Belfast's urban gulls: an assessment of breeding populations, breeding season movements and winter population

Katherine Booth Jones, Chris Thaxter, Gary Clewley, Shane Wolsey, Neil Calbrade, Phil Atkinson, John Calladine & Niall Burton

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Report of work carried out by the British Trust for Ornithology on behalf of the Northern Ireland Environment Agency and Agri-Food and Biosciences Institute.

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EXECUTIVE SUMMARY

1. The UK and Ireland hold internationally important populations of seabirds. However, monitoring evidence suggests that seabirds are undergoing widespread declines, and as such it is important to gain up-to-date population estimates and ecological information. Herring Gulls *Larus argentatus* and Lesser Black-backed Gulls *L. fuscus* are listed as Birds of Conservation Concern on the island of Ireland and in the UK, yet little is known about their urban populations or their urban ecology.

2. In Northern Ireland, urban gull populations have previously been poorly studied. The last count of urban gulls in Northern Ireland was during the last seabird census, Seabird 2000. An up-to-date estimate is therefore overdue, particularly as the most recent national census, Seabirds Count, is currently underway. In addition to the lack of knowledge of urban population sizes, there have been no previous studies of the movements and space use of urban nesting gulls in Northern Ireland, despite some tracking work on gulls nesting at natural, coastal sites. Outside the breeding season, Belfast Lough is used by wintering gulls, but numbers of these have not been assessed in recent times.

3. This project brings together a number of elements targeted at addressing knowledge gaps for the urban population of gulls in Northern Ireland, chiefly focusing on Belfast city centre. Firstly, the numbers of breeding gulls in Belfast city centre are estimated using vantage point surveys, contributing to the latest national census and providing data for organisations wishing to reduce human-gull conflict. Secondly, the latest tracking technology are used to investigate how urban-nesting Lesser Black-backed Gulls and Herring Gulls use the urban environment of Belfast, complementing the population monitoring and existing tracking data from Herring Gulls breeding in a nearby coastal colony on Big Copeland Island. Thirdly, the wintering gull population using the shoreline of Belfast Lough are quantified, as congregations of gulls in the lough may interact with human activities in the lough.

4. Vantage point surveys were carried out in mid-May in 2018 and 2019 from the two tallest buildings on the island of Ireland, which provided an excellent overview of surrounding buildings in Belfast. In 2019, counts were higher than in 2018; 260 Apparently Occupied Nests (AONs) were counted in the city centre and docks (221 Lesser Black-backed Gull AONs and 39 Herring Gull AONs) compared to 162 in 2018 (101 and 16, respectively, plus 45 of unknown species). This is probably due to a combination of survey-related factors (longer survey time, better visibility, and familiarity with the survey) rather than an actual increase in gull numbers in the city between the two years. Gull nests appeared to be concentrated in the central Belfast area and were most often distributed singly or in small groups, with exceptions being on warehouse roofs in the docks.

5. Analysis of the location data from the sample of tracked gulls from Belfast and a nearby coastal colony revealed that individual gulls tended to occupy different foraging distributions around their colonies, despite the study nests of both colonies being located in a relatively small area. Although urban-nesting gulls of both species did travel outside the city, the core areas of use were all in urban areas; they did not, on average, travel far from their nests and resource selection analysis showed that urban habitats were preferred during foraging trips. Comparatively, Herring Gulls from the coastal colony travelled further and for longer for food, but also predominantly targeted urban habitats, generally the small towns of north east County Down.

6. Tracked individuals from both colonies appeared to be consistent in the areas they visited within the breeding season and, for three urban-nesting individuals and five natural-nesting individuals for which data were available for successive breeding seasons, between years. This suggests that they were targeting spatio-temporally predictable food resources.

7. In 2005, when the latest Winter Gull Roost Survey (WinGS) was conducted in Belfast Lough, 15,645 individual gulls were counted using the lough. Both in WinGS and more recent Wetland Bird Survey (WeBS) counts (between 2013/14 and 2017/18), Black-headed Gull *Chroicocepahlus ridibundus* was the most frequently observed gull species, although numbers appear to be in decline on the lough.

8. This study demonstrates that Belfast and the surrounding urban areas are providing not only nesting habitats for gulls, but also food resources which are used throughout the breeding season and during the winter. The presence of foraging gulls within the urban environment may be a symptom of poor waste management in certain regions of the city and may be a source of human-gull conflict.

1. BACKGROUND & AIMS

1.1. The need for the project

The UK and Ireland hold internationally important populations of seabirds, with a previously estimate of 8 million seabirds of 25 species breeding annually (Mitchell *et al.*, 2004). However, monitoring evidence suggests that seabirds are undergoing widespread declines, and as such it is important to gain up-to-date population estimates and ecological information.

Some species are difficult to survey comprehensively and gulls provide an example of this, due to the diversity of habitats they nest in. In the early 20th century, urban nesting gulls were a rarity (Cramp, 1971); however, over the second half of the century, both Herring Gulls *Larus argentatus* and Lesser Black-backed Gulls *L. fuscus* increasingly occupied urban areas throughout the UK and Ireland (Balmer *et al.*, 2013; JNCC, 2020; Raven & Coulson, 1997; Rock, 2005). This range expansion is thought to mainly be due to the increase in readily available food for these opportunistic foragers from sources such as bins and litter, in addition to predator-free nesting and roosting sites (Calladine *et al.*, 2006).

Despite increases in the distribution and numbers of urban-nesting gulls, both Herring and Lesser Black-backed Gulls are listed in the Birds of Conservation Concern in Ireland 2020–2026 (Gilbert *et al.*, 2021) as well as in the UK (Eaton *et al.*, 2015). Lesser Black-backed Gulls are assigned an Amber threat level, due to a moderate decline in breeding range in the past 25 years and a localised distribution in Ireland. Herring Gulls were Red-listed in Ireland due to a population decline of 90% coupled with a reduction in breeding range of at least 70% in the former Birds of Conservation Concern list (Colhoun & Cummins, 2013), but more moderate declines have improved their status to Amber in the 2020–2026 list (Gilbert *et al.*, 2021). However, reported declines are dominated by changes in rural and coastal colonies (Coulson & Coulson, 2015; Mitchell *et al.*, 2004). Moreover, surveying breeding gulls in urban environments presents a number of challenges that can lead to an underestimation of numbers, which could conceivably have led to an exaggeration of the vulnerability of Herring and Lesser Black-backed Gulls in Ireland.

In addition, little is known about the habitat-use of urban gulls during the breeding season, as most GPS tracking to date has concentrated on rural and coastal nesting gulls (although see Rock *et al.*, 2016; Spelt *et al*., 2019). Key questions remain on how urban gulls differ from their declining rural and coastal counterparts in their use of space and food resources, particularly since urban populations are visibly on the rise.

Beyond the conservation motivation for studying urban gulls, their movement into urban environments has sparked human-wildlife conflict issues. Reports of perceived problems with gulls are on the rise from residents, the tourism sector and businesses in towns and cities across the UK, coinciding with the numbers of urban-nesting gulls increasing in recent years (Calladine *et al.*, 2006; JNCC, 2020; Raven & Coulson, 1997; Rock, 2005). Problems include the spreading of litter, noise, fouling with droppings and the potential for disease transmission through contamination with droppings (Calladine *et al.*, 2006; Fogarty *et al.*, 2003; Hatch, 1996), including antibiotic resistant strains of bacteria (Dolejská *et al.*, 2009; Fogarty *et al*., 2003). Gulls may also be a source of concern during the winter, due to the arrival of migrants from elsewhere. Winter roosting gulls caused deterioration in bacterial quality of a reservoir supplying Glasgow, with a correlation in the number of *E. coli* in the water and the numbers of gulls roosting on the reservoir (Benton *et al*., 1983). Salmonella bacteria from the gulls were also found in the treated reservoir water (Benton *et al.*, 1983). The risk of transfer of bacteria from gulls to humans is greatest at water resources (Fogarty *et al*., 2003; Hatch, 1996), and gulls are likely to become contaminated themselves at landfill sites and sewage treatment works. It is therefore important to know where gulls are foraging and resting, to reduce the risk of spreading antibiotic resistant bacteria in the environment and to humans.

In Northern Ireland, urban gull populations have previously been little studied. The last seabird census, Seabird 2000, the only assessment of urban gull populations in the region, estimated that there were six Herring Gull AONs and 43 Lesser Black-backed Gull AONs in Belfast city centre (counted from a vantage in Windsor House, Matthew Tickner, pers. comm.), and approximately four Herring Gull Apparently Occupied Nests (AONs) and 40 Lesser Black-backed Gull AONs in Belfast docks (ground level assessment, Matthew Tickner, pers. comm.; JNCC, 2017, Mitchell *et al.*, 2004). This is thought likely to have been an underestimate of true numbers, and therefore there is a need for a more comprehensive assessment. There are existing tracking data from Herring Gulls breeding in a nearby coastal colony (Atkinson *et al*., 2016), but there have been no previous studies of the movements and space use of urban-nesting gulls in Northern Ireland. The Northern Ireland Environment Agency (NIEA), Agri-Food and Biosciences Institute (AFBI) and Northern

Ireland Water (NIW) thus commissioned BTO to address these knowledge gaps for the urban population of gulls in Northern Ireland, with an initial focus on Belfast city centre.

1.2. Aims of the project

The project has three main aims:

1.2.1. Estimate population size in Belfast city centre and docks

Using a vantage-point count method at key, accessible roof sites, the project first aims to provide an estimate of the population size of urban nesting gulls in Belfast city centre, a population that has not been counted since Seabird 2000. This population estimate will contribute to the latest national census, 'Seabirds Count' (https://jncc.gov.uk/our-work/seabird-censuses/#seabirds-count-2015-2020) and provide data for organisations wishing to reduce human-gull conflict.

1.2.2. Identify space-use of urban gulls nesting in Belfast city centre

Second, tracking of Lesser Black-backed Gulls and Herring Gulls nesting in Belfast city centre aims to provide an understanding of their movements and concentrations within the city. However, it is likely that the urban environment of Belfast and surrounding towns also provide a food resource for gulls from nearby natural-nesting colonies, therefore tracking data from Herring Gulls breeding in a nearby coastal colony (Atkinson *et al.*, 2016) are also analysed to complement the tracking data from urban-nesting gulls.

Identifying areas of key use for urban-nesting gulls will be of benefit to agencies wishing to mitigate against human-gull conflict, including possible risks to human health in Belfast and other urban centres.

1.2.3. Quantify the numbers of gulls in Belfast Lough during the winter

While aims 1.2.1. and 1.2.2. address the numbers and space-use of gulls within the breeding season (April–September), gulls are also present in Belfast Lough over the winter. By analysing existing spatial data collected as part of the 2003/04–2005/06 Winter Gull Roost Survey (WinGS) and the Wetland Bird Survey (WeBS: https://www.bto.org/our-science/projects/webs) Core Count and Low Tide Count schemes, numbers of gulls using different locations in the lough through the winter are assessed. This assessment provides information on where human-gull conflicts may arise, for example over the potential for water contamination by roosting gulls, or where human activities may disturb gulls while foraging or roosting around the shore of the lough.

2. METHODS

2.1. Vantage point survey in Belfast city centre

The study originally aimed to conduct vantage-point surveys alongside a digital aerial survey. It was planned that aerial imagery of Belfast city centre and docks would be provided by the Police Service of Northern Ireland (PSNI), and that vantage point surveys would be carried out alongside to enable the accuracy of counts made from the aerial photos to be assessed. Unfortunately, PSNI were unable to contribute aerial photographs, meaning that vantage point surveys were the only practical and available means to derive an estimate of breeding gulls in the city centre.

Access to the roofs of the two tallest buildings in central Belfast, the Obel Tower and Grand Central Hotel (formerly called Windsor House) was granted, offering an overview of the roofs of surrounding buildings. The Grand Central Hotel was used as a vantage point in the Seabird 2000 census (Matthew Tickner, pers. comm.), and the height of the building has not changed since then. Ideally a range of buildings should be accessed for different viewpoints of roofs. However, the amount of time available for fieldwork was limited and there were restrictions on the type of roofs that could be accessed for health and safety reasons. Therefore, vantages from the tallest buildings available were the most efficient use of resources.

Two surveyors visited the roofs of the buildings, and provided counts of AONs (the recommended counting unit for breeding gulls) for individual roofs, marking the locations of AONs on buildings on a map, such that these could be directly compared to estimates from aerial photographs should they become available in the future. The surveyors followed the Walsh *et al.* (1995) definition of AON, counting well-formed nests attended by an adult or adults apparently incubating when the nest could not be discerned directly.

In 2019, the visible proportion of the roofs of multi-storey buildings (e.g. apartment blocks, office buildings, shopping centres) and industrial buildings was assessed during the vantage point surveys. The assessment process was not formal but involved estimating the visible proportion of the roof surface of buildings within view, inside a radius at which it was judged that gull nests could reasonably be identified. Structures such as chimneys, parapets and roof-top buildings were considered when estimating what proportion of the roof could be seen. Estimates did not consider the habit of gulls of situating nests on edges, corners and crevices, due to the complexity of accounting for this. No gulls were observed nesting on the roofs of these smaller residential buildings. In particular, if buildings had features such as small parapets, their potential impact on the visibility of nests from the vantage point was assessed, as gulls often locate their nests on roofs with shelter provided by roof features. The average rooftop visibility from the vantage was used to estimate the potential number of gull nests present that were obscured from the vantage points.

2.2. GPS Tracking

2.2.1. Urban-Nesting Gulls

Trapping gulls and fitting GPS trackers

Buildings in central Belfast were investigated for accessibility and urban-nesting gull presence in late March and April 2018 and 2019. Some candidate buildings with gull nests were also identified during the vantage point surveys in May of both years; in 2018 these all proved to be inaccessible (no permission or empty buildings), but two additional Herring Gull nests were identified in 2019. Unfortunately, it proved impossible to catch gulls at one of these due to its positioning. Due to health and safety constraints, no sloping roofs were considered for access; only flat-topped roofs surrounded by a handrail were suitable for access for gull tagging (this also applied to the vantage point surveys).

A variety of methods were used to catch gulls. Primarily, gulls were caught at nests using a walk-in chicken-wire cage, placed over the nest. For this method, nests are best targeted in mid-late May, during the later incubation period. In 2018, timing was restricted due the need for the presence of a BTO gull-tagging specialist (Gary Clewley) to train staff members to deploy tags using weak-link harnesses (see below). Four Lesser Black-backed Gull nests on two buildings (the Cecil Ward Building and Goodwood House) were located and gull catching occurred on the 25 May 2018, during the late egg stage for two of the nests, and partially through hatching for the other two. From the four nests, six Lesser Black-backed Gulls were captured, of which four were fitted with GPS tags. This allowed Shane Wolsey to be trained to deploy tags on gulls using weak-link harnesses in the future.

In 2019, to increase the likelihood of catching sufficient numbers of gulls to GPS tag, Katherine Booth Jones was trained in the use of a noose carpet by experienced gull ringers in BTO Cymru. The 2018 season demonstrated that Herring Gulls were found at a much lower density on roofs in central Belfast than Lesser Black-backed Gulls, therefore efforts were focused on accessing nests of Herring Gulls in 2019. At the four nests accessed, three Herring Gulls were caught, two using walk-in cage traps, one using the baited noose carpet method. Four Herring Gulls were caught away from nest sites using nooses, but only two of these were of sufficient weight to fit GPS tags, one sub-adult on a roof in central Belfast and one full adult in the nearby town of Bangor, County Down. Both members of a pair of Lesser Black-backed Gulls were tagged at a single nest in 2019. Katherine Booth Jones was able to begin training for fitting weak-link harnesses on two of the Herring Gulls caught in 2019.

In total, 11 tags were thus fitted to six Lesser Black-backed Gulls and five Herring Gulls. Tagging of gulls was undertaken under licence, approved by the independent Special Methods Technical Panel (SMTP) of the BTO Ringing Committee and subject to appropriate training. Tags were fitted using a weak-link wing harness, to enable long-term deployment across the annual cycle and through birds' moult periods (Clewley *et al.*, 2021). Harnesses were handmade from Teflon and fitted to the body size of the gull. Arms of the harness passed above and below the wings of the gull and were joined at the front by a cotton weak-link, which allows the harness and tag to drop off safely after a period of time when the cotton has worn through.

Morphometric measurements and an assessment of moult were conducted as standard to the ringing process, which allows age, body condition and sex to be estimated (Table 1). Using guidelines from Coulson *et al.* (1983), head and bill length were used to sex individuals at a 95% confidence level.

All 15 gulls captured were fitted with BTO metal rings and a plastic coded colour-ring, to aid field identification of individuals. In accordance with license requirements, the project aimed to also colour-ring a control cohort of at least six Lesser Black-backed and six Herring Gulls in addition to those fitted with GPS tags, in order that any potential effects of the tags and harnesses on the breeding success and annual return rates of tagged birds could be assessed. Due to the difficulty in capturing urban gulls in Belfast, only four gulls (two of each species) were colour-ringed as controls in this study. However, other studies have shown that harnessing does not impact the breeding success or survival of large gulls (Thaxter *et al.*, 2016).

In accordance with licencing requirements, annual reports on the tagging of gulls and associated monitoring (see section 2.2.3.) have been provided to the SMTP.

GPS devices

The tags used were Movetech (http://movetech-telemetry.com) Global Positioning System – Global System for Mobile Communication (GPS-GSM) devices. These devices (model: Flyway-18; 18 g; 50 x 26.5 x 18 mm) utilise the GSM network to transmit data directly to an online telemetry data repository (www.movebank.org) without the need for any in situ equipment. Due to this automation, it is not necessary to recover the GPS tags. In areas without mobile phone 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 devices were initially set to record one fix every 60 minutes between 0800 and 2000 and 180 minutes between 2000 and 0800 overnight (to conserve battery power); higher sampling rates can be achieved depending on the availability of solar energy to maintain battery charge.

2.2.2. Monitoring

In 2018, the nests of tagged and control Lesser Black-backed Gulls were revisited four times during the breeding season at regular intervals (on average, every two weeks) until chicks reached fledging age or the nest failed (in one case). Sightings of colour-ringed adults were noted and the progress of the nests was also monitored, with the number of eggs and resulting chicks hatched recorded. Estimates were made of the fledging dates of surviving chicks, which may inform the spatial behaviour of adults.

Table 1. Size, age and estimated sex of ringed individuals. Age is represented by standard 'EURING' codes and sex is estimated using a discriminant value threshold of 113 mm for Lesser Black-backed Gulls and 118 mm for Herring Gulls. Females are likely to have measurements less than this value, with 95% confidence, using guidelines from Coulson *et al.* (1983). Species: LB = Lesser Black-backed Gull, HG = Herring Gull.

BTO ring	Species	Capture date	Colour ring (Left leg)	Weight of bird (g)	Age*	Head plus bill (mm)	Estimated sex (95% probability)
GR97169	LB	25/05/2018	Yellow B10:W	890	10	123.1	M
GR97171	LB	25/05/2018	Yellow B11:W	830	8i	121.5	M
GR97172	LB	25/05/2018	Yellow B12:W	890	10	116.7	M
GR97173	LB	25/05/2018	Yellow B13:W	790	10	107.6	F
GR97174	LB	25/05/2018	Yellow B14:W	945	8	123.2	M
GR97175	LB	25/05/2018	Yellow B15:W	740	10	107.4	F
GR97176	HG	15/05/2019	Yellow B16:W	1100	10	128.7	M
GR97177	HG	15/05/2019	Yellow B17:W	1050	10	126.3	M
GR97178	HG	15/05/2019	Yellow B18:W	950	7	130.5	M
GR97179	LB	15/05/2019	Yellow B19:W	705	12	110.6	F
GR97180	LB	15/05/2019	Yellow B20:W	865	12	123.2	M
GR97181	HG	23/05/2019	Yellow B21:W	915	10	133.7	M
GR97182	HG	15/06/2019	Yellow B22:W	<910	5	115.4	F
GR97183	HG	15/06/2019	Yellow B23:W	770	9	118.1	M
GR97184	HG	15/06/2019	Yellow B24:W	965	10	132.5	M

*5 = Definitely hatched during previous calendar year (e.g. first-years in early spring); 7 = Definitely hatched in calendar year before last; 8 = Hatched three or more years ago – exact year unknown; 8i = Hatched three or more years ago – exact year unknown but definitely not full adult; 9 = Definitely hatched three years ago; 10 = Hatched four or more years ago – exact year unknown; 12 = Hatched five or more years ago – exact year unknown.

