UK Centre for Ecology & Hydrology

Hywind Scotland Ornithological Monitoring Programme

Overwintering distributions of common guillemot and razorbill populations in Eastern Scotland

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Executive summary

- The Hywind Scotland Pilot Park located off the east coast of Scotland has been in operation since 2017 and has a total generating capacity of 30 MW. Ornithological monitoring is required as part of its Marine Licence and is carried out in conjunction with a large-scale seabird monitoring and research programme in north-western Europe (SEATRACK) involving the deployment of geolocation loggers to obtain seabird location estimates throughout the winter. Of particular concern are two species of auks (common guillemot *Uria aalge* and razorbill *Alca torda*) known to be highly vulnerable to displacement and barrier effects from offshore renewable developments.
- As part of the Hywind Scotland's ornithological monitoring, this project aims to: 1) quantify year-round distribution and movements of guillemots and razorbills at three major colonies along the east coast of Scotland (East Caithness SPA, Buchan Ness to Collieston Coast SPA and Isle of May National Nature Reserve) over two years (2017-18 and 2018-19); 2) to quantify diet during the breeding season of guillemots and razorbills at the three colonies in three years (2017-19).
- In 2017, a total of 190 geolocation loggers were deployed at the three study colonies. During the 2018 breeding season, a total of 82 loggers were retrieved and 193 new data loggers were deployed. During the 2019 breeding season a total of 102 loggers were retrieved, including several deployed in the first year. We obtained reasonable sample sizes in all cases (range 11-28) except razorbills at Buchan Ness to Collieston Coast, where only five loggers were retrieved each year. The geolocation data were processed using a probabilistic method to obtain two locations per day for each bird throughout the non-breeding period. The geolocation data were analysed to determine utilisation distributions for each species at each colony in 2017-18 and 2018-19. Overlap in distributions was quantified and minimum adequate sample size of tracked birds was examined.
- For both species, the distribution of birds from the three study colonies was similar at a broad spatial scale, with key wintering areas located around the colonies and in the central and southern parts of the North Sea. In guillemots, among-colony spatial similarity in kernel densities was generally high throughout the non-breeding period. In razorbills, spatial similarity among colonies was highest in the post-breeding period and lowest in late winter.
- The analyses of minimum adequate sample size of tracked birds for each species at each of the colonies all showed the typical non-linear decline in rate of increase in the size of area used with increasing sample size. Although the cumulative curves did not level off, their shape, particularly in guillemots, suggested that a larger sample size would not have resulted in a much increased size of core wintering areas.

- Diet was quantified from observations of prey carried in the bills of breeding adults returning to the colony to feed their young. At all three colonies, the diet of guillemots was dominated by clupeids. On the Isle of May, guillemots brought back fewer 1+ group sandeels to their young compared to birds at the other two colonies. 0 group sandeels were unimportant at all three colonies. The diet of razorbills showed marked among-colony variation, with 0 group sandeels dominating at East Caithness and Buchan Ness to Collieston Coast and clupeids dominating on the Isle of May in 2017 and 2018. However, patterns were different in 2019 with 0 group sandeels the most important prey at all three colonies. Few 1+ group sandeels were observed in the diet of razorbills.

- *Conclusions.* Our results indicate that the three populations of guillemots and razorbills had a similar overall non-breeding distribution, with extensive use of the central and southern North Sea and areas around the breeding colonies, and this was broadly consistent between years. However, in both species there were important differences among colonies in the location of hotspots during the non-breeding period. The data provide important insights into the year-round space use of these two key species at three major colonies on the east coast of Scotland and their potential interaction with offshore renewable developments.

1 Introduction

1.1 Background

In 2015, Equinor ASA (formerly Statoil ASA) received a Marine Licence to develop the Hywind Scotland Pilot Park Project ("Hywind Scotland"). During the summer of 2017 five floating wind turbines (FWTs) with a total generating capacity of 30 MW were installed at Buchan Deep, approximately 25 km off the coast of Peterhead. The wind farm has been in full production since October 2017.

Ornithological monitoring is required as part of Hywind Scotland's Marine Licence (Licence Number 05515/17/0) and is described in the Project Environmental Monitoring Programme (PEMP). Equinor is already involved in an ornithological monitoring and research programme which includes different seabird species and locations in north-western Europe (the SEATRACK programme). Equinor, as the operator of the Hywind Scotland project, agreed with Marine Scotland that Hywind Scotland's ornithological monitoring programme builds on this ongoing work and extends the programme to include additional locations and species relevant to the project. Accordingly, this project delivers the ornithological programme as described in Hywind Scotland's PEMP and agreed with the Licencing Authority (Marine Scotland Licencing Operations Team).

The focus of the current project is on two species of auks (common guillemot *Uria aalge* and razorbill *Alca torda*) considered vulnerable to displacement and barrier effects from offshore renewable developments (Furness et al. 2013, Dierschke et al. 2016). The interest in these species arose also because at-sea surveys carried out as part of the PEMP indicated that they are present in the Hywind Scotland project area in large numbers throughout the year (Natural Research Projects Ltd 2015). Of particular concern were the high densities recorded during August, a period which coincides with the post-breeding moult (when individuals are flightless) and with extended parental care (in the case of males), both of which can increase vulnerability to marine developments due to increased energy expenditure and reduced mobility.

Recent technological advances in animal-borne instrumentation have enabled the over-wintering ecology of seabirds to be studied in unprecedented detail (e.g. Phillips et al. 2007; Harris et al. 2010). Studies have deployed geolocation ("GLS") loggers on a range of species across the globe, obtaining daily estimates of location, timing of movements and activity throughout the year. Important within-species variation in distribution, movements and behaviour outside the breeding season, both among individuals breeding at different colonies across the range, and among years has been shown (Frederiksen et al. 2012; Daunt et al. 2014; Bogdanova et al. 2017; Fayet et al. 2017). This new knowledge has been a critical step forward since most mortality of seabirds occurs in winter associated with reduced food abundance and poor weather conditions. Furthermore, individuals that are constrained by prevailing environmental conditions may be more susceptible to perturbations associated with anthropogenic activities, such as the effects of offshore renewable developments. As such, studies of over-wintering ecology from multiple colonies are key to establishing the drivers of change in seabird populations.

