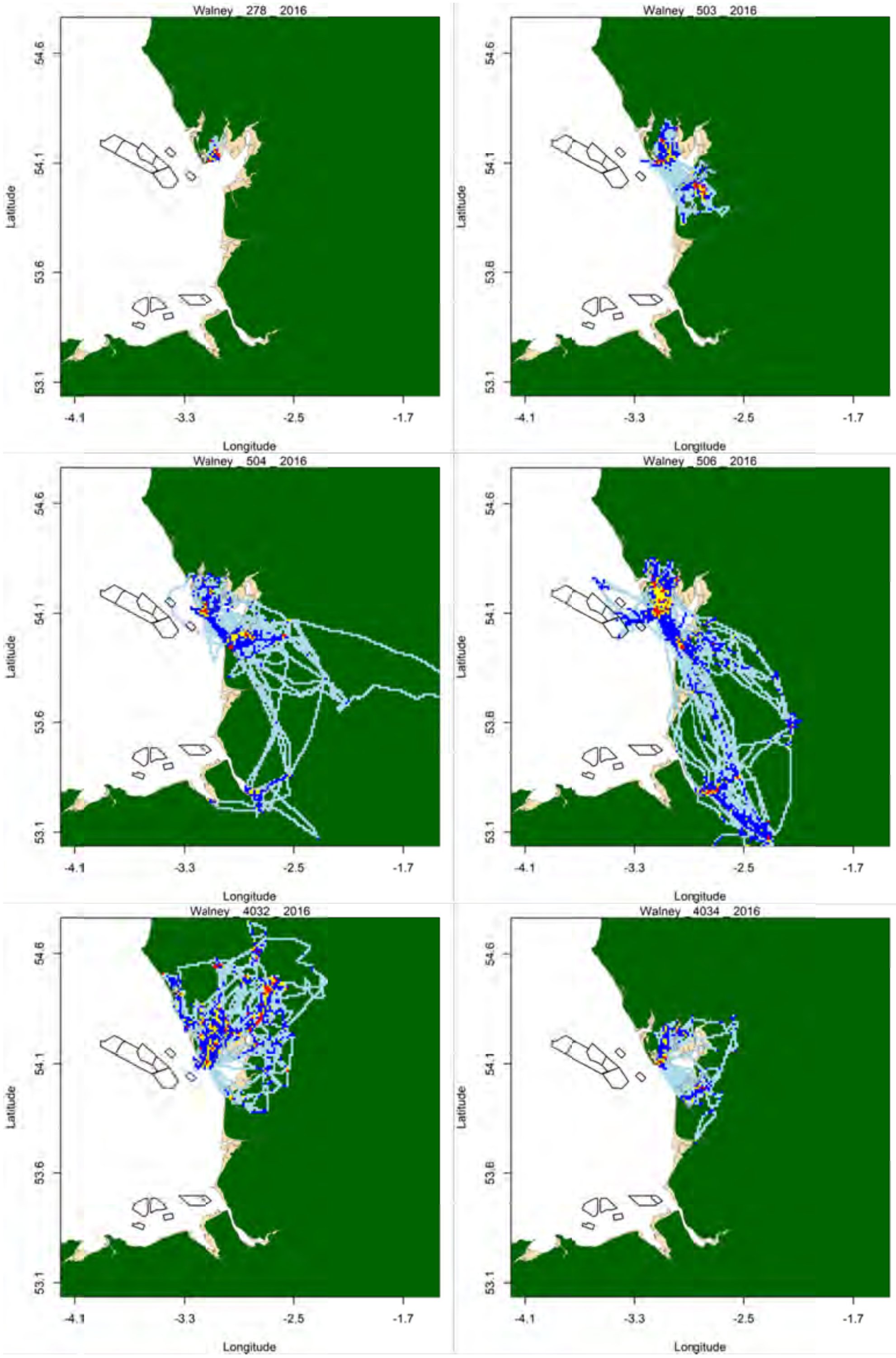
APPENDIX A3 INDIVIDUAL UTILISATION DISTRIBUTIONS CALCULATED USING A TIME-IN-AREA APPROACH FOR ALL LESSER BLACK-BACKED GULLS TRACKED FROM SOUTH WALNEY IN THE MORECAMBE BAY AND DUDDON ESTUARY SPA DURING THE 2016-2019 BREEDING SEASONS.