In addition to nest visits, a single visit was made to each of the focal foraging locations of the four gulls, as revealed by the GPS data, to attempt to re-sight the tagged adults away from their nests and to investigate potential sources of food for the gulls visiting the areas. Only a single, short visit was made to three out of the four foraging areas, due to the sensitivity of some areas of Belfast.

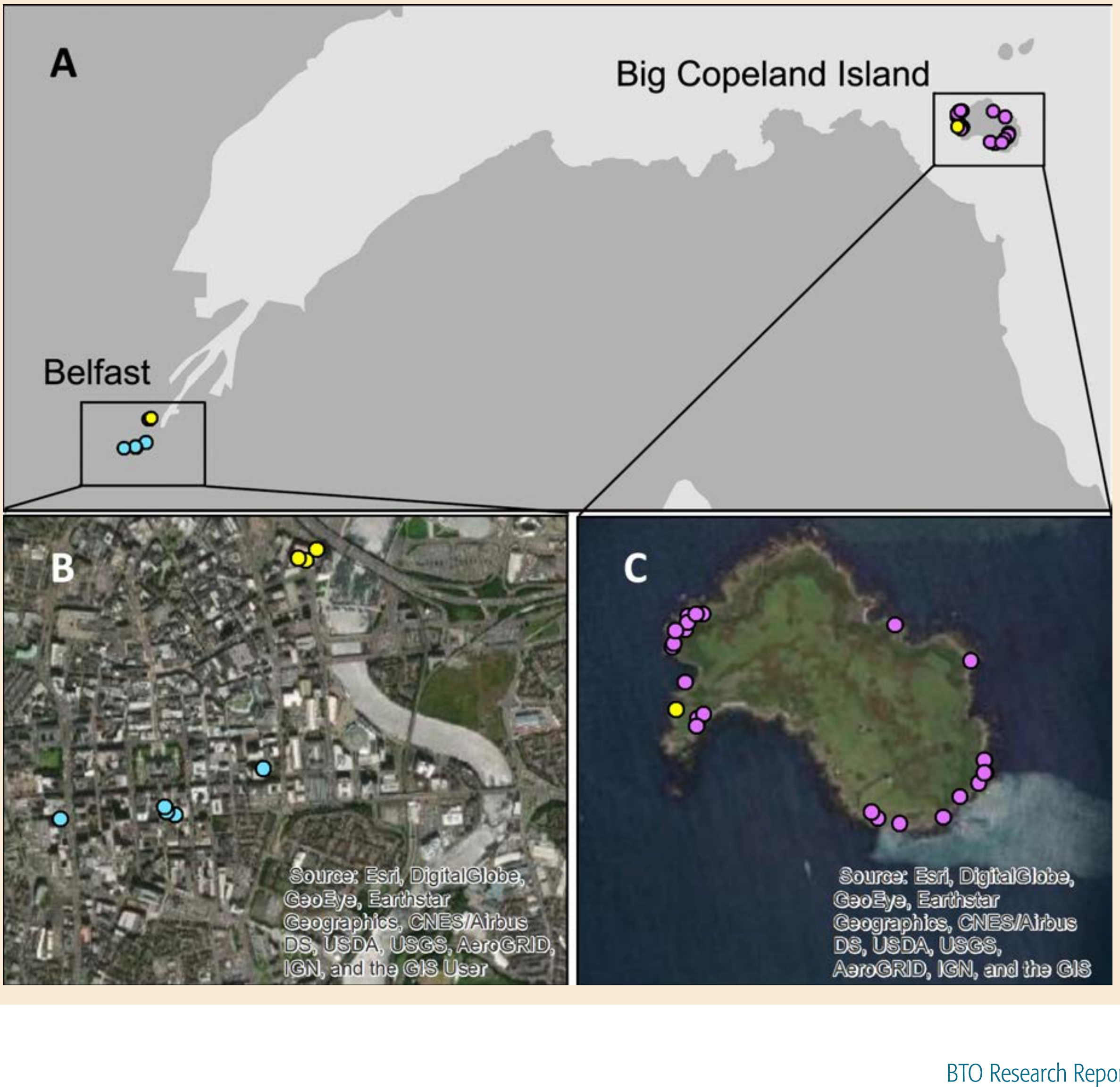
In 2019, a combination of time restrictions and problematic building access reduced the number of follow up visits to the nests of tagged and control gulls. Nests of all tagged birds (one Lesser Black-backed Gull nest and three Herring Gull nests) were visited at least once in June, and two of the three nests of birds tagged in 2019 were visited again two weeks later at the end of the month. Additionally, it was possible to observe two nests of Lesser Black-backed Gulls tagged in 2018.

In 2020, it was planned to revisit nests of previous years to check whether birds were still carrying tags (in the case of GPS tags that had stopped transmitting) and monitor subsequent breeding success as a measure of tag effect. However, the onset of the COVID-19 pandemic prohibited nest visits, and as a consequence no monitoring data were collected.

2.2.3. GPS tracking natural-nesting gulls

In 2015, 20 Herring Gulls were GPS tagged with 20 g Movetech GPS-GSM devices at Big Copeland Island, a coastal colony ~27 km from central Belfast. The tagging methodology for 2015 is outlined in Atkinson *et al.* (2016). Data from these birds were downloaded from the Movebank online repository and processed in the same manner as data from the urban gulls.

Figure 1 . A: Locations from which gulls were GPS tagged. Blue points = Lesser Black-backed Gulls tagged in 2018 and 2019, yellow points = Herring Gulls tagged in 2019, pink points = Herring Gulls tagged in 2015. B: Map of central Belfast tagging sites. Lesser Black-backed Gull nests from left to right: Europa Hotel, Cecil Ward Building (three nests), Goodwood House. Herring Gull nests and capture site of immature gull on Royal Mail. C: Map of Big Copeland Island Herring Gull nest sites. Point colours as in (A).



2.2.4. Analysis of tracking data

Analysis of GPS data followed the methods used by the BTO in previous gull tracking studies (Thaxter *et al*., 2015; Thaxter, Clark *et al*., 2017). Location data were analysed using ArcGIS 10 and the R programming environment (http://www.R-project.org). Analysis aimed to identify key areas of usage for urban gulls in and around the city and to reveal the daily time budget of individual gulls in particular areas of interest. Inter-species, individual and annual differences in space use were also assessed.

We defined foraging trips by the departure and subsequent return of individuals to their nest sites, considered as the area of the rooftop on which the nest was located for urban gulls, or Big Copeland Island for natural-nesting Herring Gulls. The exceptions to this were two Herring Gulls caught away from nests, one from a rooftop in central Belfast and one in Bangor. One of these was a sub-adult (tag 834), and trips were not calculated for this individual. Examination of the GPS locations of the other (tag 978) suggested it was breeding on Big Copeland Island off the coast of north County Down, therefore the vicinity of the island was defined as the nest area for this individual. Nest locations (or capture location in the case of tag 834) for all tracked gulls are mapped in Figure 1. Due to the temporal resolution of the tags, short trips taking fewer than 60 minutes could not be recorded.

Trip duration (the total time spent away from the nest), maximum foraging range (furthest point from the nest site) and average furthest point from the nest per foraging trip were calculated for each trip made outside the nest site area, for each tracked individual.

Space-use by gulls during the breeding season was analysed based on location data while individuals were on foraging trips away from their nests. Following Thaxter *et al.* (2017) and Soanes *et al.* (2013), a 'time-in-area' (TIA) approach was used, which calculates the time spent by each individual gull in a grid, here of 0.5 km-sided cells across the region surrounding the colonies. Although the TIA approach aims to limit the problems of subjectivity that are inherent in other methods of estimating space-use for organisms in tracking studies, cell-size does influence the output and must be subjectively chosen to calculate utilisation density (UD) contours. The focus of this study was on localised space-use, therefore a 0.5 x 0.5 km grid was used to provide a finer resolution. The R package 'trip' (v. 1.0.8., Sumner, 2016) was used to manipulate the spatial data from the GPS tags to produce areas with 100%, 95%, 75% and 50% UD contours, representing the total area used (100%), down to core area (50%).

The 50% UD contour is traditionally used in seabird tracking studies to denote core foraging areas (e.g. Catry *et al*., 2009; Kappes *et al.*, 2011; Oppel *et al.*, 2018; Paiva *et al*., 2013; Scragg *et al*., 2016), however although only trips away from the nest were analysed, areas used away from the nest may be used for other activities such as bathing and loafing, in addition to foraging. Analyses were carried out in the R programming environment (v. 3.6.1., R Core Team, 2020).

The areas of the 50% UD (core area) and 95% UD (range, excluding outliers) of each individual were calculated from the output of the trip analysis, using the R packages 'raster' (v. 3.4.5., Hijmans, 2018) 'rgeos' (v. 0.5.5., Bivand & Rundel, 2018) and 'sf' (v.0.9.7., Pebesma, 2018).

Separate generalized linear mixed models (GLMM) considered how the 95% UD foraging range area, foraging distance per trip and foraging trip duration varied between species (two categorical factors: Herring Gull and Lesser Black-backed Gull) and colony (two categorical factors: Belfast and Copelands) as fixed factors. Bird identity was included as a random factor to account for having repeated years of data for some individuals. The R package 'glmmTMB' (v. 1.0.2.1., Brooks *et al*., 2017) was used to fit models.

An initial exploration of candidate models considered Gaussian and Gamma distributions, with their potential link functions (Gaussian: identity, log and inverse; Gamma: inverse, identity and log) and with the dependent variable untransformed, log-transformed, and square-root transformed. Models were rejected if they did not converge, if non-number results (NaNs) were produced, if model simulations produced infinite values or if the simulated residuals deviated from the assumptions of uniformity and over- or under-dispersion, tested with the R package 'DHARMa' (v. 0.3.3.0., Hartig, 2020). After the initial exploration of modelling options, the models with Gamma error distributions and inverse link functions did not end up being used, to allow a more straight-forward interpretation of the outputs. The remaining models were compared using AIC; the model with the lowest value for each species and for the all-species dataset being selected as providing the best fit (see Appendix 2, Table S2.1 for comparisons).

2.2.5. Resource selection analysis

Foraging habitat selection during the breeding season for urban-nesting gulls from Belfast and natural-nesting gulls from the Copeland Islands was assessed using a Resource Selection Function (RSF) analysis in the R package 'amt' (v. 0.1.3., Signer *et al*., 2019). Breeding seasons were defined as starting when either the gull was tagged or from its arrival back to the breeding colony in May, and finished the soonest of either: the gull's departure from the breeding colony, the last recording date of the tag, or the end of September. Location points calculated to have speeds of over 3.3 m/s were filtered out to remove commuting movements as defined by Hidden Markov Models (Thaxter *et al*., 2017). Location points within a radius of 20 m from the nest were removed for all gulls excepting the non-breeding sub-adult. Nest locations for gulls breeding on Big Copeland Island were assumed through visual inspection of the GPS data. Individuals were grouped by species and location; all years of available breeding season data for gulls tracked over multiple years were utilised. Therefore, the groupings for the RSF analysis were: Lesser Black-backed Gulls from Belfast (six individuals), Herring Gulls from Belfast (three individuals) and Herring Gulls from Big Copeland Island (21 individuals, 20 tagged in 2015, and one tagged on Ballyholme beach, Bangor in 2019). Twenty random simulated points were generated per location point within the home range of each of the groupings using the 'amt::random_points' function. Real and simulated points were annotated with Corine Land Cover 2018 data (European Environment Agency, 2020) using the following habitat classes: Arable, Artificial vegetated, Forests, Heterogeneous agricultural, Industrial, Inland waters, Marine waters, Maritime wetlands, Mine, dump & construction, Pastures, Scrub, and Urban. Foraging habitat selection is presented here as the proportional availability of habitat classes in the home range of gull groups compared to the proportion of habitats used by gulls during the breeding season.

2.3. Winter populations of gulls in Belfast Lough

Data on wintering populations of gulls in Belfast Lough were sourced from the 2003/04–2005/06 Winter Gull Roost Survey (WinGS) and the BTO/RSPB/JNCC Wetland Bird Survey (WeBS) Core Count and Low Tide Count schemes. The 2003/04–2005/06 WinGS was the latest in a series of periodic surveys aiming to estimate the numbers of winter gulls wintering in the UK and its constituent countries and at important sites. The WeBS Core Count scheme is the principal scheme of the Wetland Bird Survey and aims to monitor the populations and trends of non-breeding waterbird species in the UK through monthly counts across the year. At coastal sites, counts are usually undertaken at high tide. The WeBS Low Tide Count scheme provides information on the distributions of waterbirds on estuaries at low tide, with the aim of identifying key feeding areas; counts are undertaken monthly from November to February. WeBS Core Count and Low Tide Count data were obtained for the winters of 2013/14–2017/18.

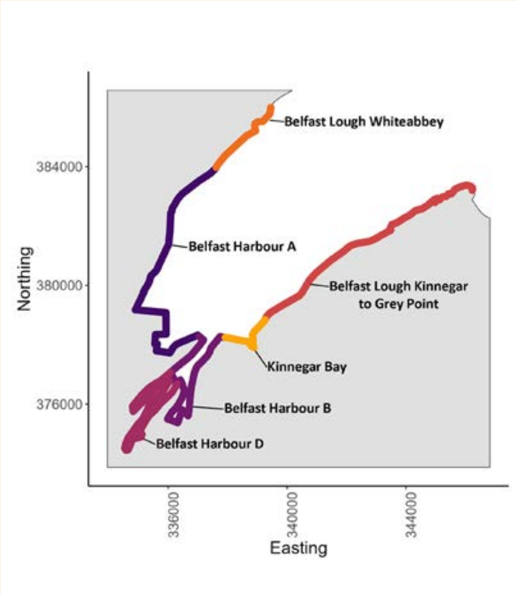
2.3.1. WinGS

Counts were made at six key coastal count sectors around Belfast Lough on dates between 14 and 21 January in 2005 (Figure 2). Following the protocols of the survey, one-off counts were made by volunteer observers arriving at sites 2–3 hours before dark, first counting any birds already settled and then counting further birds arriving to roost at dusk (Burton *et al.,* 2013).

2.3.2. WeBS – Core Counts

Average winter (November to March) counts were calculated from WeBS Core Count survey data obtained for the winters of 2013/14–2017/18 for four count sectors around Belfast Lough. These sectors are all on the southern shore of the lough. Counting of gulls is optional in WeBS Counts and gulls are not routinely counted on the north shore.

Figure 2. Map of Belfast Lough showing the locations of the WinGS count sectors: Belfast Lough Whiteabbey (orange), Belfast Harbour A (dark blue), Belfast Harbour B (purple), Belfast Harbour D (magenta), Kinnegar Bay (yellow) and Belfast Lough Kinnegar to Grey Point (red).



2.3.3. WeBS – Low Tide Counts

WeBS Low Tide data were obtained for winters 2013/14–2017/18 and average counts for each winter calculated at the sector level. Belfast Lough is divided into a greater number of count sectors for the Low Tide Counts than Core Counts. Changes in count sectors have also occurred between years in some areas. In instances when both the larger sector and a smaller sub-sector within this were counted at different times during the same winter, the counts of the smaller sub-sector were assigned to the larger overlapping sector. In total 30 low tide sectors were analysed around the lough.

3. RESULTS

3.1. Breeding gull numbers in Belfast city centre and docks

On 23 May 2018 and 20 May 2019, two BTO staff members, Katherine Booth Jones and Shane Wolsey accessed the roof of the two tallest buildings on the island of Ireland, the Obel Tower (54.602137, -5.921901; 85 m tall) and Grand Central Hotel (54.595189, -5.931711; 80 m tall), both located in central Belfast (Figure 3). Visibility was good on both days allowing surveyors to see gull AONs clearly. The furthest gull AONs seen from the vantages were approximately 4.1 km from the vantage point, although nests were not discerned at this distance in 2018 (Obel Tower to a large warehouse in the docks, Figure 3). In 2019, all gulls were identified to species level in from the vantages, and 60% more AONs were counted than in 2018 (Table 2). This is probably due to a combination of survey-related factors (longer survey time, better visibility, and familiarity with the survey) than an actual increase in gull numbers in the city between the two years. The maximum count of AONs in 2019 is more likely to be closer to the true number of gull nests in central Belfast and the docks. All nest locations observed in 2019, and the vantage from which they were viewed, can be found in Appendix 1.

In both 2018 and 2019, gull AONs appeared to be more concentrated in central Belfast than in the visible area outside the city centre (Figure 3), but clusters were also observed in the docks. Gull nests were most often distributed singly or in small groups (<4) on rooftops, with exceptions being on warehouse roofs in the docks. Although fewer buildings were occupied by gulls in the docks, gulls were more concentrated on particular roofs, leading to approximately equal numbers of nests being counted in the docks and the city centre. Over six times as many Lesser Black-backed Gull AONs were counted than Herring Gull AONs in both years (Table 2).

During the survey of 2019, the percentage visibility of 336 multi-storey and industrial buildings (buildings with roofs deemed unsuitable for nesting, e.g. due to steep sloping, were excluded) was assessed from the vantage points. It was estimated that the average percentage roof visibility from the vantages was 37% ± 3% (95% confidence interval). If we assume that the distribution of gull nests was even across roof surfaces (observational data supported this assumption, with clusters of nests only found in the harbour area), the percentage visibility can be used to estimate the number of gulls not seen from the vantage points. Thus, the total number of AONs present in the search radius of the vantage points in 2019 roof was estimated to be 703 (650–765, 95% confidence interval). Of these,

Table 2. Actual counts of Apparently Occupied Nests (AONs) of large gulls in the Belfast city centre and docks areas in 2018 and 2019. Counts corrected for the estimated roof visibility, and the lower and upper confidence interval of this, are included in brackets.

	City Centre	Docks	Total
2018			
Lesser Black-Backed Gull	72 (195, 180–212)	29 (78, 72–85)	101 (273, 252–297)
Herring Gull	11 (30, 28–32)	5 (14, 12–15)	16 (43, 40–47)
Unknown species	–	45 (122, 112–132)	45 (122, 112–132)
Total 2018	**83 (224, 208–244)**	**79 (214, 198–232)**	**162 (438, 405–476)**
2019			
Lesser Black-Backed Gull	101 (273, 252–297)	120 (324, 300–353)	221 (597, 552–650)
Herring Gull	26 (70, 65–76)	13 (35, 32–38)	39 (105, 98–115)
Unknown species	0	0	0
Total 2019	**127 (343, 318–374)**	**133 (359, 332–391)**	**260 (703, 650–765)**

Lesser Black-backed Gulls accounted for approximately 597 (552–650, 95% confidence interval) AONs and Herring Gulls made up approximately 105 (98–115, 95% confidence interval) AONs. However, accounting for visible roof area also assumes that there is an even distribution of urban habitat suitable for gulls, which is clearly not the case in the city centre, therefore estimates should be viewed with caution.