The SEATRACK project is a collaborative tracking project involving countries bordering the north-east Atlantic and North Sea whose objective is to understand over-wintering ecology across multiple colonies of a range of seabird species (http://www.seapop.no/en/seatrack/). The multi-colony approach enables space use and activity to be compared among populations in the north-east Atlantic. SEATRACK is ambitious and innovative, and will lead to important new insights in the year-round ecology of seabirds in the region. UKCEH is a partner in SEATRACK and currently deploys geolocation (GLS) loggers on four seabird species on the Isle of May National Nature Reserve: common guillemot (hereafter "guillemot"), Atlantic puffin *Fratercula arctica*, black-legged kittiwake *Rissa tridactyla* and European shag *Phalacrocorax aristotelis*.

This project addresses two limitations of SEATRACK that existed in the context of the over-wintering ecology of seabirds breeding in north-east Scotland:

- The Isle of May was the only UK colony represented in SEATRACK, where work is being carried out on the above four species. The addition of two other nearby colonies

(Buchan Ness to Collieston Coast and East Caithness SPAs) will result in considerable advances in our understanding of the extent of migration scheduling and aggregation (or segregation) during late summer moult and mid-winter of guillemots from the same region. This also allows us to test whether results from the Isle of May (Harris et al. 2015) are representative of other colonies along the east coast of Scotland.

- SEATRACK does not include the razorbill, a species of high conservation importance in the UK that shows strongly contrasting foraging and population ecology to its sister species, the guillemot (Thaxter et al. 2010; Glew et al. 2018; Dunn et al. 2019).

Working at additional colonies to the Isle of May in this project enabled us to propose a secondary goal of collecting diet data for both species. The Seabird Monitoring Programme (SMP) is a national programme of monitoring of the demography and diet of UK seabirds. It is the UK's equivalent to Norway's SEAPOP programme. The SMP monitors many sites around the UK, with varying intensity. There is current interest in the colonies on the east coast of Scotland because of proposed offshore wind farms in the region, including Hywind. For Buchan Ness to Collieston Coast and East Caithness SPAs, the quality of count data is moderate to good but there is a paucity of diet data (Anderson et al. 2014). Accordingly, diet data collection was planned for each study season. Given the regional significance of these colonies, it is strategically important to increase the intensity of diet monitoring so that any assessments of population change can be undertaken with a better understanding of predator-prey relationships, to complement data collected on the Isle of May as part of UKCEH's Isle of May long-term study (IMLOTS) that are being contributed to this project.

Furthermore, there is increasing evidence of a link between breeding conditions in summer and wintering ecology in seabirds (Daunt et al. 2006, 2014; Bogdanova et al. 2011; 2017). These so-called "carry-over" effects arise when conditions in one season have downstream consequences in subsequent seasons (Harrison et al. 2011). Impacts of summer breeding on winter ecology can occur because of the costs of reproduction; furthermore, winter ecology can affect condition in late winter and early spring, impacting on breeding scheduling and ultimately breeding success. By quantifying winter distribution and activity and summer diet, we will gain insights on seasonal interactions at the three study colonies.

1.2 Project objectives

This project has two principal objectives

- To quantify year-round distribution, movements and activity of guillemots and razorbills at East Caithness SPA and Buchan Ness to Collieston Coast SPA, and of razorbills on the Isle of May National Nature Reserve.
- To quantify diet during the breeding season of guillemots and razorbills at all the study colonies.

These data are compared with year-round distribution, movements and activity of Isle of May guillemots from the SEATRACK project to complete the structure of data collection on two ecological elements (winter ecology and summer diet) in two species at three colonies.

This report details all work carried out in the project between the 2017 to 2019 breeding seasons. The work comprised the deployment of data loggers and collection of diet data in 2017 (Daunt et al. 2017), retrieval of data loggers, deployment of new data loggers and collection of diet data in 2018 (Bogdanova et al. 2019) and the retrieval of data loggers and diet data collection in 2019. The report presents results on: 1) distribution of the two species at each study colony over the winters of 2017-18 and 2018-19; 2) similarity in the distribution of birds from the three colonies throughout each winter; 3) minimum adequate sample size of tracked birds required for a robust estimation of distribution (to ascertain whether we had enough data on each species at each colony) and 4) diet of each species at each colony in 2017, 2018 and 2019.

2 Methods

2.1 Geolocation data collection

During the 2017 breeding season, guillemots and razorbills breeding at the three colonies along the east coast of Scotland (Fig. 1) were captured at their nest sites with a noose or crook on the end of a long pole. Each bird was fitted with a geolocation logger (model MK3006, Biotrack, UK) attached to a plastic leg ring. A BTO metal ring was placed on the other leg, and the bird released. Deployment methods and protocols were the same at all colonies and handling time was less than five minutes in all cases. In subsequent years, colonies were visited and attempts made to capture birds carrying data loggers were made.

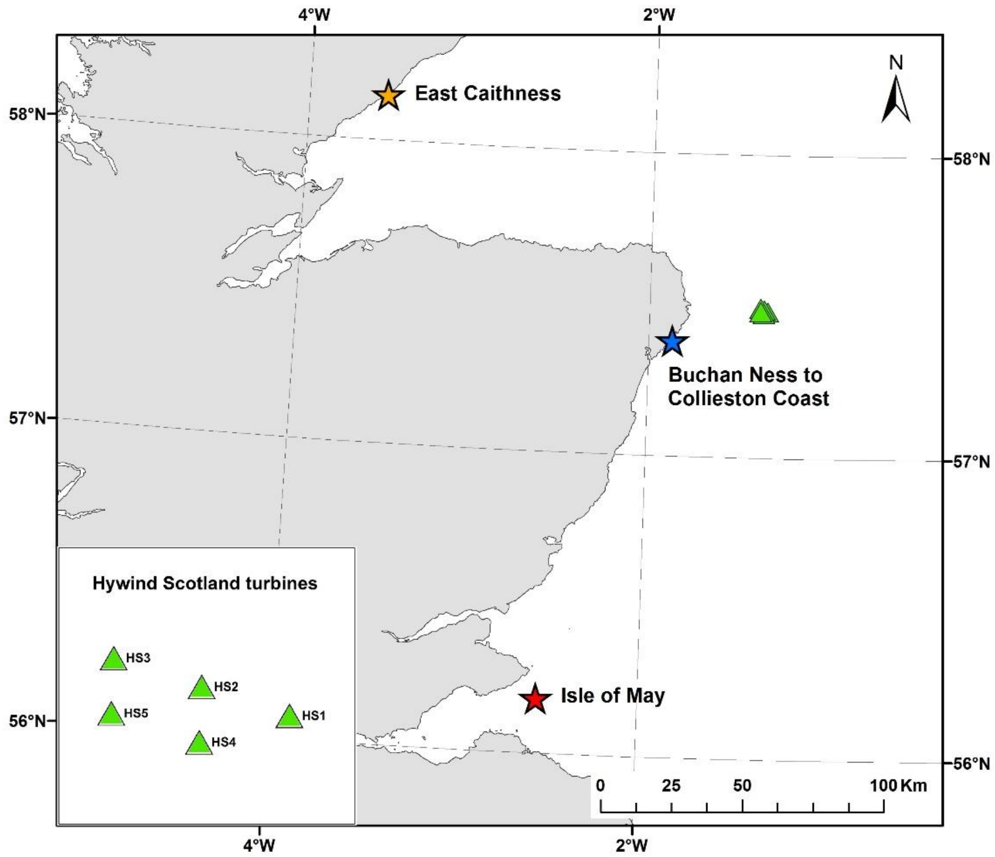


Fig. 1. Location of study colonies and Hywind Scotland Pilot Park Project (green triangles on main map and inset).