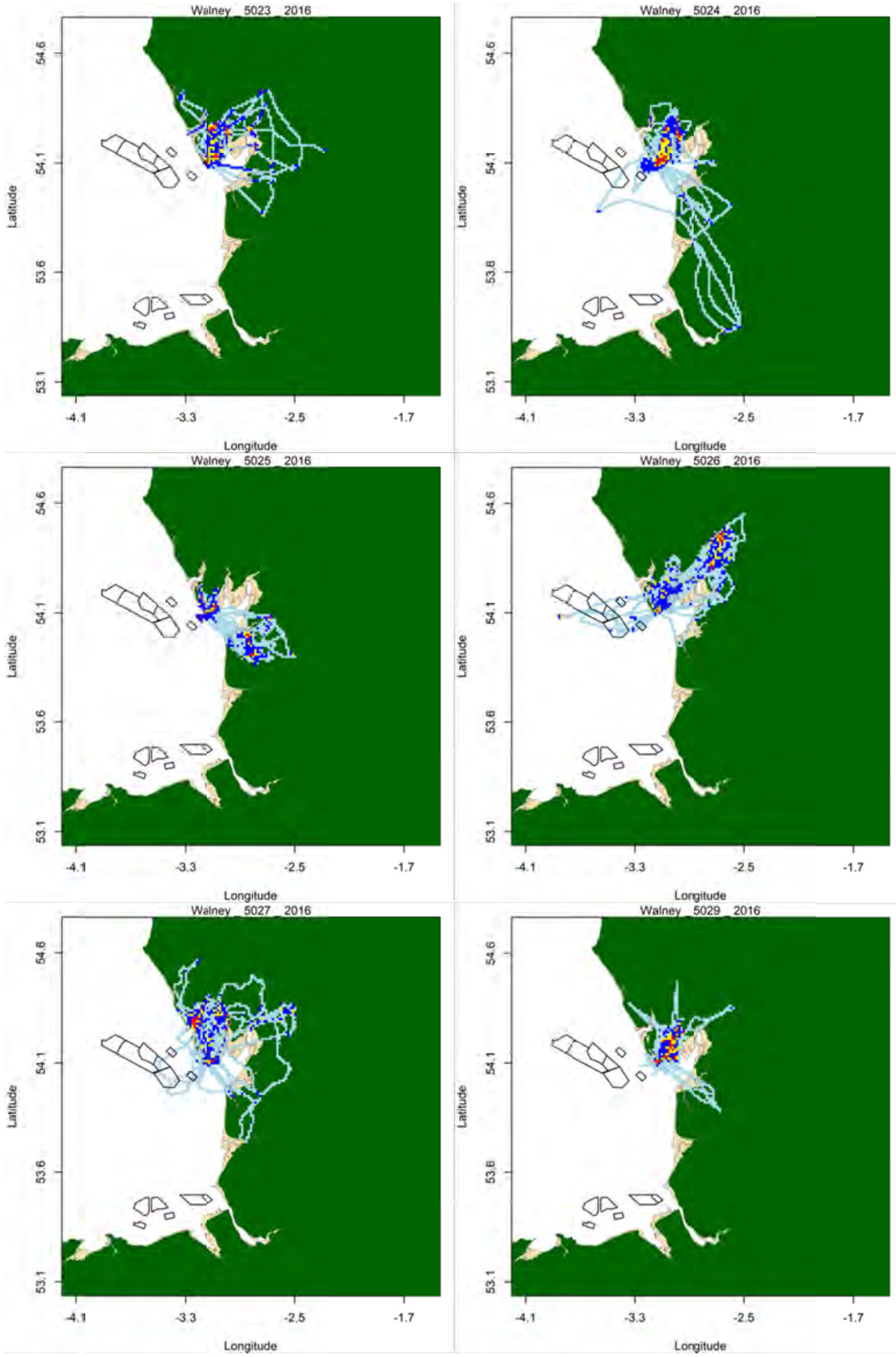
a. South Walney.

Light blue = 100% UD, dark blue = 95% US, yellow = 75% UD, red = 50% UD.

i. South Walney 2016 (n = 36).




Walney _ 278 _ 2016
Walney _ 503 _ 2016
Walney _ 504 _ 2016
Walney _ 506 _ 2016
Walney _ 4032 _ 2016
Walney _ 4034 _ 2016
Latitude
54.6
54.1
53.6
53.1
Longitude
-4.1
-3.3
-2.5
-1.7


Walney _ 5023 _ 2016
Walney _ 5024 _ 2016
Walney _ 5025 _ 2016
Walney _ 5026 _ 2016
Walney _ 5027 _ 2016
Walney _ 5029 _ 2016
Latitude
Longitude
54.6
54.1
53.6
53.1
-4.1
-3.3
-2.5
-1.7

Front cover: Edmund Fellowes; back cover: Philip Croft

Assessing movements of Lesser Black-backed Gulls using GPS tracking devices in relation to the Walney Extension and Burbo Bank Extension Offshore Wind Farms

Offshore wind farm developments form a major part of the UK government's commitment to obtain 15% of the UK's energy needs from renewable sources by 2020. However, there is concern over the potential detrimental effects that offshore developments may have on bird populations. Many seabird species included as features 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. Any impacts may also vary between years as well as between construction and operational phases of wind farm developments. This study investigated the movements of Lesser Black-backed Gulls (*Larus fuscus*) using bird-borne telemetry devices over four breeding seasons (2016–2019) and three non-breeding seasons in relation to the development of the Walney Extension and Burbo Bank Extension offshore wind farms in northwest England.

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