3.2. GPS tracking

3.2.1. Colour-ring re-sighting

All colour-ringed gulls from Belfast were re-sighted at least once after their original capture (Table 3). Gulls ringed in 2018 were also re-sighted in 2019. Members of the public also contributed to re-sightings between May 2018 and March 2021, reporting colour-ringed Lesser Black-backed Gulls on seven occasions (including re-sightings outside of Northern Ireland from Cork, Madrid and Casablanca) and Herring Gulls on 11 occasions. The longest period between capture and re-sighting at the time of writing was 603 days (YN (B:15W)). GPS tagged gulls (N = 11) were not re-sighted more or less frequently than non-tagged (colour ringed only, N = 4) gulls (Welch Two Sample t-test, t = -0.37, P = 0.72).

Figure 3. Central Belfast survey area. Vantage point buildings are marked with a red square (Grand Central Hotel) and red triangle (Obel Tower). Approximate locations of Apparently Occupied Nests of gulls are marked with coloured circles. A: Lesser Black-backed Gull (light blue = 2018, dark blue = 2019), B: Herring Gull (yellow = 2018, orange = 2019). Large gulls too far away to be identified to species level in 2018 are not pictured.

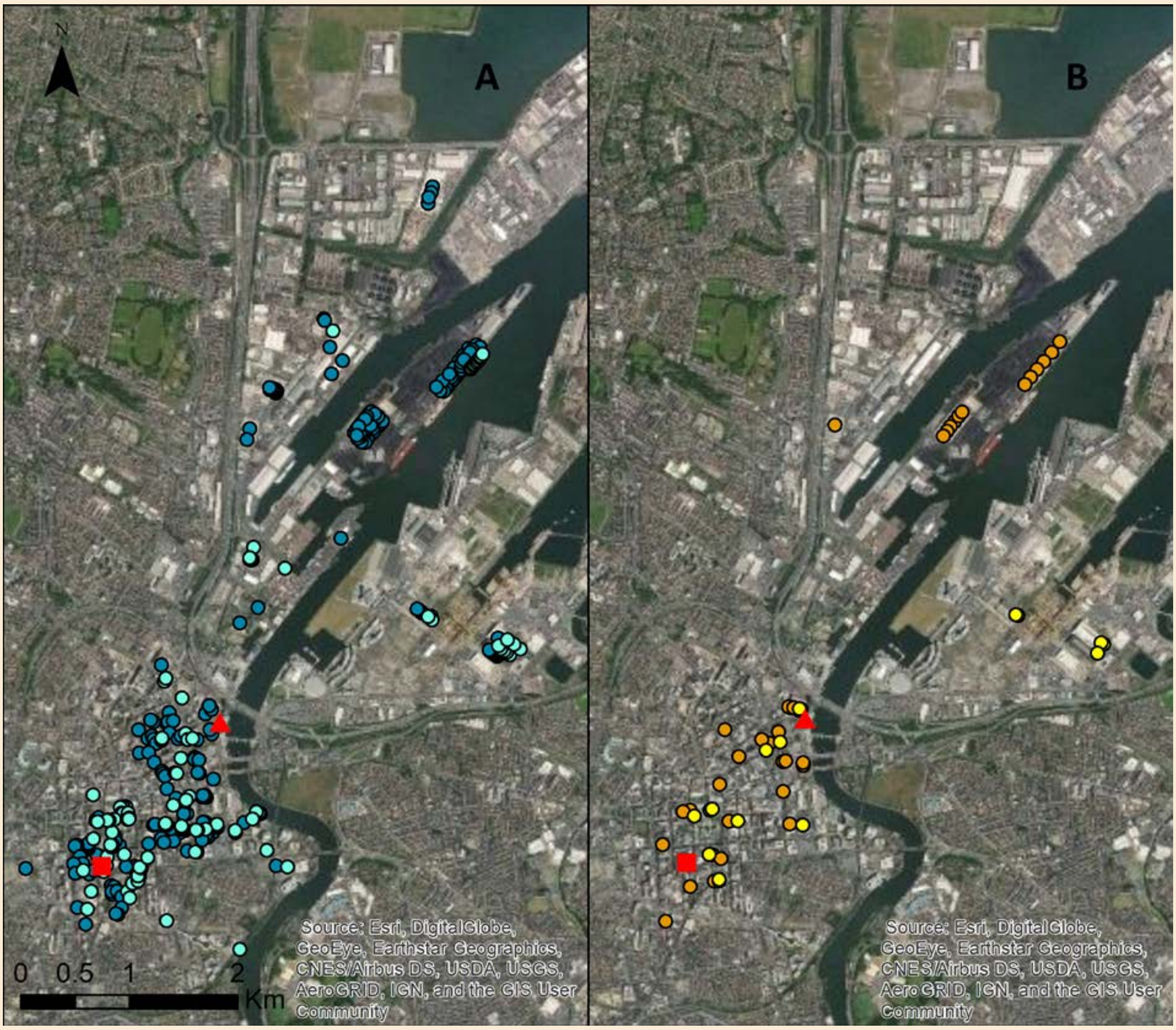


Table 3. Re-sighting dates and locations of gulls colour-ringed in Belfast in between May 2018 and March 2021. Species: LB = Lesser Black-backed Gull, HG = Herring Gull.

Individual	Species	1	2	3	4	5	6
YN (B10:W) Tag 867	LB	14/06/2018, nest	22/06/2018, nest	06/07/2018, nest	20/07/2018, nest	13/05/2019, nest	27/06/2019, nest
YN (B11:W) Tag 866	LB	14/06/2018, nest	06/07/2018, nest	20/07/2018, nest	13/06/2019, nest	14/10/2019, Casablanca, Morocco.	
YN (B12:W) Tag 865	LB	14/06/2018, roof residential building, Belfast	14/06/2018, nest	22/06/2018, nest	06/07/2018, nest	20/07/2018, McClure Street Belfast	21/05/2019, nest
YN (B13:W) Control	LB	22/06/2018, nest	06/07/2018, nest	20/07/2018, nest	13/06/2019, nest		
YN (B14:W) Tag 864	LB	14/06/2018, nest	22/06/2018, nest	06/07/2018, nest	20/07/2018, nest	24/07/2018, Laurelbank, Belfast	17/10/2019, Blackrock Cas-tle, Cork Har-bour, Ireland
YN (B15:W) Control	LB	22/06/2018, nest	06/07/2018, nest	20/07/2018, nest	02/12/2018, Colmenar Viejo landfill, Madrid, Spain	19/11/2019, Colmenar Viejo landfill, Madrid, Spain	15/02/2020, Colmenar Viejo landfill, Madrid, Spain
YN (B16:W) Tag 1002	HG	13/06/2019, nest					
YN (B17:W) Tag 833	HG	13/06/2019, nest	13/06/2019, Obel Tower, Belfast	20/08/2019, Obel Tower, Belfast	23/11/2019, Titanic Belfast	14/04/2020, Obel Tower, Belfast	06/09/2020, Whitehouse Lagoon, Belfast
YN (B18:W) Tag 834	HG	31/05/2019, Bridge Street, Belfast	23/11/2019, Titanic Belfast	22/08/2020, High Street, Belfast			
YN (B19:W) Tag 1134	LB	13/06/2019, nest	27/06/2019, nest				
YN (B20:W) Tag 1128	LB	13/06/2019, nest					
YN (B21:W) Tag 1001	HG	13/06/2019, nest	29/08/2020, Kinnegar Beach	11/10/2020, Belfast Lough (West Shore)			
YN (B22:W) Control	HG	17/06/2019, Ormeau Em-bankment, Belfast					
YN (B23:W) Control	HG	08/07/2019, Belfast Harbour	10/09/2019, Belfast Harbour				
YN (B24:W) Tag 978	HG	27/06/2019, Ballyholme Esplanade	08/03/2020, Ballyholme Esplanade				

3.2.2. Breeding Success

The JNCC report that Lesser Black-backed Gull productivity is often very variable, but is usually generally below 0.6 chicks per pair (average 0.52, JNCC, 2020), and that Herring Gull productivity is on average 0.75 chicks per pair (JNCC, 2020). The productivity of the sample of nests appeared to be higher than the UK average (JNCC, 2020, Table 4). In 2018, four Lesser Black-backed Gull nests produced seven chicks, of which six successfully fledged (1.5 chicks per nest). In 2019, difficulty in accessing the nests meant that hatched chicks could not be followed to a fledging age, so the ultimate outcome of all the nests is less certain. However, three Lesser Black-backed Gull nests produced five chicks (0.6 chicks per nest) and three Herring Gull nests produced eight chicks (2.67 chicks per nest).

The average hatch-to-fledge period of a gull chick is approximately 35 days (Nager *et al*., 2000; Verboven et al., 2003) but the surviving chicks from the sample of four Lesser Black-backed Gull nests in 2018 were still present at the nest at 56 days, although some juveniles were observed flying around the nest sites at this visit. The nest failure that occurred around the 2 July 2018, approximately 14 days after the hatching of the single chick, corresponded with a heatwave. Another probable casualty occurred around the 10 July 2018, when one chick (46 days old) was observed by the staff of Belfast City Council at the base of the building after presumably falling from the nest site. The Lesser Black-backed Gull study nest in 2019 failed to hatch any chicks. Both adults were present at the nest site on 16 June 2019, a month after capture. While both adults remained present at the nest in the hours after being fitted with GPS tags, it is possible that the disturbance during May caused by catching both adults led to them temporarily leaving the nest un-incubated, causing the eggs to become chilled and die.

3.2.3. Foraging trips

Belfast

Of the 11 gulls fitted with GPS tags in Belfast, location data were received from 10 (Table 5). One tag fitted to a Herring Gull (tag 1001), captured at its nest on the Metro Building in 2019, failed to produce any data. However, this gull was re-sighted by its colour ring on 28 August 2020 and on 11 October 2020 on the western shore of Belfast Lough, although the presence of the tag could not be confirmed. Therefore, it is certain that the lack of data from this individual was not due to its death but was likely due to a fault with either the tag or the tag attachment. Two Lesser Black-backed Gulls tagged in 2018 (tag 865 and tag 866) were tracked for a second breeding season in 2019, and two gulls (one Lesser Black-backed Gull and one Herring Gull) tagged in 2019 were tracked for a second breeding season in 2020 (tag 1134 and tag 978). The nine gulls tracked from roof nests (i.e. excluding the sub-adult Herring Gull, tag 834, and Bangor-caught Herring Gull, tag 978) made a total of 2,746 trips (mean 250, SD = 78) away from their nest sites during the breeding season(s) they were tracked in and prior to migration, between May and mid-August to early September (Table 5). On average, the furthest point in each foraging trip was less than 8 km from the nest site; well within the urban area of Belfast. The furthest foraging trip was 47 km from the nest site, and took the Lesser Black-backed Gull east and offshore into the Irish Sea. The entire trip lasted 5 hours and 10 minutes and occurred during the later stages of chick rearing, when chicks would have been around 28 days old. The longest trip was a 187 hour (7.8 day) absence from the nest site. However, during this time the Lesser Black-backed Gull (tag 1134) did not travel far and stayed within the city, travelling a maximum of 6 km from the nest site, mostly appearing to spend time in the Spórtlann na hÉireann and Corrigan Park sports fields, and staying within the urban area during this time. This trip occurred in the first week of July, while the gull only arrived back into Belfast on 3 May, therefore it is unlikely that it bred successfully in 2020.

Big Copeland

Of the 21 Herring Gulls fitted with GPS tags that nested on Big Copeland Island (20 tagged at nests in 2015, one tagged in Bangor in 2019 and subsequently deemed to be breeding on Big Copeland through visual inspection of tracking data), 16 were tracked in a single breeding season (2015) and five were tracked over multiple seasons (four over two seasons, one over five seasons, Table 6). Trip statistics from two gulls (D012 and D016) were discarded from further analysis because only one foraging trip was recorded for each bird. Across all gulls and years, a total of 1,864 trips (mean 69, SD 47) were recorded. This was lower than the number of complete trips collected for the urban gulls, likely due to tag drop-out in the earlier models used in 2015. The mean furthest foraging distance per trip was 12.37 km (SD 6.75 km) from the nest site, while the most distant trip from the nest was 75 km away, which took place during a trip away from the colony 9 June 2015. Between the 6 June and 9 June, the gull (D011) made two trips directly south from the colony and out into the Irish Sea to around 60 km east of the mouth of Carlingford Lough. The prompt return to the colony after both of these trips might suggest that this gull was still raising young. On average gulls' trips away from the nest were 16 hours (SD 8 hours). The longest trip away from the nest was 658 hours (27 days) which occurred between 8 August and 4 September 2015 and was therefore likely to represent a post-breeding dispersal away from the colony. During this time the gull (D023) exclusively used Belfast Harbour buildings and nearby shoreline.

Table 4. Breeding success at eight gull nests in central Belfast. Adults were caught and ringed and/or tagged at the nests on the 25 May in the 2018 season and 15 May in the 2019 season. In 2018, nests were revisited on average every two weeks until the chicks were of fledging age. In 2019, four new nests were followed, but building access limited revisits to one or two occasions, the first being a month after the ringing event. Two of the 2018 study nests were also observed in 2019. a Nest failed on approximately 2 July 2018. b One chick fell from building 10 July 2018. c Nest failure. Species: LB = Lesser Black-backed Gull, HG = Herring Gull.

Nest	Species	Parent(s) Colour ring	GPS tag ID	Visit number				
				1	2	3	4	5
2018 Season								
Goodwood House	LB	YN (B10:W)	867	2 eggs, 1 small chick, 25/05/2018	2 medium chicks, 14/06/2018	2 large chicks, 22/06/2018	2 large chicks, 06/07/2018	Chicks fledged, 20/07/2018
Cecil Ward Building, 1	LB	YN (B11:W) and YN (B15:W)	866	2 eggs, 25/05/2018	1 small chick, 14/06/2018	1 small chick, 22/06/2018	a Nest failure, 06/07/2018	
Cecil Ward Building, 2	LB	YN (B12:W)	865	2 eggs, 1 small chick, 25/05/2018	3 medium chicks, 14/06/2018	3 medium chicks, 22/06/2018	3 large chicks, 06/07/2018	b Chicks fledged, 20/07/2018
Cecil Ward Building, 3	LB	YN (B13:W) and YN (B14:W)	864	3 eggs, 25/05/2018	2 medium chicks, 14/06/2018	2 medium chicks, 22/06/2018	2 large chicks, 06/07/2018	2 large chicks, 20/07/2018
2019 Season								
Goodwood House	LB	YN (B10:W)	867	3 eggs, 13/05/2019		2 medium chicks, 27/06/2019		
Cecil Ward Building, 3	LB	YN (B13:W) and YN (B14:W)	864		3 medium chicks, 13/06/2019			
Royal Mail 1	HG	YN (B16:W)	1002	2 eggs, 15/05/2019	2 medium chicks, 13/06/2019			
Royal Mail 2	HG	YN (B17:W)	833	3 eggs, 15/05/2019	3 medium chicks, 13/06/2019			
Europa Hotel	LB	YN (B19:W) and YN (B20:W)	1134 and 1128	3 eggs, 15/05/2019	c3 eggs (warm, un-hatched), 13/06/2019	3 eggs (warm, un-hatched), 27/06/2019		
Metro Building	HG	YN (B21:W)	1001	3 small chicks, 23/05/2019	3 medium chicks, 13/06/2019	3 large chicks, 27/06/2019		

Table 5 . Trip statistics for eight GPS tracked urban-nesting gulls. One sub-adult Herring Gull (834, YN(B18:W)) was not nesting, and therefore only core and home range areas were calculated. Means are reported with standard deviation (SD). Utilisation Density (UD) areas were calculated from the 0.5 x 0.5 km Time-in-Area grid, created using the R package 'trip'. Species: LB = Lesser Black-backed Gull, HG = Herring Gull.

Tag ID	Year	Species	95% UD area (km²)	50% UD area (km²)	Number of trips	Furthest trip (km)	Average (SD) furthest point from the nest per trip (km)	Average (SD) foraging trip length (km)	Average (SD) trip duration (hours)	Maximum foraging trip duration (hours)
Urban-nesting Lesser Black-backed Gulls										
864, YN(B14:W)	2018	LB	71	2	245	46.74	7.16 (5.76)	16.37 (14.73)	5.60 (3.79)	29.41
865, YN(B12:W)	2018	LB	20.75	0.5	247	18.06	3.08 (3.44)	7.46 (8.58)	8.03 (8.14)	75.52
	2019	LB	11.5	0.5	248	18.92	1.98 (2.75)	4.64 (6.69)	5.88 (4.17)	29.39
866, YN(B11:W)	2018	LB	18	1.5	195	26.69	4.30 (3.51)	9.13 (7.64)	5.92 (4.62)	38.62
866, YN(B11:W)	2019	LB	21	1.25	113	19.73	4.15 (3.02)	9.08 (7.21)	7.54 (5.78)	26.93
867, YN(B10:W)	2018	LB	56	0.25	182	40.03	4.70 (7.96)	12.85 (21.43)	10.53 (9.88)	52.13
1128, YN(B20:W)	2019	LB	159	1.75	323	41.50	7.12 (7.23)	18.27 (23.12)	6.07 (5.92)	59.94
1134, YN(B19:W)	2019	LB	60.25	0.5	292	24.42	3.20 (4.31)	7.15 (10.07)	5.05 (4.29)	33.50
	2020	LB	13.25	0.75	184	33.57	3.40 (3.97)	11.20 (16.95)	15.47 (20.92)	187.23
Urban-nesting Herring Gulls										
833, YN(B17:W)	2019	HG	10.75	0.25	362	8.53	1.56 (2.10)	3.40 (4.85)	5.49 (4.37)	23.37
1002, YN(B16:W)	2019	HG	30.50	0.25	355	15.35	2.27 (3.34)	5.56 (9.24)	7.02 (6.54)	50.67
Sub-adult Herring Gull										
834, YN(B18:W)	2019	HG	8.75	0.25	–	–	–	–	–	–

Table 6. Trip statistics for 21 GPS tracked natural-nesting Herring Gulls, 20 tagged at nests in 2015 and one from 2019 presumed to be breeding on Big Copeland Island through visual inspection of the tracking data (978, YN (B24:W)). Means are reported with standard deviation (SD). Utilisation Density (UD) areas were calculated from the 0.5 x 0.5 km Time-in-Area grid, created using the R package 'trip'.