In total, 190 loggers were deployed in 2017, and 82 of these were retrieved in 2018 (representing 43% success rate). An additional 18 loggers were retrieved in 2019, bringing the overall success rate over the project duration to 53%. Sample size of deployments and successful retrievals per colony and species is shown in Table 1.

Colony and species	Deployed 2017	Retrieved 2018	Downloaded 2018	Retrieved 2019	Downloaded 2019
a) East Caithness					
Guillemot	40	20	17	5	4
Razorbill	30	13	13	2	2
b) Buchan Ness to Collieston Coast					
Guillemot	40	24	24	4	4
Razorbill	20	2	2	3	3
c) Isle of May					
Guillemot (as part of SEATRACK)	30	12	12	4	4
Razorbill	30	11	11	0	0

Table 1: Summary of logger deployments in 2017 and number of birds tracked from each species and colony.

In 2018, a total of 193 loggers were deployed of which 84 were retrieved in 2019 (representing 44% success rate). Loggers were deployed on a mixture of individuals followed over 2017-18 and new individuals (see Appendix for details). Sample size of deployments and successful retrievals per colony and species is shown in Table 2.

Colony and species	Deployed 2018	Retrieved 2019	Downloaded 2019
a) East Caithness			
Guillemot	40	22	22
Razorbill	30	5	5
b) Buchan Ness to Collieston Coast			
Guillemot	40	23	22
Razorbill	19	5	5
c) Isle of May			
Guillemot (as part of SEATRACK)	34	18	18
Razorbill	30	11	11

Table 2: Summary of logger deployments in 2018 and number of birds tracked from each species and colony.

2.2 Geolocation data processing

The geolocators measure light intensity every 60 seconds, and record the maximum value within each 10 minute interval. The loggers we deployed also have added sensors that record activity (wet – in the water or dry – on land/in flight) and temperature when the logger is submerged in water. The timing of twilight events (dawn and dusk) is estimated from thresholds in the light curves. To compute locations from the twilight events we used a new method involving an iterative forward step selection where each possible position is weighed using a set of parameters based on the species biology/behaviour (travel speeds) and environmental characteristics (sea surface temperature). The probabilistic algorithm used provides high accuracy of locations throughout the year, and substantially reduces location error particularly around the equinoxes due to the additional behavioural and environmental information incorporated (Merkel et al. 2016). This allowed us to retain in the processed dataset locations during the equinox periods when key migration movements often take place. All data processing was carried out in R (version 3.6.1, R Core Team 2019) using package probGLS (Merkel et al. 2016; available from GitHub).

Although overall positions estimated using probGLS had considerably improved accuracy compared to those estimated using the standard threshold methods, plotting the processed data showed that some erroneous/implausible locations (where birds moved more than 500 km in a day) were included, particularly during the equinox periods. These represented 0.6% of the guillemot dataset and 1.4% of the razorbill dataset and were removed from the final dataset.

2.3 Geolocation data analysis

2.3.1 Species utilisation distribution (UD)

Utilisation distribution was determined for guillemots and razorbills from each study colony by calculating the kernel density of locations at sea. Locations were projected in Lambert azimuthal equal-area projection and kernel density was calculated in R (R development core team, 2019; package adehabitatHR, Calenge 2006), using a cell size of 1,000m^2 and a smoothing parameter *h* identified with the least-squares cross validation (LSCV) method (Worton 1989). For each species, the 50%, 75% and 90% UD contours were extracted in R (package adehabitatHR) and then mapped in ArcGIS. The 50% contour was used to define core areas and the 90% contour - to define the area of active use. Maps of population UDs were generated for the whole winter period (August to March) and for each month during the non-breeding season.

To assess the consistency of core areas among individuals, we determined individual UDs, extracted the 50% UD contours, converted these into grids with 2 km^2 cell size and calculated the total number of birds using each grid cell. The analysis was conducted in R using packages adehabitatHR and raster (Hijmans & van Etten 2018). We then generated maps of the cumulative individual core areas for the whole winter period in ArcGIS 10.4.1.

2.3.2 Overlap in utilisation distributions

To quantify variation in non-breeding distribution linked to breeding colony origin, we estimated the spatial similarity between the UDs of birds from the three study colonies (based on the area of active use) using Bhattacharyya's affinity measure (Fieberg & Kochanny 2005). This measure ranges from zero (no similarity) to 1 (identical densities). Bhattacharyya's affinity measures are presented for each month and for the whole non-breeding period in 2017-18 and 2018-19.

2.3.3 Minimum adequate sample size of tracked birds

To establish whether the sample size of tracked individuals was adequate to estimate the core wintering areas used by the population of each species during the sampling period, we examined the relationship between size of core areas and number of individuals using a resampling procedure. This procedure was performed in R, and involved two steps: 1) calculating each individual's UD and 50% UD contour (using the adehabitatHR package within R); 2) calculating the total cumulative area for each sample size of birds ranging from 1 to n (where n denotes the total number of birds for which we had data) 1,000 times, by choosing birds randomly allowing replacement (Manly, 2009). The distribution of these areas across the 1,000 resampling rounds was used to quantify the typical at-sea area used for a given sample size of birds and the uncertainty associated with estimating this area. This analysis was carried out for the whole non-breeding period (August to March) in each year.

2.4 Diet studies

Diet of these two species has been studied on the Isle of May since the 1980s (Harris & Wanless 1985, 1986; Wilson et al 2004; Daunt et al. 2008; Thaxter et al 2013). To our knowledge, only one previous study of diet has been undertaken at Buchan Ness to Collieston Coast SPA (in 2006; Anderson et al. 2014), and no previous study of diet has been undertaken at East Caithness SPA.

The basic approach to assessing common guillemot and razorbill diet is observing prey carried in the bills of breeding adults returning to the colony to feed the young or, in the case of common guillemot only, to display to other adults. This is achieved by setting up an observation location with a clear view of a group of breeding birds with sufficient numbers of nests to obtain good sample sizes (up to 100 pairs), that is close enough that prey can be identified and a categorical size estimated using binoculars. All staff involved in observations had training and experience in these techniques. All data were collected in the field in notebooks and field data sheets. These were transcribed to spreadsheets after each check was made and files backed up on CEH servers. All notebooks and field sheets are archived at UKCEH.

In 2017, two hour watches covering the period of 04:00 – 22:00 twice were undertaken at East Caithness (13 June - 1 July) and Buchan Ness to Collieston Coast (19 June - 5 July). One plot was used for each species at East Caithness, and one plot for guillemots and two for razorbils at Buchan Ness to Collieston Coast. The rationale for using two plots for razorbills at the latter colony was that all chicks had fledged from the original plot, but staff were still *in situ*, so further samples were collected at a plot which still contained active nests in the remaining time available at the colony. On the Isle of May, two continuous dawn to dusk watches were carried out at separate plots used as part of the UKCEH long-term study on 21 June and 25 June. These two plots have been used for observation watches on the Isle of May since 1993. At all colonies, further observations were made opportunistically (range of dates the same as above for East Caithness and Buchan Ness to Collieston Coast; range of dates for Isle of May 2 April – 16 July).

In 2018, two-hour watches covering the period 04:00 - 22:00 twice were undertaken between 18 June and 4 July at East Caithness and between 25 June and 11 July at Buchan Ness to Collieston Coast. One plot was used for each species at both East Caithness and Buchan Ness to Collieston Coast. However, the plots used in 2018 at Buchan Ness to Collieston Coast were different to those used in 2017 for both species, because high failure rates at the original plots in 2018 resulted in few chicks and therefore limited opportunities for diet observations. On the Isle of May, dawn to dusk watches were carried out on 1 July and 3 July at the same two plots used in 2017. Further observations were made opportunistically (range of dates 28 April – 21 July).

In 2019, two-hour watches covering the period 04:00 - 22:00 twice were undertaken between 18 June and 4 July at East Caithness and between 10 June and 29 June at Buchan Ness to Collieston Coast. One plot was used for each species at both East Caithness and Buchan Ness to Collieston Coast. The plots used in 2019 at Buchan Ness to Collieston Coast were the same as those used in 2018 for both species. On the Isle of May, dawn to dusk watches were carried out on 24 June and 30 June at the same plots as in 2017 and 2018. Further observations were made opportunistically (range of dates 4 June to 17 July).

Guillemots return to the colony with a single prey item in their bill. During observation watches, time of arrival, prey species and prey size were recorded. For opportunistic observations, only the latter two were recorded. In all years of the long-term study on the Isle of May, the vast majority of prey are lesser sandeel or clupeids. Clupeids comprise sprat and herring, which are all but impossible to separate from observations in the field. In the current and previous years on the Isle of May, a small number of clupeids have been collected from breeding ledges and identified as sprat. However, all prey from this fish family are classed as clupeids in the dataset.

Prey were assigned to one of four size classes (very small, small, medium, large) using the bill length of the adult as a guide. When feeding a prey item to the chick the adult partly spreads its wings and arches its back, sometimes obscuring the view of the prey. All prey items presented in this way were presumed to have been eaten although classification by size and/or species was not always possible.

The protocol for collecting diet observations from razorbills was similar, except that razorbills may carry multiple prey in their bills. Thus, in addition to prey type and size, prey number was also estimated where possible, either as an exact estimate or as a broad category (“few”; “many”). Broader categories are necessary since estimating the number of prey in the bill is challenging. Fish found on guillemot breeding ledges allowed an estimate of the lengths of fish in each size category.