Tag ID	Year	Species	95% UD area (km^2)	50% UD area (km^2)	Number of trips	Furthest trip (km)	Average (SD) fur-hest point from the nest per trip (km)	Average (SD) foraging trip length (km)	Average (SD) trip duration (hours)	Maximum foraging trip duration (hours)
Herring Gull tagged as part of 2019 cohort from Ballyholme, Bangor										
978, YN(B24:W)	2019	HG	5.75	0.25	173	9.45	6.17 (0.71)	14.43 (4.07)	11.05 (6.24)	23.46
	2020	HG	8.75	0.75	28	9.59	6.59 (0.83)	6.00 (5.46)	9.40 (9.95)	45.24
Herring Gulls tagged at nests as part of 2015 cohort from Big Copeland Island										
D002, YN(IU:W)	2015	HG	6.25	1	94	18.85	5.22 (2.53)	10.47 (5.86)	14.14 (11.77)	53.13
D004, YN(IV:W)	2015	HG	55.75	6.5	51	19.35	16.20 (5.30)	30.09 (12.77)	13.02 (10.48)	55.99
D006, YN(1L:W)	2015	HG	19.25	1.25	117	14.37	8.62 (1.50)	16.71 (4.90)	19.28 (12.15)	69.42
	2016	HG	16.25	3.25	42	18.50	9.03 (2.24)	18.44 (4.86)	11.47 (6.80)	29.20
D01, no CR information	2015	HG	21	5	5	12.39	10.66 (0.98)	24.15 (14.53)	18.23 (9.64)	32.87
D010, YN(1M:W)	2015	HG	71.25	6.75	84	25.16	11.06 (3.60)	22.89 (8.53)	19.24 (18.73)	122.29
D011, YN(2E:W)	2015	HG	286.5	29.5	23	75.18	36.50 (18.25)	74.68 (38.63)	18.11 (11.48)	50.08
D012, YN(2L:W)	2015	HG	NA	NA	1	3.36	3.36 (NA)	0.07 (NA)	NA	23.53
D013, YN(2P:W)	2015	HG	17.5	2	78	18.16	7.37 (2.36)	15.15 (5.20)	8.49 (5.97)	32.97
D014, YN(I4:W)	2015	HG	26.5	3	156	21.11	6.42 (2.11)	13.55 (6.01)	11.42 (15.25)	164.66
D015, YN(3V:W)	2015	HG	10.75	1.5	25	14.17	10.18 (0.97)	18.19 (4.63)	14.45 (12.91)	48.10
D016, YN(3X:W)	2015	HG	5	2	1	8.92	8.92 (NA)	17.64 (NA)	NA	4.09
D017, YN(3T:W)	2015	HG	26.25	3.25	35	25.32	9.51 (5.61)	15.32 (8.09)	13.89 (14.07)	70.89
D020, YN(2U:W)	2015	HG	74.75	4.5	71	31.65	11.52 (5.09)	23.22 (11.48)	11.40 (8.77)	41.66
	2016	HG	42.5	3.25	41	18.04	11.05 (3.00)	31.46 (50.50)	39.72 (76.84)	393.05
	2017	HG	37.75	2.25	95	19.10	9.55 (2.15)	19.04 (7.53)	19.18 (11.30)	51.05
	2018	HG	36.25	2.5	107	19.13	9.73 (2.59)	18.89 (6.91)	11.30 (8.96)	53.67
	2019	HG	34.25	2.25	102	14.97	9.07 (2.11)	18.12 (5.22)	5.30 (4.42)	23.75

Tag ID	Year	Species	95% UD area (km²)	50% UD area (km²)	Number of trips	Furthest trip (km)	Average (SD) fur-hest point from the nest per trip (km)	Average (SD) foraging trip length (km)	Average (SD) trip duration (hours)	Maximum foraging trip duration (hours)
D021, YN(2J:W)	2015	HG	71.25	7.5	49	31.26	8.47 (5.80)	16.20 (14.14)	13.66 (13.12)	59.67
D022, YN(IX:W)	2015	HG	9.5	1.75	26	8.08	7.18 (0.43)	13.79 (3.97)	14.08 (7.60)	31.48
D023, YN(2N:W)	2015	HG	NA	NA	82	26.00	22.14 (7.93)	44.21 (21.52)	29.45 (82.68)	657.88
	2016	HG	83.25	18.25	29	28.81	21.69 (7.76)	45.65 (16.86)	7.75 (4.09)	18.34
D024, YN(IJ:W)	2015	HG	80	3.25	37	51.84	14.95 (10.26)	31.11 (32.11)	20.31 (12.29)	61.55
D026, no CR information	2015	HG	58	7	11	33.55	14.29 (10.83)	26.34 (22.13)	21.00 (13.92)	41.74
D03, YN(3Y:W)	2015	HG	47	8.75	62	22.41	12.41 (2.52)	22.90 (7.99)	14.17 (13.47)	80.19
D05, YN(2X:W)	2015	HG	69.25	8.5	172	28.05	17.96 (6.85)	37.94 (18.82)	11.44 (11.72)	112.21
	2016	HG	50	1	69	23.98	20.52 (4.01)	40.39 (20.07)	33.57 (41.27)	282.28

3.2.4. Space use and core activity areas

Belfast

With the exception of the Herring Gull tagged in Bangor, which upon examination of the tracking data appeared to be nesting on Big Copeland Island, the foraging distribution of gulls during the breeding season was predominantly focused in urban areas of Belfast (Figure 4). Each individual GPS tagged gull had a different foraging distribution around Belfast and the docks despite their nests being a maximum of 1.17 km apart (three Lesser Black-backed Gull nests were located on the same roof). Although the gulls did travel outside the city, their core areas (50% UDs) were all in urban areas (Figure 4). Individual gulls showed varying foraging distributions around the nest sites; for example, the Lesser Black-backed Gulls tagged in 2018, 864 (Figure 5C) and 867 covered a broad area (reflected in the greater 50% UD area for these individuals, Table 5), while 865 and 866 (Figure 5D) remained closer to the nest sites throughout the season (Appendix 3). The two breeding Herring Gulls from the roof of the Tomb Street Royal Mail building in 2019 also did not appear to range far from their nests (Figure 5A and B). However, 833 spent time at the RSPB Belfast Window on Wildlife and areas around the docks, while 1002 had a broader 95% UD (Table 5), visiting Albert Quay in the docks but also Belvoir Park housing estate further inland.

While all gulls appeared to focus their activity in predominantly urban areas, more distant trips also occurred, taking different directions. The furthest point recorded was by 864, 47 km from the nest in the Irish Sea east of Portavogie. The nest failure of Lesser Black-backed Gulls with tags 1128 and 1134 may have contributed to their exploitation of a range of areas around Belfast. In particular 1128 had a large 95% UD and travelled a long way during trips (Table 5). During the breeding season it mostly spent time in a housing estate in west Belfast near playing fields, but also visited a wide spread of locations in Belfast Lough (offshore), in farmland surrounding Belfast and made a visit to the Murlough Nature Reserve (41 km south of Belfast). Its partner, 1134, also foraged in west Belfast (around Corrigan Park, Belfast Metropolitan College and Falls Park), but spent more time spread out in the farmland around Belfast and little time in Belfast Lough, in contrast to 1128. Despite the nest failure early in the season, gull 866 appeared to use a smaller, more concentrated core area than the other gulls in the sample (Appendix 2, Table 5).

Three Lesser Black-backed Gulls retained their GPS tags in successive breeding seasons (865, 866 and 1134). These gulls returned to the same nest sites and used predominantly the same core foraging locations (Figure 6), although their overall UDs did vary between years (Appendix 2).

Figure 4. Time-In-Area (TIA) grid at a 500 m resolution, showing the utilisation density (UD) of nine Lesser Black-backed and Herring Gulls tracked from Belfast during the breeding season. Pale blue = total area in which the gull spent time (100% UD), dark blue = 95% UD, yellow = 75% UD, red = core area, 50% UD. A: 2018 (N = 4), B: 2019 (N = 7), C: 2020 (N = 1).

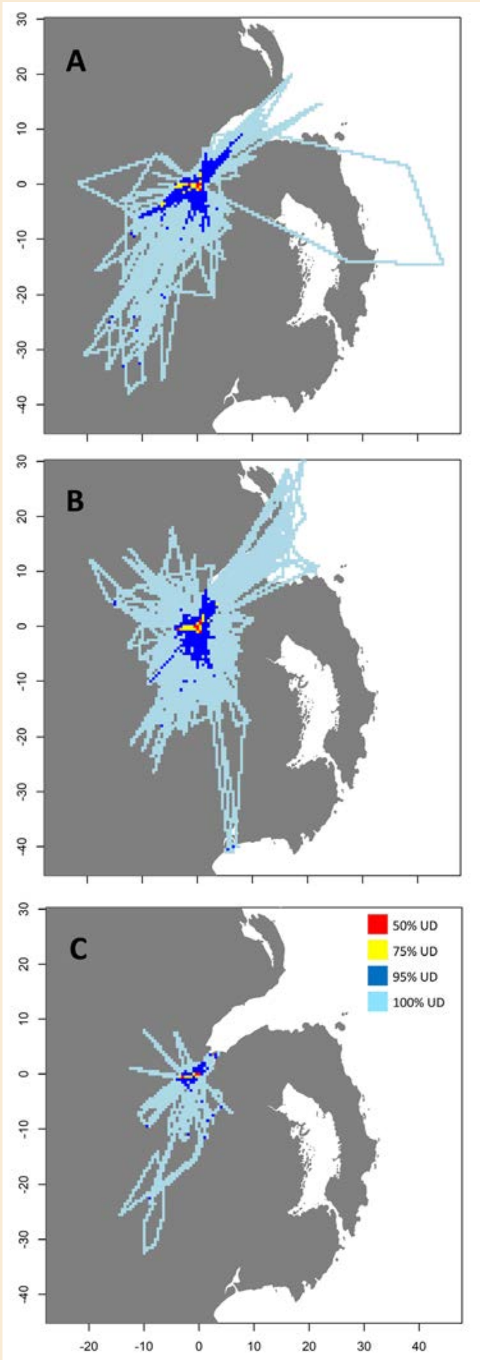


Figure 5. Time-In-Area grids at a 500 m resolution, showing the utilisation density (UD) of an example of two urban-nesting Herring Gulls and two Lesser Black-backed Gulls in central Belfast. Pale blue = total area in which the gull spent time (100% UD), dark blue = 95% UD, yellow = 75% UD, red = core area, 50% UD. A: Tag 833, Herring Gull. B: Tag 1002, Herring Gull. C: Tag 864 (2018), Lesser Black-backed Gull. D: Tag 866 (2018), Lesser Black-backed Gull. All individual TIA maps are available in Appendix 1.

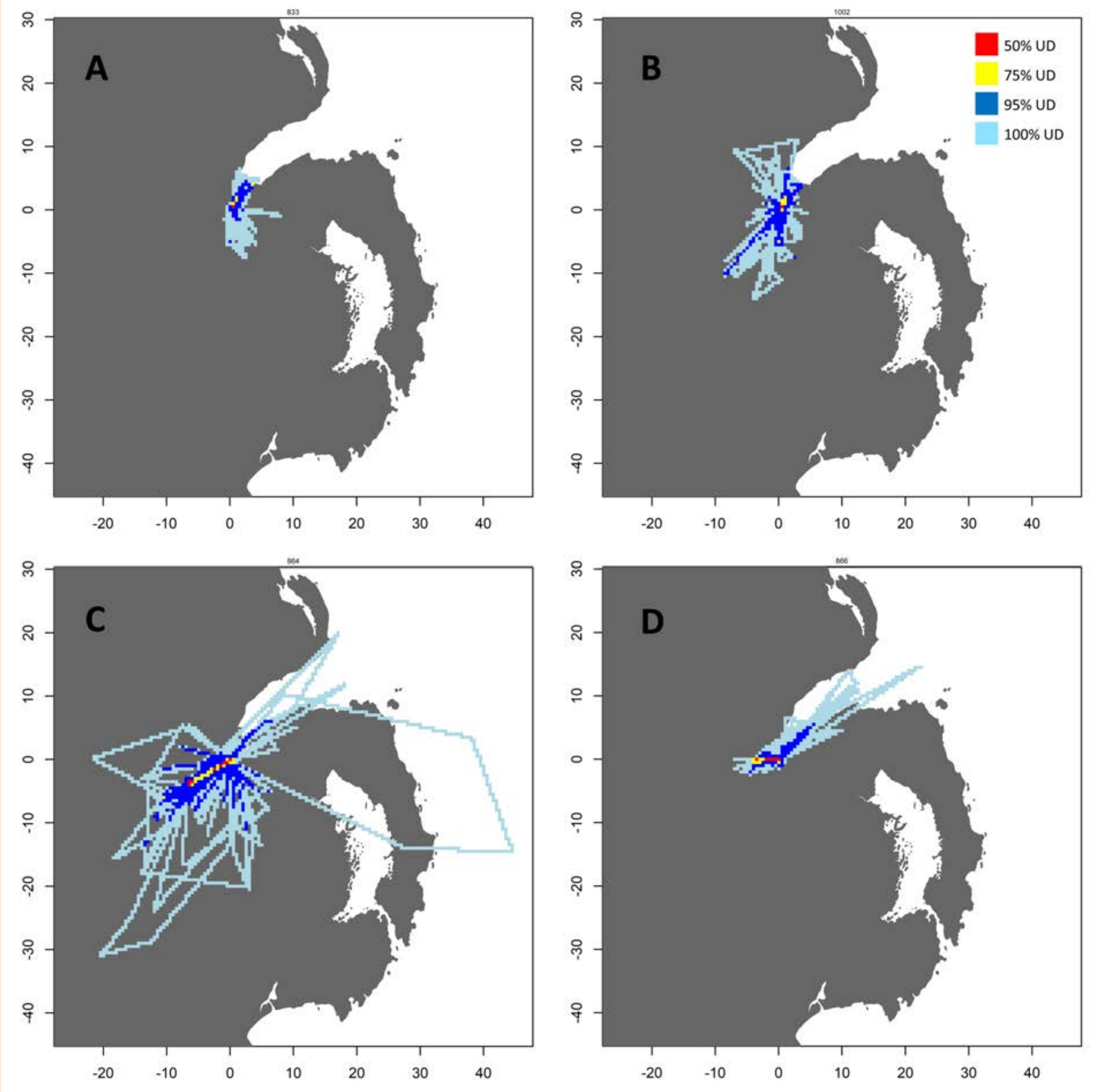
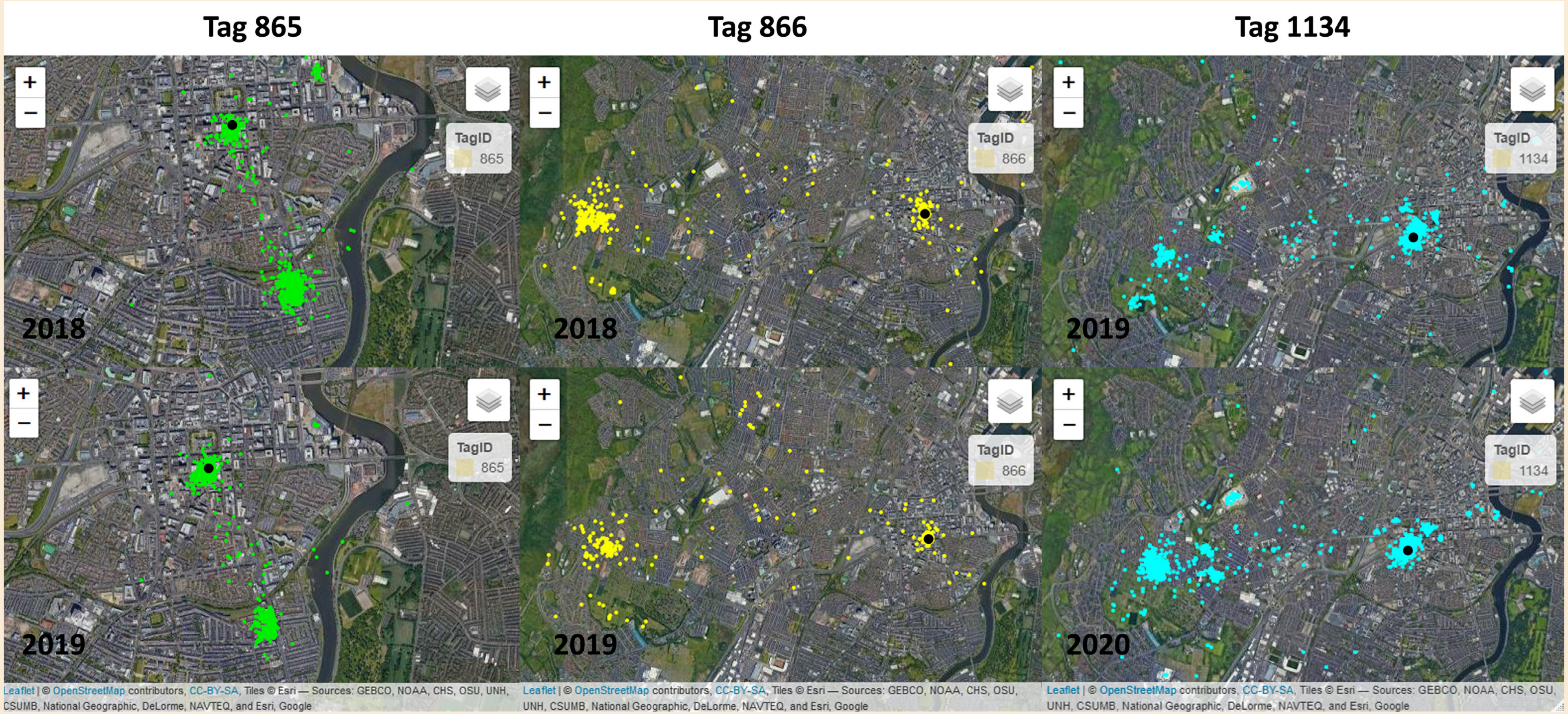


Figure 6. Between-year comparison of the foraging trips of three Lesser Black-backed Gull in central Belfast. Nest locations are marked with a black point. Left: Tag 865 (2018 and 2019); middle: Tag 866 (2018 and 2019), Right: Tag 1134 (2019–20).



Copelands

Herring Gulls from Big Copeland Island predominantly focused their time in the coastal towns in north-east County Down (Figure 7), although some regularly travelled as far as the Kings Road Shopping Centre in the outskirts of Belfast and to the Belfast docks (for example Figure 8C). Only four gulls tagged in 2015 retained their tags into 2016 (Figure 7B), but the overall footprint of the TIA grid was similar to the 2015 grid, focusing on north-east County Down. The core area (50% UD) highlighted Bangor, Groomsport, Donaghadee and Millisle as places where the cohort spent the majority of their time. As discovered by analysing trip distances (see Section 3.4.2 and Table 6), some birds made long trips out into the Irish Sea, although these were not common and the 95% UD area was focused inland.

While all nesting on a relatively small island, each gull appeared to have a distinct area of focus on mainland Northern Ireland (Figure 8) and similarly to urban nesting gulls, many of these appeared to be in residential areas. For example, D002 and D014 (Figures 8A and B) had relatively restricted TIA grids, with focal areas in residential areas on the sub-urban outskirts of Donaghadee, although unlike D002, D014 also used the farmland area around the focal housing estate. The Herring Gull captured in Bangor was particularly restricted and habitual in its space use, consistently spending time on a few roofs in a residential area of east Bangor, the shoreline directly north of these and the rocks on the western peninsula of Big Copeland Island (Appendix 2). Some gulls appeared to have a different behaviour pattern and ranged further afield, resulting in larger 95% UDs (Figures 8C and D). For example, while D020 spent the majority of its time in a residential area in Bangor, it also focused on the intertidal area at the north end of Strangford Lough and generally spread out in the farmland between Newtownards and Bangor (Figure 8C). In contrast, D010 was much more coastal, with its 50% UD core areas highlighting Ballywater and Ganaway Bays as important, as well as in the farmland inland of Ballywater (Figure 8D). Different again was D023, which commuted very directly to Belfast and spent the majority of its time on warehouses and in tidal shoreline around Belfast harbour (Appendix 2).

Five Herring Gulls were tracked over successive breeding seasons, and this demonstrated that, like urban-nesting Lesser Black-backed Gulls, individuals were largely consistent between years in the areas they foraged (Figure 9).One gull (D020, Figures 8C and 10) retained its tag for five successive breeding seasons (2015–19) and even across multiple years appeared to be consistent in its space-use.

Figure 7. Time-In-Area grid at a 500 m resolution, showing the utilisation density (UD) of 21 Herring Gulls tracked from Big Copeland Island during the breeding season. Pale blue = total area in which the gulls spent time (100% UD), dark blue = 95% UD, yellow = 75% UD, red = core area, 50% UD. A: 2015 (N = 20), B: 2016 (N = 4).