3 Results

3.1 Species winter distribution

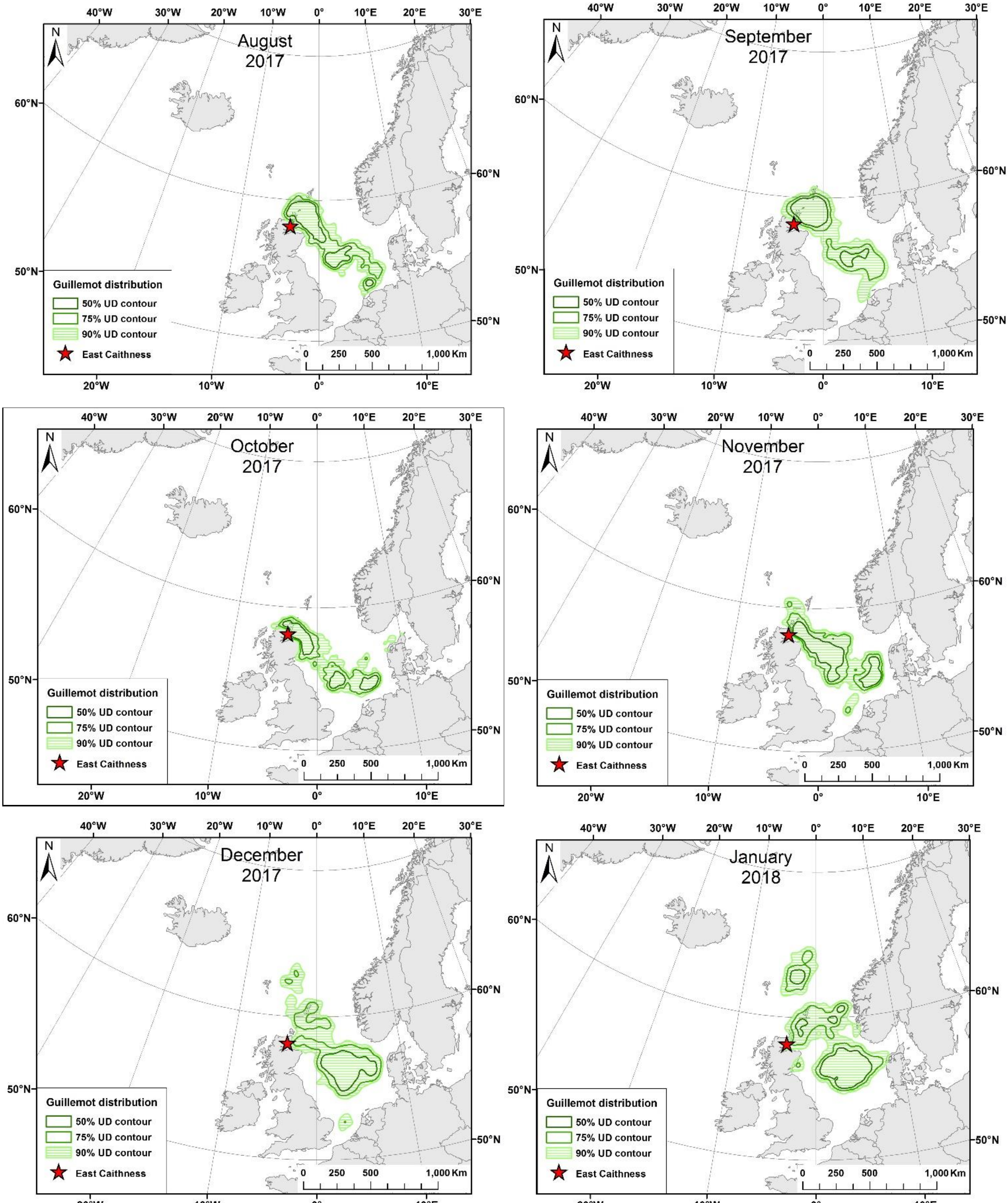
3.1.1 Distribution maps

3.1.1.1 2017-18

Maps of utilisation distributions of guillemots in the first study year are provided in Figures 2-7. Corresponding maps for razorbills are presented in Figures 8-13.

After the breeding season in 2017, core areas of guillemots from East Caithness were located close to the colony and further south within the central North Sea (Fig. 2a). Between September and November areas near the colony and in central and south-western parts of the North Sea were used (Fig. 2b-d). In mid-winter most birds had moved further away from the colony, with core areas concentrated in the central and northern North Sea as well as the Norwegian Sea (Fig. 2e-f). In February, key areas extended from the central North Sea to the area of the colony, suggesting that part of the population returned close to the breeding grounds already in late winter (Fig. 2g). In March, core areas were located in the central North Sea, around the colony and in the Norwegian Sea indicating that some birds made substantial movements north in the pre-breeding period (Fig. 2h).

Overall, throughout the non-breeding period, the guillemots from East Caithness ranged across the North Sea and in parts of the Norwegian Sea but two key areas were apparent – one surrounding the colony and the other in the central parts of the North Sea (Fig. 2i). In line with this, individual core areas overlapped to greatest extent near the colony where areas were used by up to 12 out of 21 birds, and to lesser extent in the central parts of the North Sea - used by 5-9 out of 21 birds (Fig. 3).


August 2017
September 2017
October 2017
November 2017
December 2017
January 2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
East Caithness
0 250 500 1,000 Km
40°W 30°W 20°W 10°W 0° 10°E 20°E 30°E
60°N 50°N
20°W 10°W 0° 10°E
N

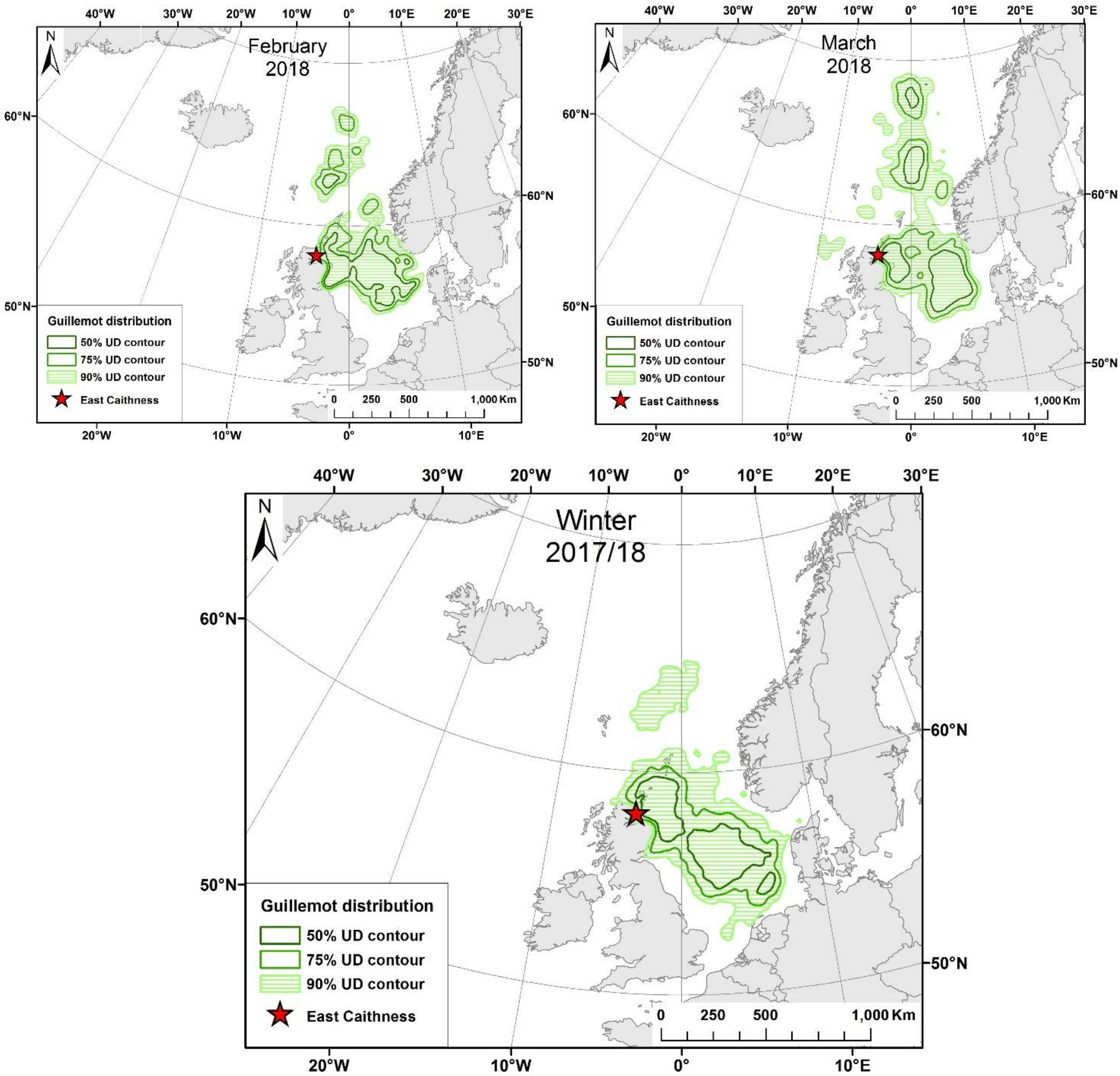


Fig. 2: Utilisation distributions (50%, 75%, 90% contours) for guillemots from East Caithness (n=21) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2017-2018 (August – March).

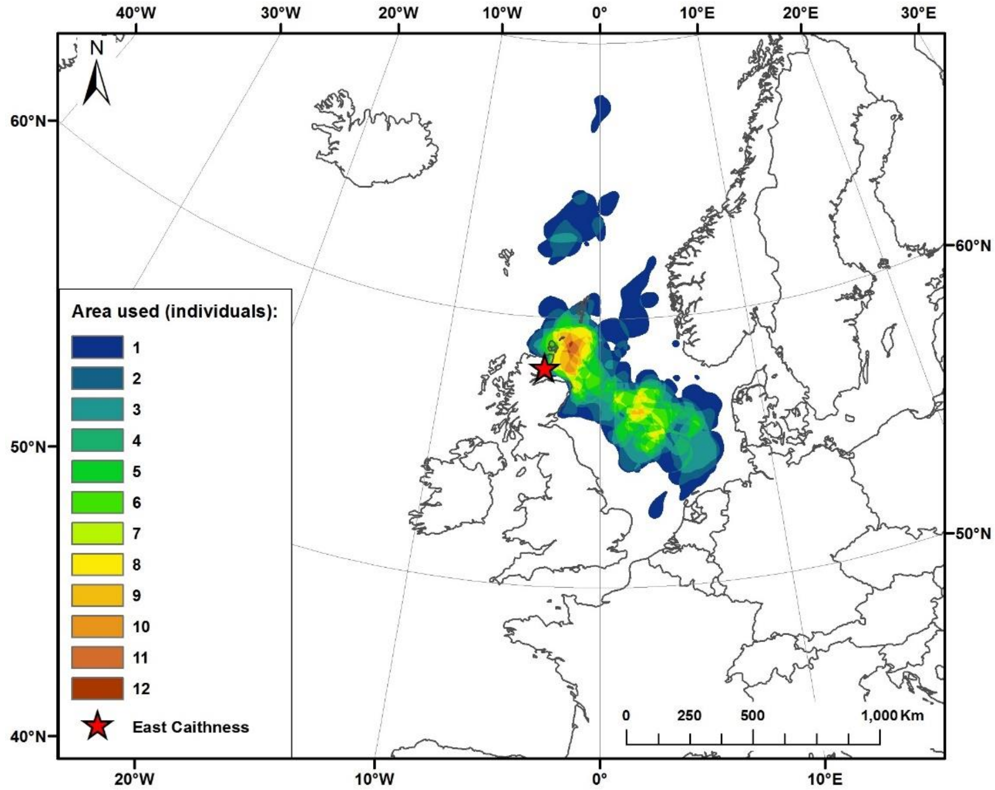
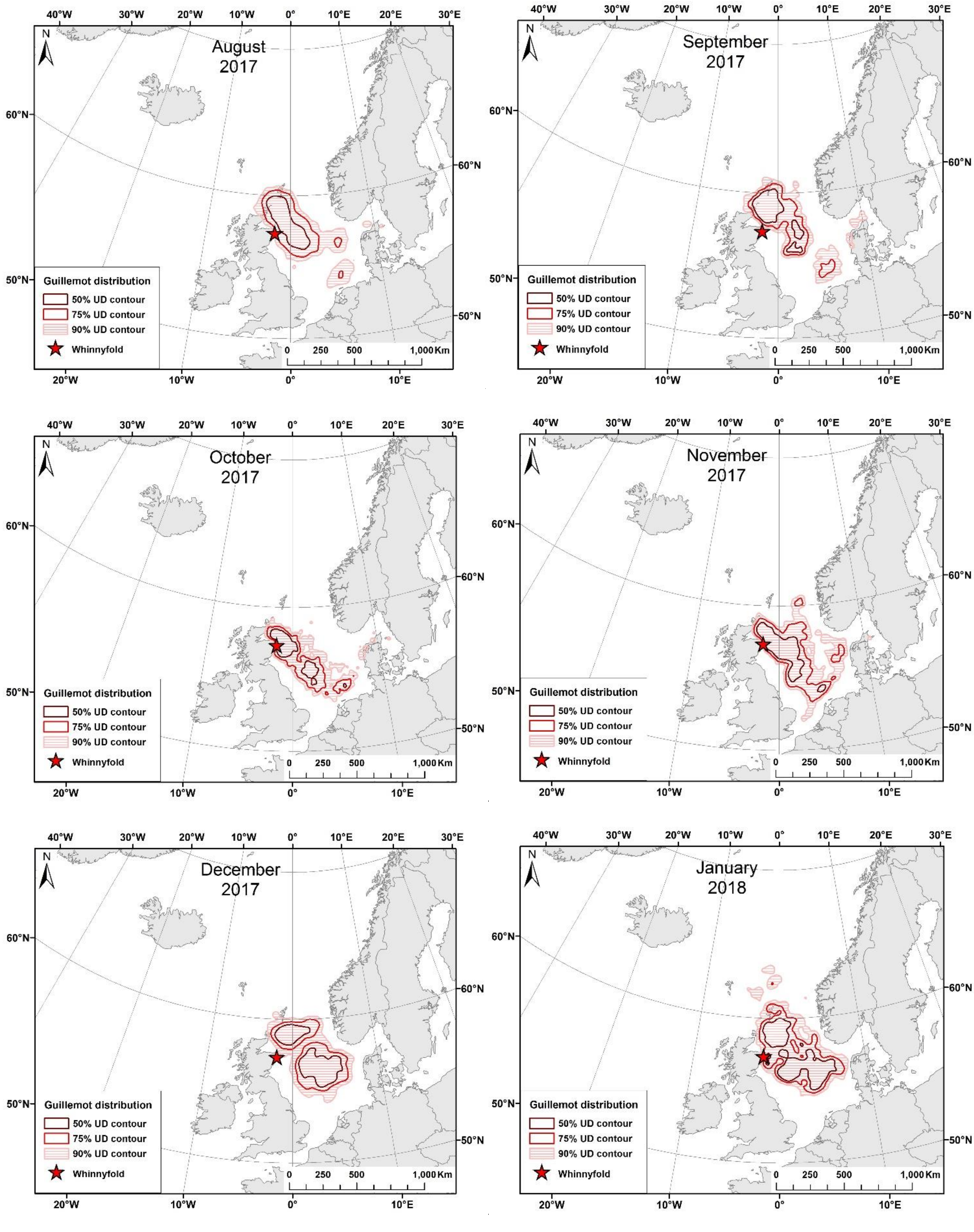


Fig. 3: Consistency in core areas (50% UD contours) of guillemots from East Caithness (n=21) in winter 2017-2018 (August – March).