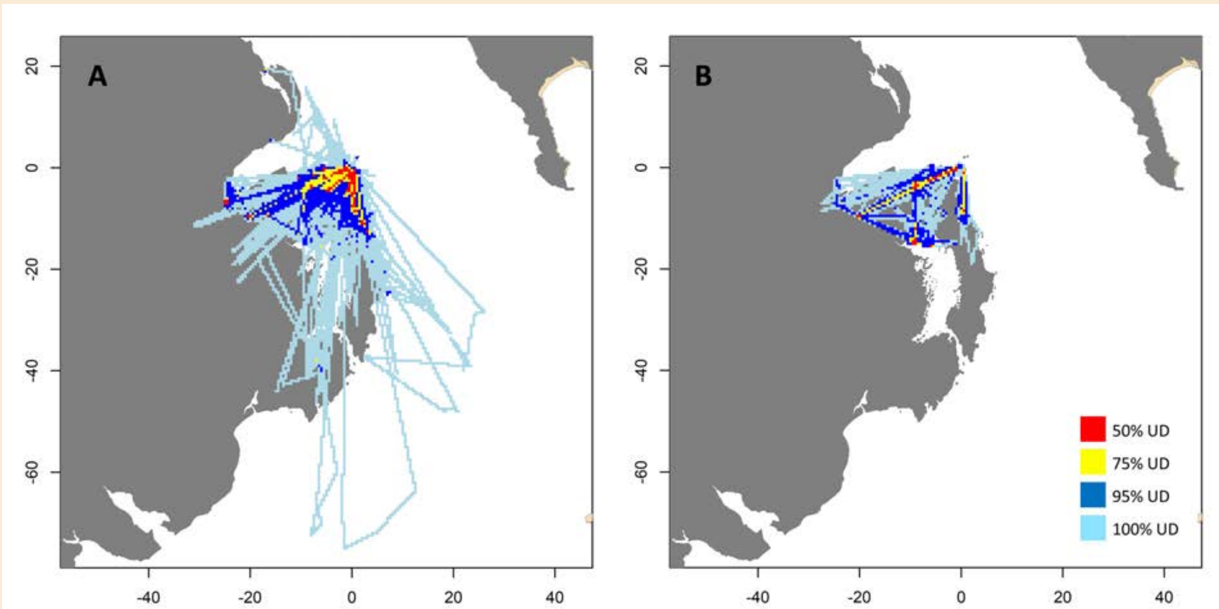


Figure 8. Time-In-Area grids at a 500 m resolution, showing the utilisation density (UD) of an example of four coastal-nesting Herring Gulls from Big Copeland Island in 2015. Pale blue = total area in which the gull spent time (100% UD), dark blue = 95% UD, yellow = 75% UD, red = core area, 50% UD. A: Tag D002. B: Tag D014. C: Tag D020. D: Tag D010. All individual TIA maps are available in Appendix 1.

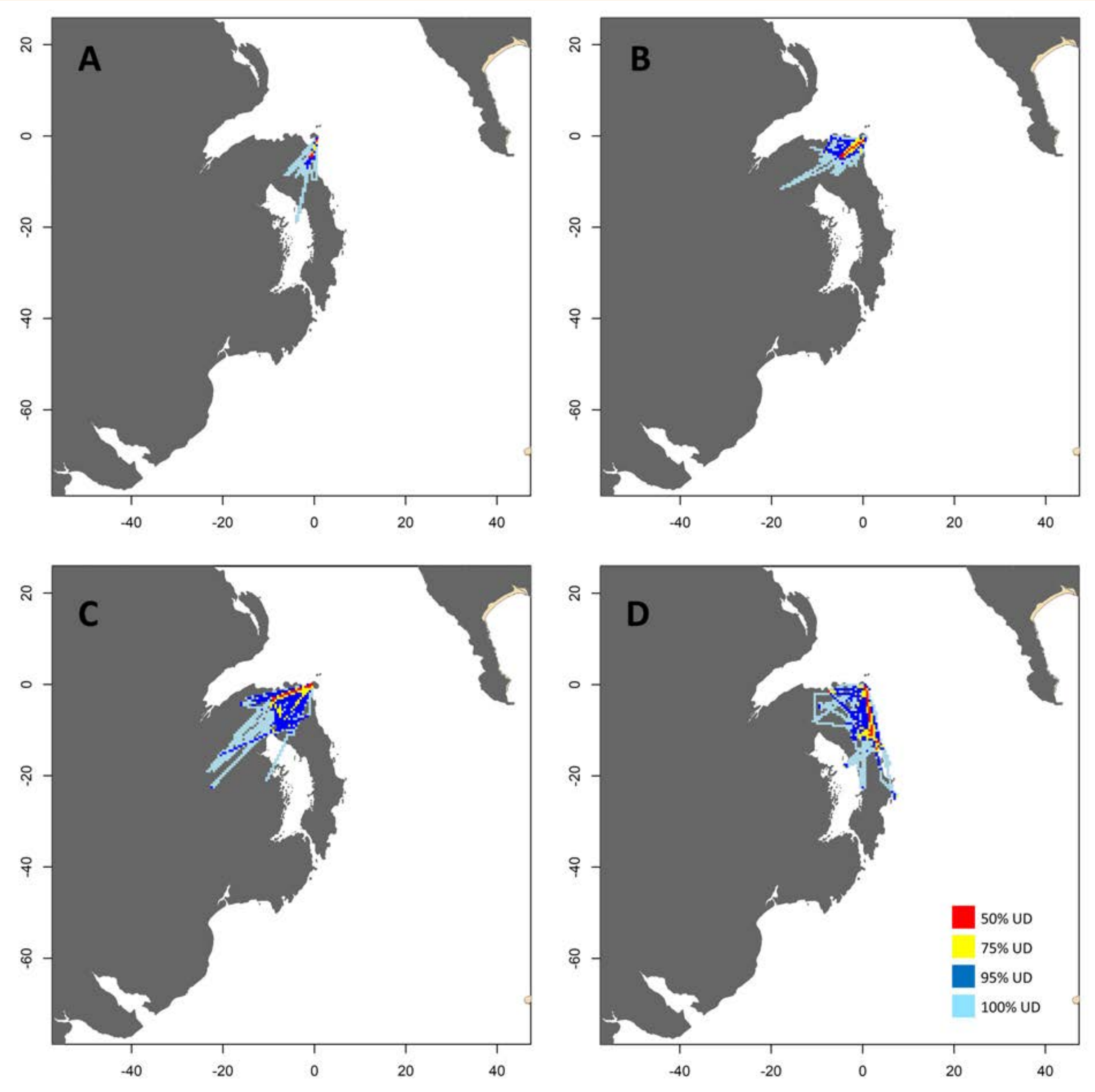


Figure 9. Between-year comparison of the foraging trips of two Herring Gulls nesting on Big Copeland. Nest locations are marked with a black point. Left: Tag D023 (2015 and 2016); Right: Tag D05 (2015 and 2016).

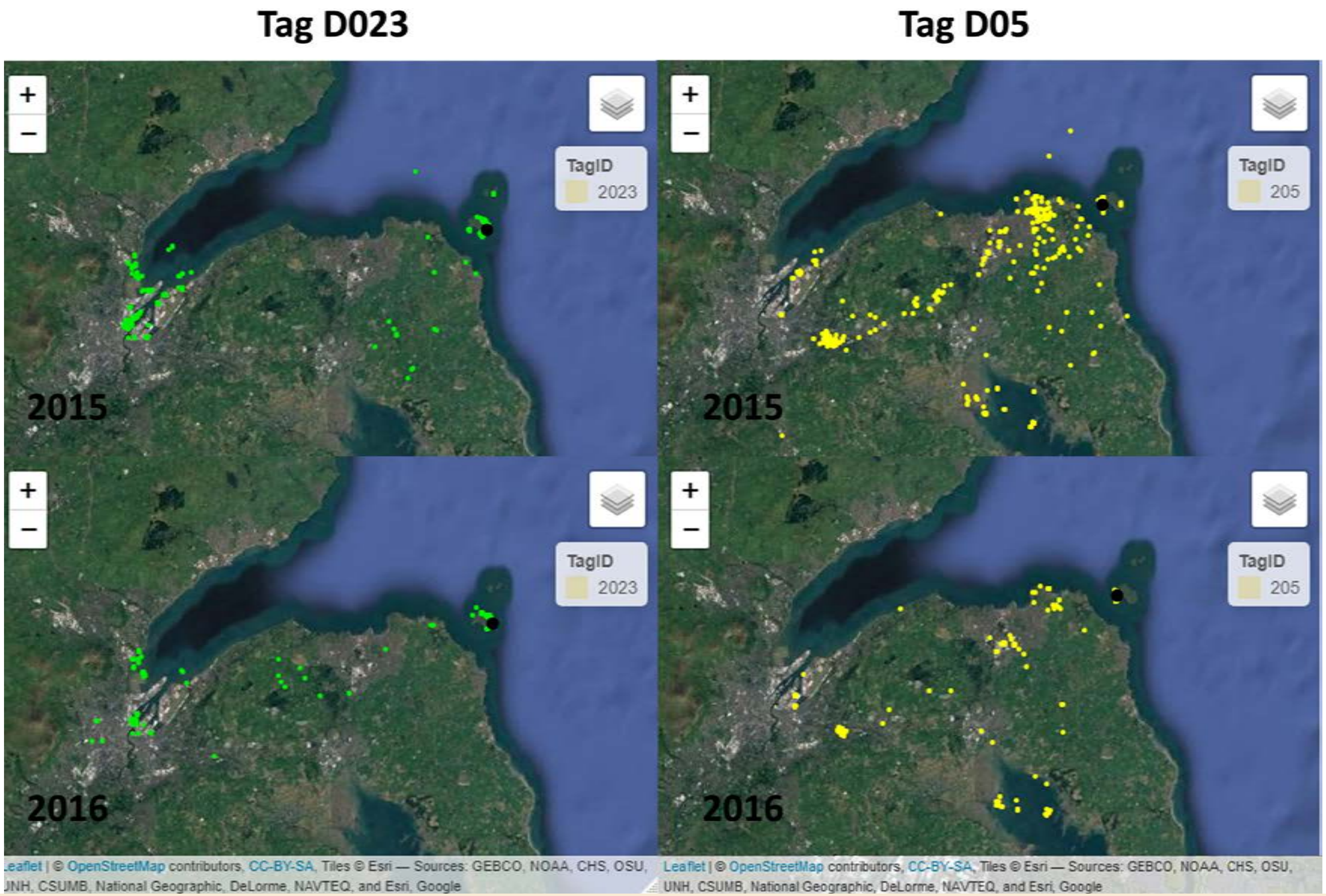
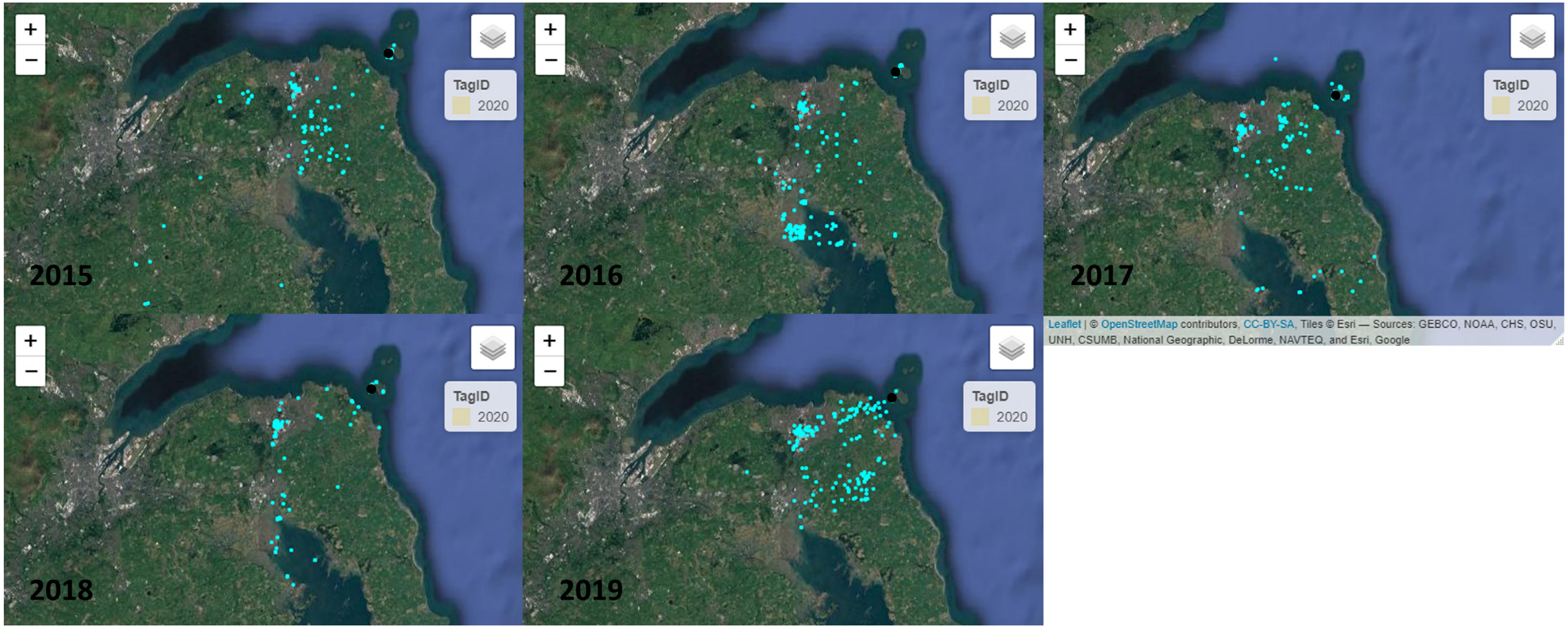


Figure 10. Between-year comparison of the foraging trips of one Herring Gull nesting on Big Copeland (D020) over five years, 2015 - 2019. Nest locations are marked with a black point.



3.2. Effect of species and colony on foraging trip characteristics

Species and colony could not be modelled as interaction terms, due to the lack of data for Lesser Black-backed Gulls tracked from the Copeland Islands. Model outputs for 95% UD foraging range area, mean foraging distance per trip and mean foraging trip duration can be found in Appendix 3 (S3.2–3.4).

Figure 11 shows how foraging range area, trip distances and durations compared between Herring Gulls and Lesser Black-backed Gulls tracked from nests based in Belfast and on the Copeland Islands. Analysis with GLMMs showed there was not a significant effect of species or colony on the 95% UD, but gulls from the Copelands (all Herring Gulls) travelled significantly further (1.32, $P < 0.001$, Appendix 3, Table S3.2) than gulls from Belfast, and that Lesser Black-backed Gulls (all from Belfast) spent less time away from the nest during foraging trips (-0.68, $P = 0.002$, Appendix 3, Table S3.3). However, given no Lesser Black-backed Gulls were tracked from the Copelands, it was not possible to investigate how species and colony interacted in terms of their influence on foraging trip characteristics.

3.2.6. Habitat Selection

Lesser Black-backed Gull (N = 6, Figure 12A, Appendix 4) home range encompassed a greater area of pasture around Belfast, resulting in this being represented strongly in the available habitat for these gulls (61% of available area). However, despite this availability in their ranges, the proportional use of this habitat type was very low (3%). Of all the groups, it appeared that the urban-nesting Lesser Black-backed Gulls had the strongest preference for foraging in urban areas (87% of used areas), with the only habitat with a greater proportion of real locations than simulated being industrial areas (4%).

The Herring Gulls tagged in Belfast (N = 3, Figure 12B, Appendix 4) were all captured closer to Belfast Harbour and the docks. The presence of their nests in this area may be due to a preference for these habitats, which was reflected in the greater proportional use of marine waters (7%, including coastal lagoons, estuaries, sea and ocean) and industrial areas (12%) than Lesser Black-backed Gulls tagged in the city. Their home ranges included a lower proportion of pasture (21%) than the urban Lesser Black-backed Gulls, and this was barely used (0.6% of used area). By far the habitat used in the greatest proportion was urban (79%), despite this only covering 42% of the available area within their home ranges.

Marine waters were the dominant habitat (57% of available area) in the home ranges of natural nesting Herring Gulls from Big Copeland (N = 21, Figure 12C, Appendix 4), and of the three groups studied, they used this habitat the most (19%). While scrub (which includes semi-natural areas such as natural grasslands and heathlands and was the land use classification of the colony) made up only 0.3% of the available area in

Figure 11. A comparison of the trip statistics of breeding Lesser Black-backed Gulls (LB, nine breeding seasons, six individuals) and Herring Gulls (HG, 29 breeding seasons, 21 individuals) from Belfast and from the Copeland Islands using box plots. In each case, the dark horizontal line represents the median value, the bounds of the box represent the interquartile range and the whiskers represent the spread of the data, excluding outliers. A: The home range area, represented by the logarithmically transformed Utilisation Density (UD) at 95%, calculated from the 0.5 x 0.5 km Time-in-Area grid, created using the R package 'trip'. B: The logarithmically transformed average foraging trip distance (km). C: The logarithmically transformed trip duration (time spent away from the nest per trip, in hours).

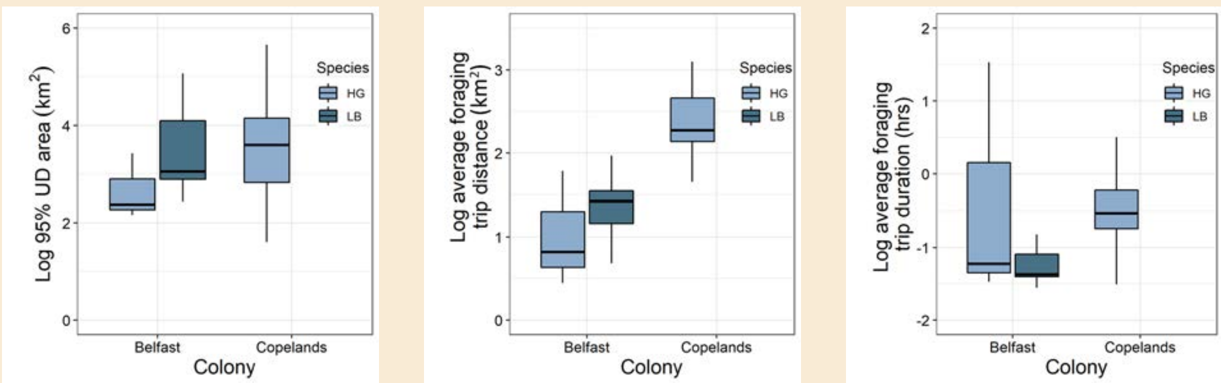
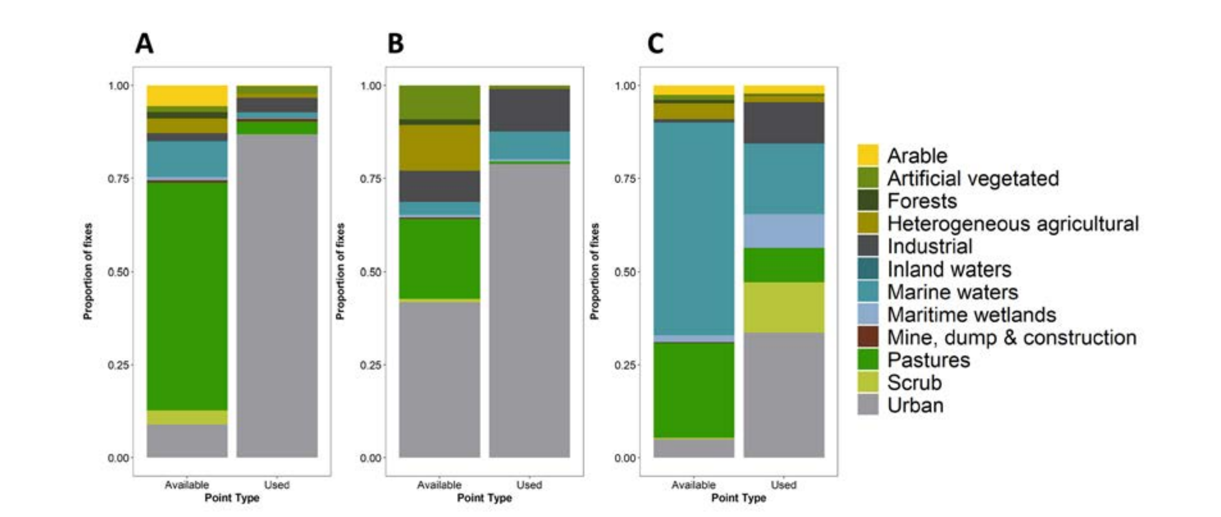


Figure 12. Resource selection plots for A: Lesser Black-backed Gulls caught in Belfast (six breeding individuals), B: Herring Gulls caught in Belfast (two breeding, one sub-adult), and C: Herring Gulls caught in Big Copeland (21 breeding individuals). Land cover derived from Corine Land Cover 2018 data (European Environment Agency, 2020). Bars represent the proportion of real ('Used') and simulated ('Available') points to fall in each of the land use categories.



their home ranges, this was used in 14% of locations. Natural nesting Herring Gulls also appeared to target maritime areas much more than urban gulls of either species (9% used compared to 2% availability). However, similarly to the urban gulls, Herring Gulls from Big Copeland appeared to strongly favour foraging in urban habitats (34% used) despite the much lower availability of this in their home ranges (5%).