In 2017, during the post-breeding period (August) guillemots from Buchan Ness to Collieston Coast remained within the northern North Sea, with core areas located close to the colony (Fig. 4a). Between September and November core areas were near the colony and in central and south-western parts of the North Sea (Fig. 4b-d). In December and January, two key areas were apparent - one in the central, the other in the northern North Sea (Fig. 4e,f). Similar to birds from East Caithness, in February and March core areas extended from the central North Sea, through the northern North Sea to the Norwegian Sea, including the area around the colony (Fig. 4g,h).

Overall, during the non-breeding period, guillemots from Buchan Ness to Collieston Coast ranged across the North Sea and parts of the Norwegian Sea but core areas were concentrated around the colony and in the central North Sea (Fig. 4i). Accordingly, highest overlap in individual core areas was observed within the area around and north of the colony, which was used by up to 18 out of 28 birds (Fig. 5).


August 2017
September 2017
October 2017
November 2017
December 2017
January 2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
40°W 30°W 20°W 10°W 0° 10°E 20°E 30°E
60°N 50°N
20°W 10°W 0° 10°E

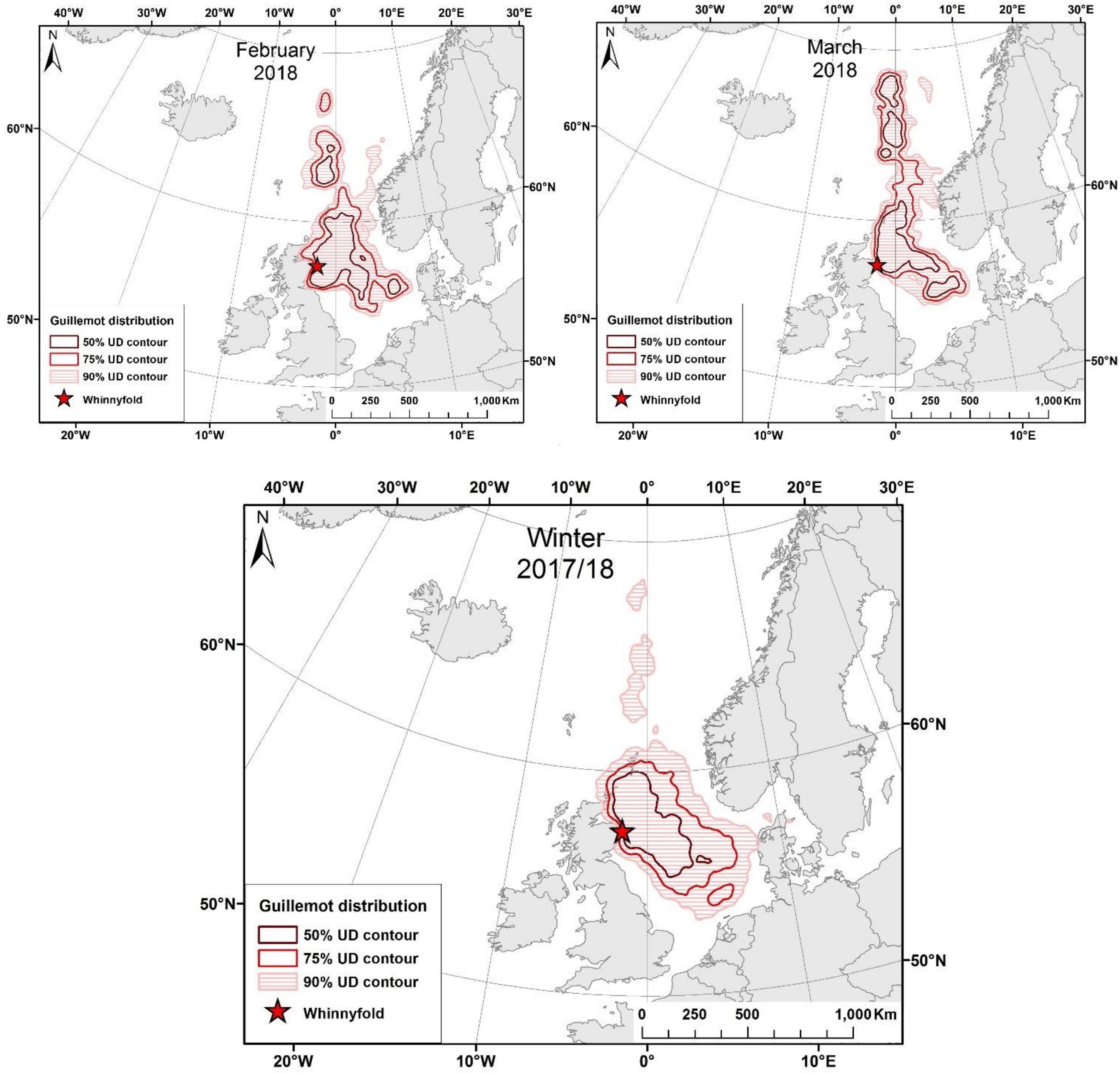


Fig. 4: Utilisation distributions (50%, 75%, 90% contours) for guillemots from Buchan Ness to Collieston Coast (n=31) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2017-2018 (August – March).