3.3. Winter Populations of Gulls in Belfast Lough

3.3.1 WinGS results

Belfast Lough was covered by WinGS in January 2005 and, in total, 15,645 individual gulls were counted at roost, the majority of which were Black-headed Gulls *Chroicocephalus ridibundus* (11,055, Figure 13). Herring Gulls (459 individuals, Figure 14) and Common Gulls *L. canus* (421, Figure 13) were the next most frequently recorded gull species in the lough. While Lesser Black-backed Gulls are common in the summer (see section 3.1), only one Lesser Black-backed Gull was observed using the lough in January 2005, in the most northern Belfast to Whiteabbey site. However, Lesser Black-backed Gulls are generally migratory in the winter, and therefore are not expected in high numbers outside the breeding season. The total proportion of large gulls, including Great Black-backed Gulls *L. marinus*, Herring Gulls, Lesser Black-backed Gulls and unidentified large gulls was low (5%) compared to the proportion of small gulls, including Black-headed Gulls, Common Gulls and unidentified small gulls (81%) that made up the total present in Belfast Lough. Many gulls could not be identified to the species level, and these made up 23% of the total number of gulls counted (including unidentified small gulls, unidentified large gulls and unspecified unidentified gulls).

The north shore of Belfast Lough held the most gulls during the WinGS counts. In particular, Belfast Harbour A held the highest number of Black-headed Gulls and Common Gulls (Figure 14) making it the most important sector for gulls around the lough (7,750). However, no other species of gull were counted in this sector. In contrast, Belfast Lough to Whiteabbey held large numbers of Black-headed Gulls (2,030), unidentified small gulls (1,200), Herring Gulls (184), unidentified large gulls (265) and unidentified unspecified gulls (2,200). The lack of species-specific identification in this section may be due to the distance at which observers had to make counts from. Kinnegar Bay on the south shore of the lough was a more important roosting site for the larger gulls, Herring Gull (275) and Great Black-backed Gull (42), but also held the second largest population of Common Gulls (170). Belfast Harbour B and Belfast Harbour D only had populations of Black-headed Gulls (890 and 435 respectively) and no gulls were counted at Belfast Lough Kinnegar to Greypoint.

Figure 13. Pie chart representing the proportion of each gull species category across all sectors of Belfast Lough counted in January 2005.

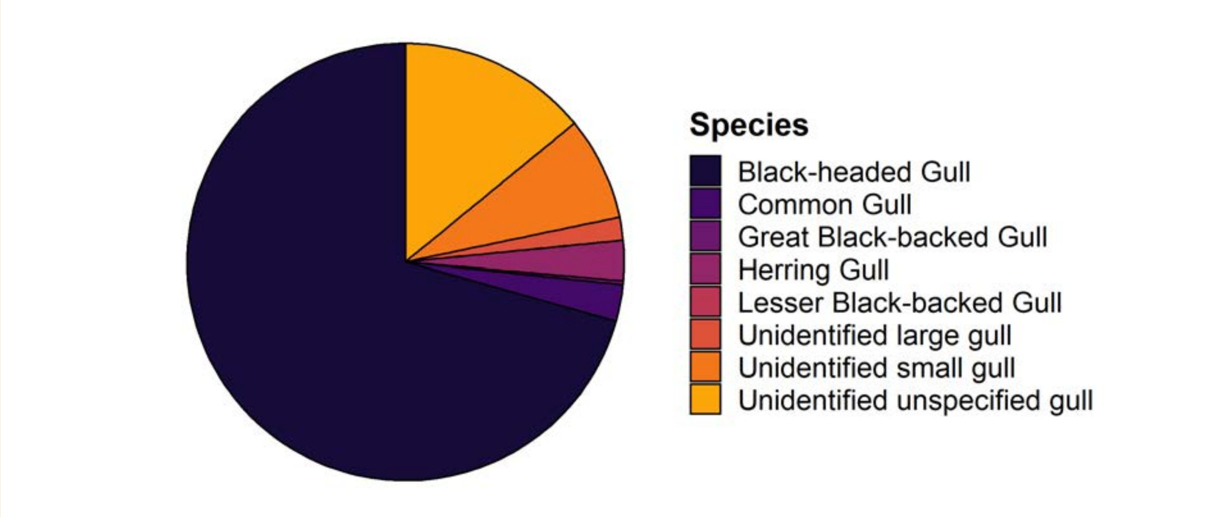
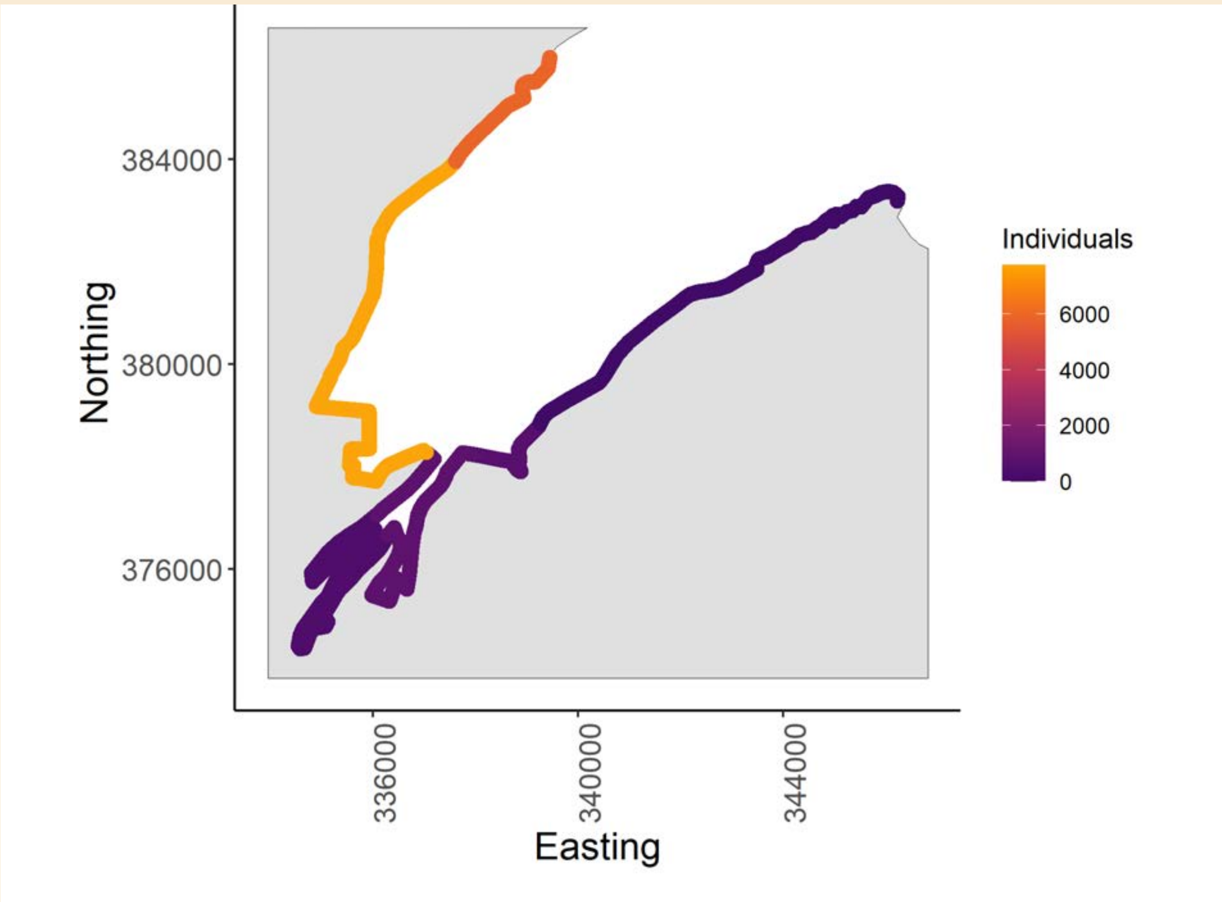


Figure 14. Counts of individual gulls of all species at WinGS sectors around Belfast Lough, as counted in January 2005.



3.3.2. WeBS – Core Counts

Of the nine gull species recorded in the Core Count sectors between winters 2013/14 and 2017/18, three were only counted once or twice in any year (Iceland Gull *L. glaucoides*, Little Gull *Hydrocoloeus minutus* and Mediterranean Gull *Ichthyaetus melanocephalus*), the maximum average counts of Great Black-backed Gull and Kittiwake *Rissa tridactyla* per year were 12 and 35 individuals respectively. Lesser Black-backed Gulls and Common Gulls were uncommon in the sectors, with a maximum average count per year of fewer than 100 individuals. By far the most commonly recorded gull species was Black-headed Gull. In the most recent winter of data available, 2017/18, an average of 928 individual Black-headed Gulls was counted across the four Core Count sectors of the lough (Figure 15). However, numbers of Black-headed Gulls appear to have declined in Belfast Lough since 2013, when the annual average was 1,170 individuals. In contrast, numbers of Herring Gull and Common Gull appear to have remained fairly stable across the four sectors as a whole (Figure 15).

Figure 15. Average winter WeBS Core Counts of the Belfast Lough – BP Pools and Victoria Park, Belfast Lough - Greys Point to Ballymacormick Point, Belfast Lough – Kinnegar to Greys Point and Belfast Lough – Whiteabbey to River Lagan count sectors of Black-headed Gull, Herring Gull and Common Gull, the most numerous gulls in Belfast Lough, between 2013/14 and 2017/18. 2013 = winter 2013/14, etc.

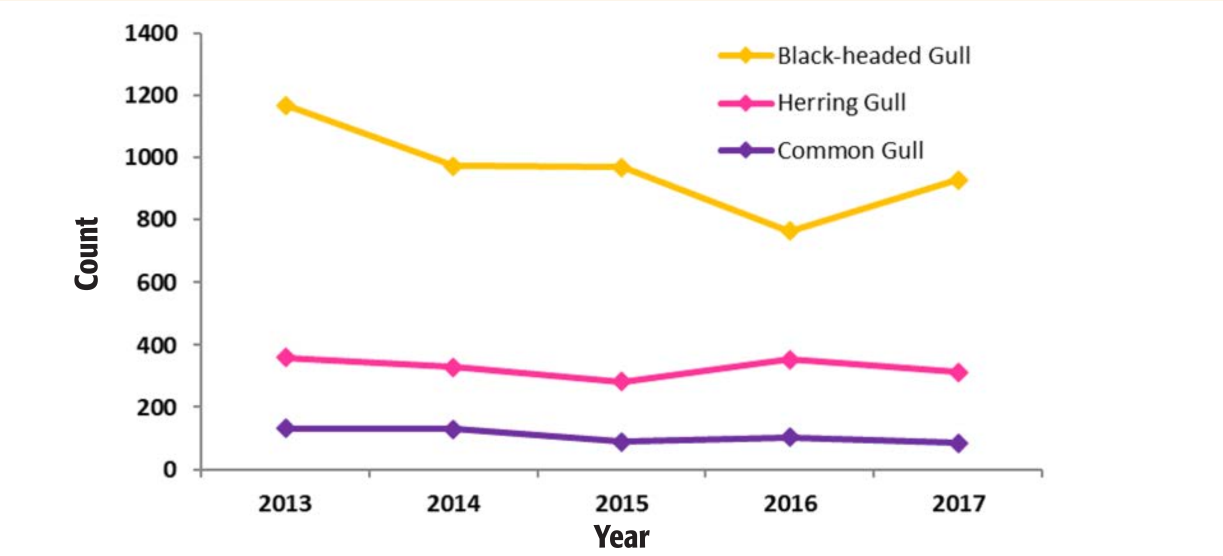
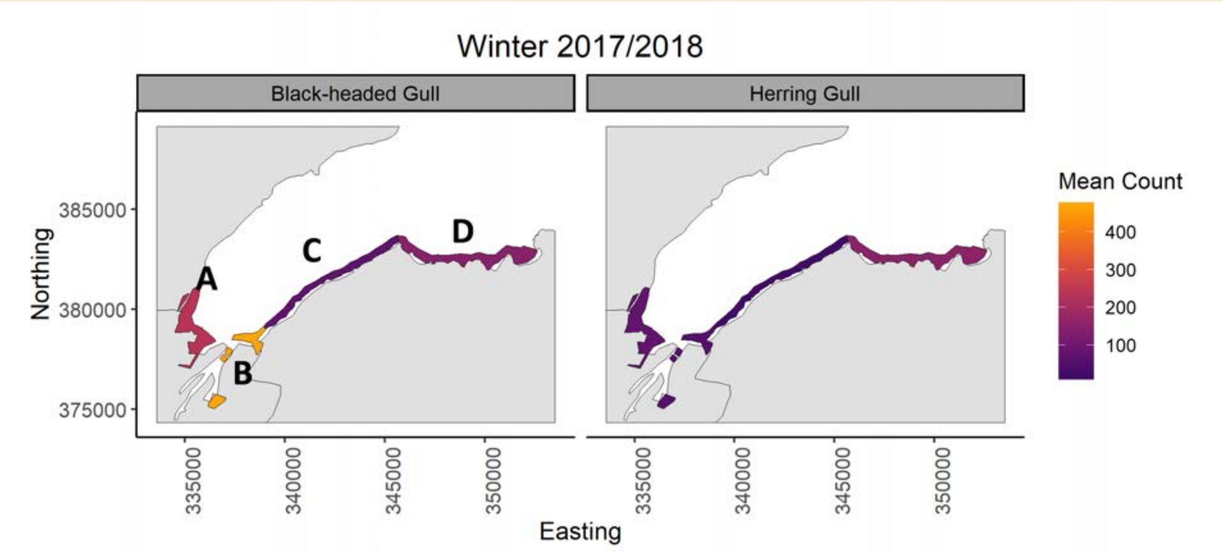


Figure 16. Map showing average winter WeBS Core Counts of the two most common species of gull in Belfast Lough, Black-headed Gull and Herring Gull, in each of the four sectors in winter 2017/18. A: BP Pools and Victoria Park, B: Greys Point to Ballymacormick Point, C: Kinnegar to Greys Point and D: Whiteabbey to River Lagan.



3.3.3. WeBS – Low Tide Counts

The number of gulls counted in WeBS low tide sectors around Belfast Lough appears to have fallen between 2013/14, when a total of 5,798 individual gulls were counted around the lough, and 2017/18 when 3,895 were counted. It might be considered that this drop in numbers could have been due to one key sector, BB010, not being counted in 2017/18 (Figure 17). However, the 2016/17 count (3,651) was lower than the 2017/18 count despite the inclusion of BB010, therefore a general drop in gull numbers across the lough may be occurring.

The decline between 2013/14 and 2016/17 is reflected in the numbers of the most common species found in the lough, the Black-headed Gull (Figure 18). As with the WeBS Core Count numbers, numbers of Herring and Common Gulls appeared to remain relatively stable between survey winters (Figure 18). Concentrations of gulls also appeared to be dominated by Black-headed Gulls, and were focused near the mouth of the River Lagan (Figure 18). Herring Gulls appeared to favour sectors further out towards the edges of the lough (Figure 19).

Figure 17. Map showing average winter WeBS Low Tide Counts of gulls in sectors around Belfast between 2013//14 and 2017/18, shaded from low (purple) to high (yellow) numbers. Sectors are shaded dark grey when counts were not available for the sector in the given year. 2013=winter 2013/14, etc. Sector BB010 was not counted in 2017/18.

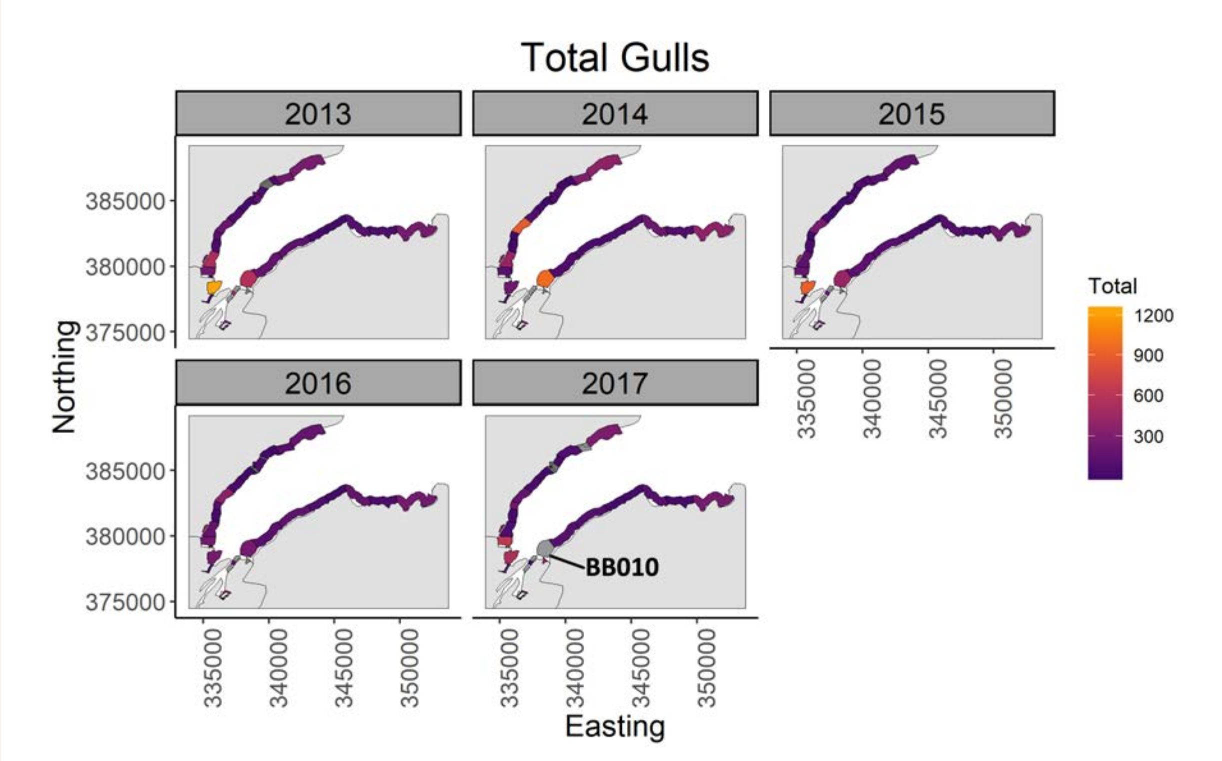


Figure 18. Average winter WeBS Low Tide counts of Black-headed Gull, Herring Gull and Common Gulls, the most numerous gulls in Belfast Lough, between 2013/14 and 2017/18. 2013=winter 2013/14, etc.

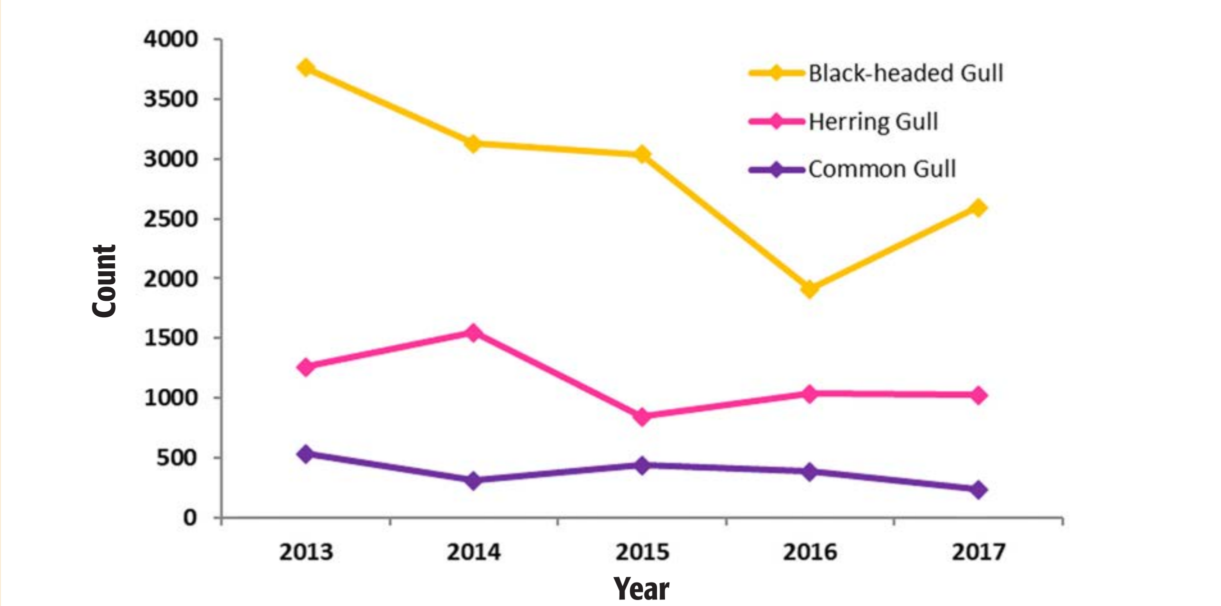
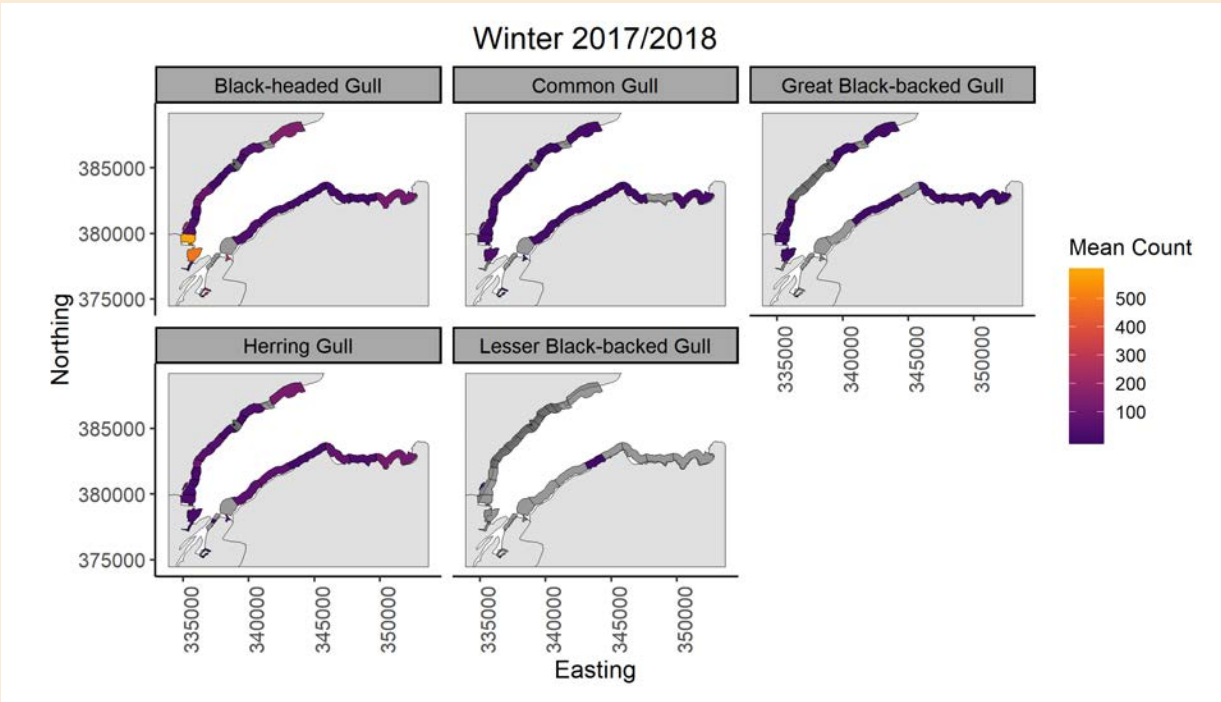


Figure 19. Map showing average winter WeBS Low Tide Counts of gulls in sectors around Belfast in 2017/18, shaded from low (purple) to high (yellow) numbers. Sectors are shaded dark grey when counts were not available for the sector for the species.



4. DISCUSSION

4.1. Breeding gull populations in central Belfast and docks area

The often complex landscape of rooftops within urban areas means that not all gull AONs are visible from the street, and sometimes not even from vantage points, if indeed these can be safely obtained (Coulson & Coulson, 2015; Rock, 2005; Ross *et al.*, 2016). Research by Coulson & Coulson (2015) has estimated that, across a town or city, vantage point surveys at best may only record 78% of the total number of AONs present, while combining street-level and vantage point counts in urban environments may raise detection probability to around 84%. Furthermore, it has been shown that 30–40% of Herring and Lesser Black-backed Gulls in coastal or rural colonies may not attempt to breed in any one year (Calladine & Harris, 2008) adding to the underestimate of the total population size. Nevertheless, comparisons with earlier counts will still indicate proportional changes in population size over time. Difficult surveying conditions may have led to previous underestimation of breeding gull populations in towns and cities, relative to rural/coastal populations, which may have contributed to an exaggeration of the vulnerability of Herring and Lesser Black-backed Gulls on the island of Ireland.

The buildings accessed for surveying offered excellent vantages as they were considerably taller than surrounding buildings in Belfast. The furthest AON observed from the vantages (Obel Tower in this case) was 4.1 km away. More AONs were detected in 2019 (260 AON) than in 2018 (162 AON), and this is likely to be due to better weather conditions, longer survey times and a familiarity with the survey, rather than a sudden increase in the urban gull population between years. However, it is highly likely that due to the heterogeneous nature of rooftop landscapes that some nests will have been hidden from view. An estimation of the hidden roof area was beyond the available time allowance for 2018 fieldwork; however in 2019 the percentage visibility of 336 roofs was estimated as 37% (± 3% CI). If the Coulson & Coulson (2015) best-case detection rate probability (78%) is applied to the 2019 count of 221 Lesser Black-backed Gull AON and 39 Herring Gull AON, Belfast centre and docks would hold approximately 283 Lesser Black-backed Gull AON and 50 Herring Gull AON. However, applying the estimate of roof visibility conducted in 2019 to the number of nests visible from our vantages in the same year, the population of Lesser Black-backed Gulls in central Belfast and the docks can be estimated as 593 (553 to 650) AON and the population of Herring Gulls estimated as 105 (98 to 115) AON. The difference in the best-case and roof-visibility predicted population estimates demonstrates how difficult it is to provide a robust estimate of urban gull numbers, even when decent vantage points are obtained.

In the Seabird 2000 census, 63 Lesser Black-backed Gull and eight Herring Gull AONs were recorded in the Belfast city centre and docks areas (JNCC, 2017; Mitchell *et al.*, 2004), therefore the 2019 count represents a 251% increase in Lesser Black-backed Gulls and a 388% increase in Herring Gulls, assuming no correction factor was applied to Seabird 2000 counts to include a measure of roof visibility. However, it must be noted that the exact coverage of the Seabird 2000 census in Belfast is unknown: Grand Central Hotel (then Windsor House) was used as one of the vantage points (Matthew Tickner, pers. comm.), but it is unclear which areas were covered in the docks and how these were viewed and therefore recent and historical counts cannot be directly compared.

It is interesting that there were more Lesser Black-backed Gulls (85% of total AONs) observed nesting in Belfast than Herring Gulls (15% of total AONs), since Herring Gulls were initially the first adopters of urban-nesting in the UK (Cramp, 1971). The large, mixed-species natural colony 28 km away in the Copeland Island group was surveyed at a similar time in both 2018 and 2019 (Booth Jones, 2020; Booth Jones & Wolsey, 2019), finding relatively equal numbers of Lesser Black-backed Gulls (547 AONs) and Herring Gulls (483 AONs). However, the last census estimated that there were fewer Herring Gulls overall in Northern Ireland than Lesser Black-backed Gulls. The population of Herring Gulls fell to just 721 pairs after a 96% decline, thought to be the result of an outbreak of botulism (JNCC, 2017; Mitchell *et al.*, 2004), while Lesser Black-backed Gulls were increasing in Northern Ireland (1,973 pairs in Seabird 2000, JNCC, 2017; Mitchell *et al.*, 2004). Therefore, the lower numbers of urban-nesting Herring Gulls in Belfast may be a result of the lower total population of Herring Gulls in Northern Ireland. Alternatively, the urban environment may be more suitable to Lesser Black-backed Gulls than Herring Gulls. Lesser Black-backed Gulls have a tendency to forage further from their nests elsewhere, contradictory to our findings in this study (Camphuysen, 1995; Garthe, 1997; Noordhuis & Spaans, 1992), and have a more favourable wing-loading than Herring Gulls (Camphuysen, 1995), which may offer them a manoeuvrability advantage in urban environments (Shepard *et al.*, 2016).

The results of this survey will feed into the Britain and Ireland-wide Seabirds Count census. The surveys clearly show that Belfast is providing attractive nesting habitat for gulls and that their numbers have increased since the Seabird 2000 census. The largest colonies for Lesser Black-backed Gulls in Northern Ireland are Lower Lough Erne (1,584 AONs in 2019), the Copeland Islands (547 AONs in 2019 on Lighthouse Island alone, excluding uncounted AONs on Big Copeland and Mew Island) and Strangford Lough (316 AONs in 2019, Booth Jones, 2020). While recent estimates of AONs are lacking, it is likely that breeding numbers of Lesser Black-backed Gulls at Lough Neagh are at least as large as those on Strangford Lough. For Herring Gulls, the largest colonies are Strangford Lough (1,273 AONs in 2019) and the Copeland Islands (484 AONs in 2019 on Lighthouse Island alone, excluding uncounted AONs on Big Copeland and Mew Island, Booth Jones, 2020).

Accepting the estimate of roof nesting gulls adjusted for visible roof area (593 Lesser Black-backed Gull AONs and 105 Herring Gull AONs), Belfast city centre and docks are supporting comparatively large populations of Amber-listed priority gull species at a national scale, particularly of Lesser Black-backed Gulls.

4.2. Breeding success in Belfast

Breeding success was recorded to provide a means of measuring any potential impacts of fitting trackers on the study birds. In the case of the Lesser Black-backed Gulls tagged in 2019, both male and female were captured from a shared nest on the same day. The disturbance caused by tagging may have led to the pair's eggs becoming chilled even though the pair remained on the roof of the building near the nest for the hours after tagging, and despite incubation being recorded at the time the nest was visited a month later (the eggs were discovered to be warm) they did not hatch. It is therefore important for future tagging that only a single member of a nesting pair be captured and fitted with a tracker to prevent nest failure. However, across the two years of the study, Lesser Black-backed Gull productivity was 1.71 chicks per nest (four nests in 2018, three nests in 2019), and Herring Gull productivity was 2.67 chicks per nest (three nests in 2019), higher than the UK average productivity for Lesser Black-backed Gulls and Herring Gulls (0.6 and 0.75 chicks per nest, respectively, JNCC, 2020). This is a small sample size but indicates that tagging had no strong effect on breeding success overall.

There is an obvious lack of ground predators on city centre rooftops, which may contribute to high breeding success. However, the low density of gulls on rooftops may also play a part. Monaghan (1979) found that the cannibalism of conspecific offspring prevalent in high-density natural Herring Gull colonies was lacking in urban colonies, which are usually of lower density, and that this contributed to a higher breeding success. Cannibalism also occurs in Lesser Black-backed Gull colonies (Davis & Dunn, 1976), and may drive breeding dispersal from high-density colonies to nearby low density colonies (Monaghan, 1979). In addition, high productivity in a colony may be an indicator used by potential recruits to the breeding population searching for a nesting site (Coulson *et al*., 1982). This affect then attracts more recruits than might be expected when relying on local output alone. Thus, the urban gull population of Belfast may be increasing not only due to high breeding productivity, but because as the population density in Belfast is currently low and the productivity is high, it may represent an attractive prospect for emigrating gulls from neighbouring colonies.

4.3. Foraging behaviour

TIA analysis of location data from GPS tracked gulls tagged from the city centre (Herring Gulls N = 3, Lesser Black-backed Gulls N = 6) showed that the core area of use was almost exclusively urban (at 50% and 75% UD). Analysis of trips away from the nest of breeding birds (Table 5) showed that gulls spent the majority of their breeding and post-breeding season within the urban area of Belfast, with individual average maximum foraging range per trips varying from around 1.56 km to 7.16 km. Differences were due to individuals having specific foraging areas that they would return to regularly throughout the season. The two urban-nesting Herring Gulls for which data were available had more similar distributions to each other compared to the tracked Lesser Black-backed Gulls. They mostly appeared to be foraging very close to the building on which they were nesting, an area beside the River Lagan which is popular with tourists and therefore may potentially be providing food waste to the gulls. The findings of the TIA and trip analyses were supported by the resource selection analysis, which found that for both urban-nesting Lesser Black-backed Gulls and Herring Gulls, that urban habitats were disproportionately used in relation to their overall availability in the home ranges of both species (87% and 79% of used areas, respectively), despite the high availability of farmland within their home ranges. It is revealing that gulls chose to forage within the city, given that gulls have an average flying speed of around 40 km/h (Klaassen *et al.*, 2012; Spear & Ainley, 1997), and therefore have the capability to fly quickly to areas of non-urban food resources. This suggests that the urban food resources that gulls are exploiting in Belfast offer an advantage over natural food resources. Advantages may include increased temporal consistency over natural resources, shorter travel distance or a higher energetic or nutritional content of urban food. The gulls did not use the urban and sub-urban areas exclusively, however. Some locations were observed in farmland around Belfast, and the countryside to the south of Belfast was used particularly by Lesser Black-backed Gulls 867 and 1128. Most gulls used Belfast docks to some extent, and some also visited Belfast Lough. The areas visited by gulls outside urban areas of Belfast tended to be more dispersed, unlike the smaller, repeatedly visited locations in the city, suggesting that urban foraging areas are providing more concentrated food resources for gulls, which may be exacerbating nuisance effects. Extra-urban environments are therefore providing resources for gulls, be this foraging, bathing or loafing opportunities.

Complementary GPS data from the large colony of Herring Gulls situated on Big Copeland Island, 27 km from central Belfast, provided an opportunity for comparison between the foraging distribution of urban-nesting gulls and natural-nesting gulls, albeit limited to a single species. Similarly to the tracked urban gulls, coastal Herring Gulls displayed a high level of individual difference between focal foraging areas with between year consistency, reflecting the results of other studies (Rock *et al*., 2016; Shlepr *et al.*, 2021). The Herring Gulls from Big Copeland, while the most marine in their foraging behaviour of the three groups (roof nesting Lesser Black-backed Gulls, urban-nesting Herring Gulls, and natural-nesting Herring Gulls), similarly favoured foraging in urban environments (34% used) despite the comparatively lower availability of this in their home ranges (5%). This is an important finding, as it has been assumed in the past that populations of urban gulls increased while there have been declines in their natural-nesting counterparts due to the availability of food resources in towns and cities (Calladine *et al.*, 2006). However, if gulls nesting in natural sites also forage preferentially in urban areas, then contrasting population trends may be driven not by food availability itself, which can be utilised by both urban- and natural-nesters, but by differences in breeding success linked to reduced predation pressure, favourable micro-climate effects and a lower distance to foraging areas for urban gulls, for example (Calladine *et al.*, 2006). Gulls from the Copelands were found to travel significantly further from the nest than our tracked urban gulls. However, because few Herring Gulls could be tagged from Belfast and no Lesser Black-backed Gulls were tagged from Big Copeland, the influence of species on this result cannot be disentangled. Unlike for urban-nesting gulls, no information was available on the breeding status of Copeland birds, therefore the end of breeding season was defined as either the last tracked point or the end of September, which ever was the latest. Therefore, because many birds would have finished raising chicks before the end of September and would be released from central place foraging we might expect foraging ranges to increase (Elliott *et al.*, 2009), and this might explain the significantly further and longer trip distances and times away from the nest site observed in natural nesting birds. However, visual examination of the tracking data from this colony suggested that individuals were fairly consistent in their space use across the full time period for which they were tracked. Therefore, it is more likely that the offshore position of the colony resulted in the need for further and longer foraging trips for Big Copeland Herring Gulls. It is also possible that some of the longer marine trips of Herring Gulls from the Copeland Islands may could be a result of boat-following behaviours (Hudson & Furness, 1989).

Crucially in terms of managing the conflict between gulls and humans in urban spaces, analysis of GPS data from urban-nesting and natural-nesting gulls demonstrated that there was not one single location or resource that gulls were attracted to during the breeding season. Individuals were largely repeatable in the areas they visited throughout the breeding season and between years, but these areas were different between individuals. The gulls appeared to travel directly to these sites in many cases, suggesting that they were targeting spatio-temporally predictable food resources.

Between-individual differences in breeding seabird foraging distributions can be attributed to a range of biological factors, for example sex (Ceia *et al*., 2012; Pinet *et al*., 2012; Quillfeldt *et al*., 2014; Thiers *et al*., 2014; Weimerskirch *et al*., 2014), breeding stage (Cleeland *et al*., 2014; Pinet *et al*., 2012; Weimerskirch *et al*., 1993) and age (Péron & Grémillet, 2013; Thiers *et al*., 2014; Weimerskirch *et al*., 2014). Differences have also been shown to be the result of the exploratory experiences of immature individuals for some seabird species, for example in Northern Gannets *Morus bassana* and Wandering Albatrosses *Diomedea exulans* (Grecian *et al*., 2018; Riotte-Lambert & Weimerskirch, 2013). Cases of between-individual differences combined with within-individual consistency are less well documented however; specialisation in foraging sites has been referred to as individual foraging site fidelity (IFSF) (Wakefield *et al*., 2015). Individual differences in foraging strategy have been reported in Northern Gannets (Patrick *et al*., 2014; Votier *et al*., 2010), gulls (Ceia *et al*., 2014; Navarro *et al*., 2017) and Common Guillemots *Uria aalge* (Woo *et al*., 2008, specialisation in foraging behaviour rather than site). Possible causes for IFSF are plentiful and varied, but may in part be due to differences in personality (Patrick & Weimerskirch, 2014) or as a mechanism to reduce intra-specific competition (Navarro *et al*., 2017).

The implications of IFSF when it comes to urban gulls may be important when it comes to minimising human-gull conflicts in towns and cities. For example, gulls causing a public nuisance at a particular site may represent part of the local population or not be local to the site; therefore mitigation measures applied to local populations will not have the desired effect (Stone, 2019). However, targeting management of resources may remove issues over nuisance behaviour at a particular site.

The individual differences observed in the foraging sites of the gulls tracked so far in Belfast demonstrate the importance of obtaining a representative sample size for a population (Soanes *et al*., 2013; Thaxter *et al*., 2017), though sample sizes are generally restricted by the cost of tagging devices and effort involved in tagging individuals. In particular, the small population size of urban-nesting Herring Gulls compared with Lesser Black-backed Gulls (Table 2) made tagging the target number of Herring Gulls impossible in the time available. However, the pattern of predominantly urban and suburban foraging seen in our study is consistent with results of a similar urban gull tracking study based in Bristol (Spelt *et al*., 2019), so we can be reasonably confident that our results are representative.

4.4. Winter populations of gulls in Belfast Lough

WinGS (2004/05) and WeBS (2013/14 to 2017/18) data were examined to describe the winter distribution of gulls in Belfast Lough. The surveys provide complimentary approaches to identifying important areas, as WeBS represent daytime counts while WinGS represent night-time roosts. Generally gulls are more dispersed during the day, hence the lower numbers seen in the WeBS data. Analysis showed that Black-headed Gulls were the dominant gull species along the shoreline of Belfast Lough (Figures 13, 15 and 18). However, both WeBS Core (high tide) Counts and Low Tide Counts also indicated that numbers of Black-headed Gulls had declined slightly over the 2013/14 to 2017/18 period.

Breeding Black-headed Gulls are Red-listed in the Birds of Conservation Concern in Ireland list (Colhoun & Cummins, 2013) and Amber-listed in the Birds of Conservation Concern 4 list (Eaton *et al*., 2015), and a drop in winter numbers may in part be related to changes in breeding populations (Banks *et al*., 2009). For example, Lough Neagh held 30,000 Black-headed Gull pairs in the 1980s (Allen & Mellon, 2018), while the most recent count of the lough only found 8,906 individuals – likely fewer than 4,400 pairs (Booth Jones & Wolsey, 2019). Likewise, Strangford Lough's breeding Black-headed Gull population has dropped from a peak of 7,023 pairs in 1994 to 1,305 pairs in 2019 (Booth Jones, 2020). However, Black-headed Gulls are migratory outside the breeding season and it has been estimated that the UK holds 60% of the European population of Black-headed Gull during the winter (Burton *et al*., 2013), therefore declines may also be linked to population changes elsewhere in Europe. It is therefore difficult to say whether or not there are specific factors in Belfast Lough that caused a drop in winter numbers of Black-headed Gulls during the study period. Stability in the populations of other gull species using the lough suggests that this may be a problem with Black-headed Gull populations unconnected with conditions in Belfast Lough. WeBS trends for Northern Ireland show a decline after 2006/07 through to 2016/17, but a slight rise in 2017/18 (Frost *et al*., 2019)

In contrast to the WinGS count in January 2005 when gulls were concentrated on the north-west shore, winter averages of WeBS Low Tide data show that gulls were more concentrated in the sectors close to Belfast harbour and the mouth of the River Lagan between 2013/14 and 2017/18 (data for the north-west shore were not available as part of the WeBS Core Count). This may be a result of averaging across the winter months for the WeBS survey, erasing between-month differences in distribution, or may indicate a change in conditions around the lough between WinGS and the WeBS study periods. For example, in 2005, the Dargan Road landfill-site (now Giant's Park) was still active and would have been used as a foraging location for wintering gulls at the time, but this was closed by the time period covered by WeBS in this study. However, it may also reflect the difference in the gulls' use of sectors. WinGS focused on recording evening gull roosts, whereas Low Tide surveys are more reflective of foraging distribution, as birds hunt for food on the area exposed by the tide. Therefore, different areas of the lough are likely to be important to gulls at different times of day and for different reasons, and these may change with the tidal cycle. Hence, while the north-east shore may be a focus for potential human-gull conflicts when gulls are roosting, areas closer to the city in the south of the lough may be more likely to experience conflicts while gulls are foraging. However, the detailed habitat use of gulls in Belfast Lough through tidal and diurnal cycles is still unknown and would require a more detailed field study to assess daily movements around the lough.

Belfast Lough is an incredibly important hub for Northern Ireland in terms of human use, providing the space for recreational activities such as walking, cycling, boating and dog-walking, and commercial activities such as aquaculture, shipping and transport. Due to the concentration of human and gull activities in the lough, there is potential for conflict. Human activities in the lough may cause disturbance to the important bird communities using the lough, while gulls may be causing water contamination issues. This study has shown using historical data that areas of conflict are more likely to occur where gulls concentrate on the north-east shore and around the Belfast harbour area.

5. CONCLUSIONS

The city of Belfast supports populations of gulls in a range of different ways, from providing safe nesting habitat, providing foraging resources for gulls nesting both within and outside the city during the summer and providing foraging and roosting habitat during the winter along the shore of Belfast Lough.

During the breeding season, Herring Gulls and Lesser Black-backed Gulls nest on multi-storey buildings and warehouses. Although precise breeding numbers are extremely difficult to obtain, comparison of raw counts (i.e. without adjusting for visible roof area) suggest that the breeding populations of these have species increased since the last census in 2001 by approximately 388% for Herring Gull and by 251% for Lesser Black-backed Gull. It is feasible that numbers could continue to rise in the city as there is plenty of available space and breeding success is high. This may be an emerging human conflict issue, as the presence of nesting gulls on roofs is often perceived as a nuisance by building owners due to the potential for noise, mess and damage to buildings caused.

In contrast to the breeding season, when Herring and Lesser Black-backed Gulls are the dominant species in Belfast, the most frequent winter visitor to the shores of Belfast Lough and in particular the docks area was the Black-headed Gull. Nevertheless, WeBS Core Count and Low Tide Counts indicated that numbers of this species declined over the 2013/14 to 2017/18 period considered. A decline was also seen over the last decade in counts across Northern Ireland, suggesting that site factors may not have been the main driver in this decline. Possible non-site-related factors that could impact gull numbers include reduced food availability linked to improved waste management (Banks *et al.*, 2009), and disturbance (e.g. recreation, aquaculture, transport). However, other gull species that may be similarly influenced by these factors did not experience a change in population size, therefore changes that particularly affect Black-headed Gulls should be considered.

During the breeding season, tracking data showed that individual gulls are specific in the areas they target for foraging, and that urban areas are probably providing resources through street litter. Urban foraging resources are also attracting gulls nesting outside of urban areas, as observed through the analysis of tracking data from a nearby coastal colony of Herring Gulls. The results of this study show that if street-level nuisance behaviour is a problem, targeting particular sources of street litter may help to reduce human-gull conflicts. In extreme cases, the removal of a few individual gulls may temporarily solve the problem, although if the source of food is still present in the environment then it is likely that new individuals will be drawn to it (Stone, 2019).

The food, nesting and roosting resources that Belfast provides are important to gulls and Herring, Lesser Black-backed and Black-headed Gulls are all considered to be of high conservation value due to the observed declines in natural-nesting populations and are listed as Birds of Conservation Concern in Ireland (Gilbert *et al*., 2021). In particular, the number of breeding gulls supported by urban resources is likely to represent a considerable proportion of the total population of Northern Ireland for both Herring and Lesser Black-backed Gulls, especially because it is likely that natural-nesting gulls are travelling to forage within the city and surrounding urban areas. It is therefore crucial that sources of conflict between humans and gulls in the city are addressed to support the recovery of these conservation priority species.

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APPENDIX:

Potential methods for estimating the faecal contribution of gulls to pathogenic pollution in Belfast Lough.

Introduction

Belfast Lough is a hub for human and wildlife activity in Northern Ireland. It is used intensively by humans, providing employment and recreation to the region's capital city and surrounding conurbations which border the lough, is the site of a major industrial shipping port and hosts an economically important mussel shellfishery, for which it is designated a Shellfish Water Protected Area (DAERA, 2019). It also holds two Special Protection Area designations for the waterbird populations it supports; one for the shoreline and one for the open water area (DAERA, 2015a, 2015b). Recent Wetland Bird Survey (WeBS) results suggest that there are approximately 15,000 individual waterbirds present in the lough during the winter (Frost *et al.*, 2021). Separately to these counts, the last survey of winter gulls (Winter Gull Survey, WinGS) reported that nearly 16,000 individual gulls used the lough to roost (Booth Jones *et al*., this report, Burton *et al*., 2013).

While the lough supports important numbers of wintering gulls, there is concern over the potential for these to contribute to the bacterial load of the water in the lough, particularly as the Lough is also designated as a Shellfish Water Protected Area under the Water Framework Directive. While human sewage sources were the most serious potential contributor to pathogenic bacterial in the water of Belfast Lough, the Belfast Sanitary Survey (Hendrikz *et al*., 2017) identified birds as the most significant wildlife contamination risk, due to their high numbers. There is an extensive literature linking gulls to pathogenic bacteria (for example: Ahlstrom *et al*., 2021; Alm *et al*., 2018; Benton *et al*., 1983; Ferns & Mudge, 2000; Fogarty *et al*., 2003; Hatch, 1996; Navarro *et al*., 2019). Contamination by pathogenic bacteria is a potential human health hazard in both the aquaculture industry and more generally for all users of the lough.

This report aims to consider the potential for gulls to contribute to water pollution in Belfast Lough and produce recommendations for quantifying this. This work will facilitate agencies wishing to address conflict issues over the potential for gulls to spread pathogenic bacteria to mussel beds in Belfast Lough.

Previous research

Studies have found gulls to be carriers of microorganisms such as pathogenic yeasts (Al-Yasiri *et al*., 2016), protozoans (Gamble *et al*., 2019) and, chiefly, bacteria known to cause enteric infections in humans such as *Escherichia coli*, Salmonella and Campylobacter (Benton *et al*., 1983; Bonnedahl *et al.*, 2009; Ferns & Mudge, 2000; Fogarty *et al.*, 2003; Girdwood *et al.*, 1985; Hatch, 1996). Due to their close association with humans, gulls can act as "wildlife sentinels" for tracking the presence of infectious pathogens in the environment (Gamble *et al*., 2019). Gulls have the potential to move these pathogens around in the environment, during daily movements between foraging and roosting locations (Navarro *et al*., 2019), and when on migration (Ahlstrom *et al*., 2021), therefore they not only act as reservoir hosts for bacteria, but may also provide a bridge between infected and uninfected populations of humans, livestock and other wildlife (Franklin *et al*., 2020). Research has shown that water sources are a particular area in which the transfer of pathogens is a concern (Benton *et al*., 1983; Dolejská *et al*., 2009; Fogarty *et al*., 2003; Hatch, 1996). Gulls may forage at sites with high levels of harmful bacteria, for example at refuse dumps and sewage plants, and then travel to shorelines or reservoirs to roost, transferring the bacteria they have encountered via defecation.

In addition to the risk of spreading pathogens in the environment, gulls have been shown to host bacteria with Anti-Microbial Resistance (AMR) genes (Ahlstrom et al., 2021; Dolejská et al., 2009; Fogarty *et al*., 2003; Franklin *et al*., 2020), and have been posited as an indicator of the prevalence of antibiotic resistance in the environment (Stedt *et al*., 2014), linked to the use of antibiotics in humans and livestock.

Requirements for the study of gull faecal contribution to Belfast Lough

To enable an estimation of the quantity of pathogenic bacteria potentially contributed to the water of Belfast Lough by gulls, and how this varies spatially and temporally, it is necessary to estimate (i) the quantity of faecal output from gulls, (ii) the bacterial concentration of faecal output, and (iii) data on numbers of birds and their spatial and temporal variation. Quantification of bacterial concentration is not discussed as part of this investigation, as methodologies for establishing this are already known, and likewise, survey methodologies already exist to provide information on the spatial and temporal variation in abundance of gull species using the lough. Quantifying faecal output, defined here as the volume of faeces generated by an individual gull in a normal day, is not straightforward and will likely depend on species, habitat and individual foraging preferences. There are two primary approaches to collecting information on faecal output: investigations on captive birds or from birds in the wild.

Gulls in captivity

One potential method to estimate faecal output would be to take gulls from the wild into captivity for short periods of time. For example Girdwood *et al*. (1985) captured wild Herring Gulls and took them into captivity for three weeks to study. Gulls were kept individually in cages and faecal matter was collected from the cages twice a day, pooled and weighed. A similar process was also used by Dekinga *et al.* (1993), who took Knot into captivity to collect faecal samples from cage floors, albeit to study the diet rather than bacterial load.

However, there are ethical, practical and licensing implications to bringing wild birds into captivity, even for short periods of time. To mitigate these issues, it may be possible to work with wildlife rehabilitation centres who already have gulls in captivity and therefore have the means to collect information on gull faecal output in the manner of Girdwood *et al.* (1985) without the need to specifically capture wild birds. The advantages to this are that rehabilitation centres will already have the facilities to keep and feed caged gulls, and there would be no need to capture wild birds thus reducing the negative impacts on gull wellbeing, which would in turn reduce the overall cost of data collection. A disadvantage of this method might be that sample sizes would be limited by the availability of gulls in rehabilitations centres and the time of staff or volunteers that look after captive gulls. Additionally, there may be a mismatch between the faecal output of a captive gull versus a free flying gull, as diet, water consumption and stress levels will be different.

Gulls in the wild

Quantification of the faecal output of wild gulls has been attempted in the past, although under very specialised conditions. During a study of the potential for birds to contribute to contamination of bathing waters at Blackpool, North West England, Wither et al. (2003) placed plastic crates below birds roosting on the piers. These were covered by plastic sheets that formed funnels that channelled falling faecal deposits into a sterile container. By scaling up the area of plastic sheeting to the total area the birds were roosting in, the estimated output per bird per night could be made by factoring in the number estimated numbers of roosting birds in that area, although the researchers found that the quantity of faecal matter collected by each crate was very variable. Passive collection of faecal volume was also collected by Portnoy & Soukup (1990) by placing a plastic tarpaulin under a well-used loafing and roosting locations, and collecting faecal deposits as these were generated.

On the Isle of May, faecal output is currently being collected opportunistically during GPS tagging and ringing of gulls at the colony (pers. comm. Karen Spencer, University of St Andrews). The collection of faecal samples from adult birds during the ringing or tagging process is not guaranteed, therefore two methods are used to increase the potential sample size. The primary method involves placing gulls into cotton bird bags (as standard in ringing practice to keep captured birds safe and calm) with plasticised bases, for example using a sheet of heavy-duty PVC. While in the bag gulls may defecate, and this can then be collected easily. The second method involves placing a tarpaulin under the area from which gulls were released after tagging. Gulls often defecate upon release from the hand, therefore directing the gull over the tarpaulin after tagging may allow for faecal output to be collected. While the methods used in the study do not aim to collect the full faecal volume, they nevertheless could potentially provide this. However, the lack of predictability of collecting samples during ringing/tagging and the potentially small sample sizes involved may prohibit this from being useful to reliably collect a large number of samples.

Collecting faecal samples from individual wild birds does not give any information on the frequency of defecation throughout the day. Therefore, these methods would have to be paired with watches of free-flying birds over a period of time to quantify the defecation rate , as has been attempted for other waterbird species such as geese (Ebbinge *et al*., 1975; Summers & Grieve, 1982), ducks (Anders *et al*., 2009) and waders (Dekinga & Piersma, 1993). This has also been achieved in the past for gulls, for example Portnoy & Soukup (1990) estimated the defecation frequency of Herring Gulls (*Larus argentatus*) was 3.1 per hour, while Great Black-backed Gulls (*L. marinus*) was 4.4 per hour, by watching gulls for multiple 10-minute blocks.

Additional considerations

Total faecal output per gull per day is likely to be highly variable, reflecting birds' activity patterns. Different species will vary in their output (e.g. Portnoy & Soukup, 1990); Belfast Lough primarily hosts three species in large numbers: Black-headed Gulls, Herring Gulls and Lesser Black-backed Gulls, and the overall numbers of these changes dramatically between the breeding and winter seasons, so the contamination risk posed by each species will vary throughout the year. Additionally, individuals within a species will have particular dietary specialisations and therefore will likely vary in their daily faecal output but will also most likely vary considerably in the pathogenic load of their faecal deposits. This too may change over the course of a year as the availability of foraging resources varies between seasons.

Recommendations

In summary, there are three steps required to assess the extent of gull faecal contribution to the pathogen load of Belfast Lough and how this may vary over time and space: (i) studies of individual levels of faecal output, (ii) assessment of pathogenic loads and then (iii) counts of birds present in the lough (for example through WeBS and WinGS) to be able to scale the findings of (i) and (ii) up to the population level.

From a practical perspective, the quantifying faecal output would be most reliably undertaken using observations of captive individuals, and for ethical and cost considerations, working with rehabilitation centres may be the best way of sourcing study individuals. Rehabilitation gulls will not be perfect models for wild birds, but if fed a natural diet may provide a good substitute. Such a study of faecal output in captivity could then be combined with the opportunistic collection of faecal samples from wild birds, for example during routine ringing and tagging projects, to compare and contrast pathogenic load. Ideally the collection and analysis of in-vivo faecal samples should be combined with tracking studies to identify sources of pathogens. This is of particular importance in the winter as roosts of gulls may have travelled from far afield to their roosting location on migration, and therefore may be carrying novel sources of contaminants.

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Cover images: Katherine Booth Jones

Belfast's urban gulls: an assessment of breeding populations, breeding season movements and winter population

In Northern Ireland, urban gull populations have previously been poorly studied. The last count of urban gulls in Northern Ireland was during the last seabird census, Seabird 2000. An up-to-date estimate is therefore overdue, particularly as the most recent national census, Seabirds Count, is currently underway. In addition to the lack of knowledge of urban population sizes, there have been no previous studies of the movements and space use of urban nesting gulls in Northern Ireland, despite some tracking work on gulls nesting at natural, coastal sites. Outside the breeding season, Belfast Lough is used by wintering gulls, but numbers of these have not been assessed in recent times.

This project brings together a number of elements targeted at addressing knowledge gaps for the urban population of gulls in Northern Ireland, chiefly focusing on Belfast city centre. Firstly, the numbers of breeding gulls in Belfast city centre are estimated using vantage point surveys, contributing to the latest national census and providing data for organisations wishing to reduce human-gull conflict. Secondly, the latest tracking technology was used to investigate how urban-nesting Lesser Black-backed Gulls and Herring Gulls use the urban environment of Belfast, complementing the population monitoring and existing tracking data from Herring Gulls breeding in a nearby coastal colony on Big Copeland Island. Thirdly, the wintering gull population using the shoreline of Belfast Lough was quantified, as congregations of gulls in the lough may interact with human activities in the lough.

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