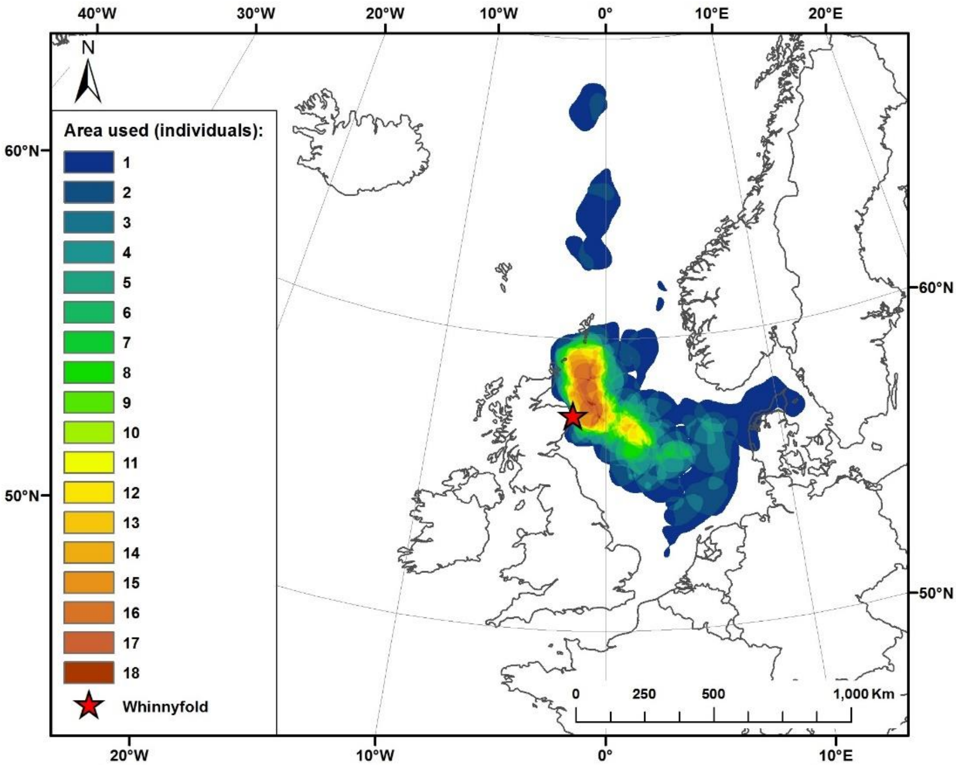
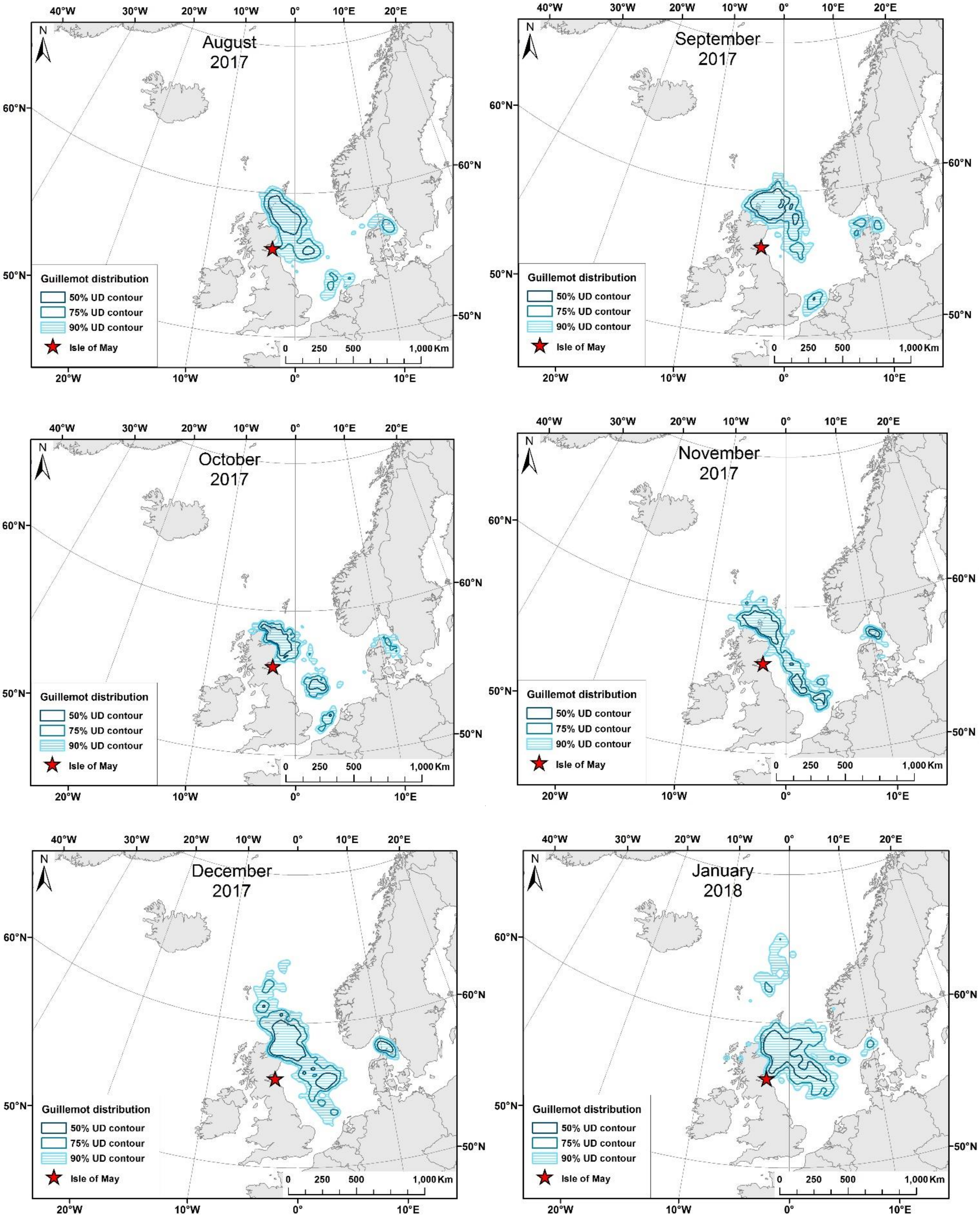


Fig. 5: Consistency in core areas (50% UD contours) of guillemots from Buchan Ness to Collieston Coast (n=31) in winter 2017-2018 (August – March).

During the post-breeding period in 2017, Isle of May guillemots were distributed mainly to the north and east of the colony, with some individuals moving to the southern North Sea and the Skagerrak/Kattegat area that links the North and Baltic Seas (Fig. 6a). Over the following months (September – December) core areas were located off north-east and northern Scotland, in the southern North Sea and around the Dogger Bank and in the Skagerrak/Kattegat area (Fig. 6b-e). In January the core areas were within the central and northern North Sea, including the area surrounding the colony (Fig. 6f). In February and March core areas extended from the northern North Sea to the Norwegian Sea, including the area around the Isle of May (Fig. 6g,h).

During the whole non-breeding period, guillemots from the Isle of May ranged widely across the North and Norwegian Seas but the key areas they used were mainly located in the waters off north-east Scotland (Fig. 6i). In line with this, highest overlap in individual core areas was observed within this area, which was used by up to 12 out of 16 birds (Fig. 7).


August
2017
September
2017
October
2017
November
2017
December
2017
January
2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
40°W
30°W
20°W
10°W
0°
10°E
20°E
60°N
50°N
N

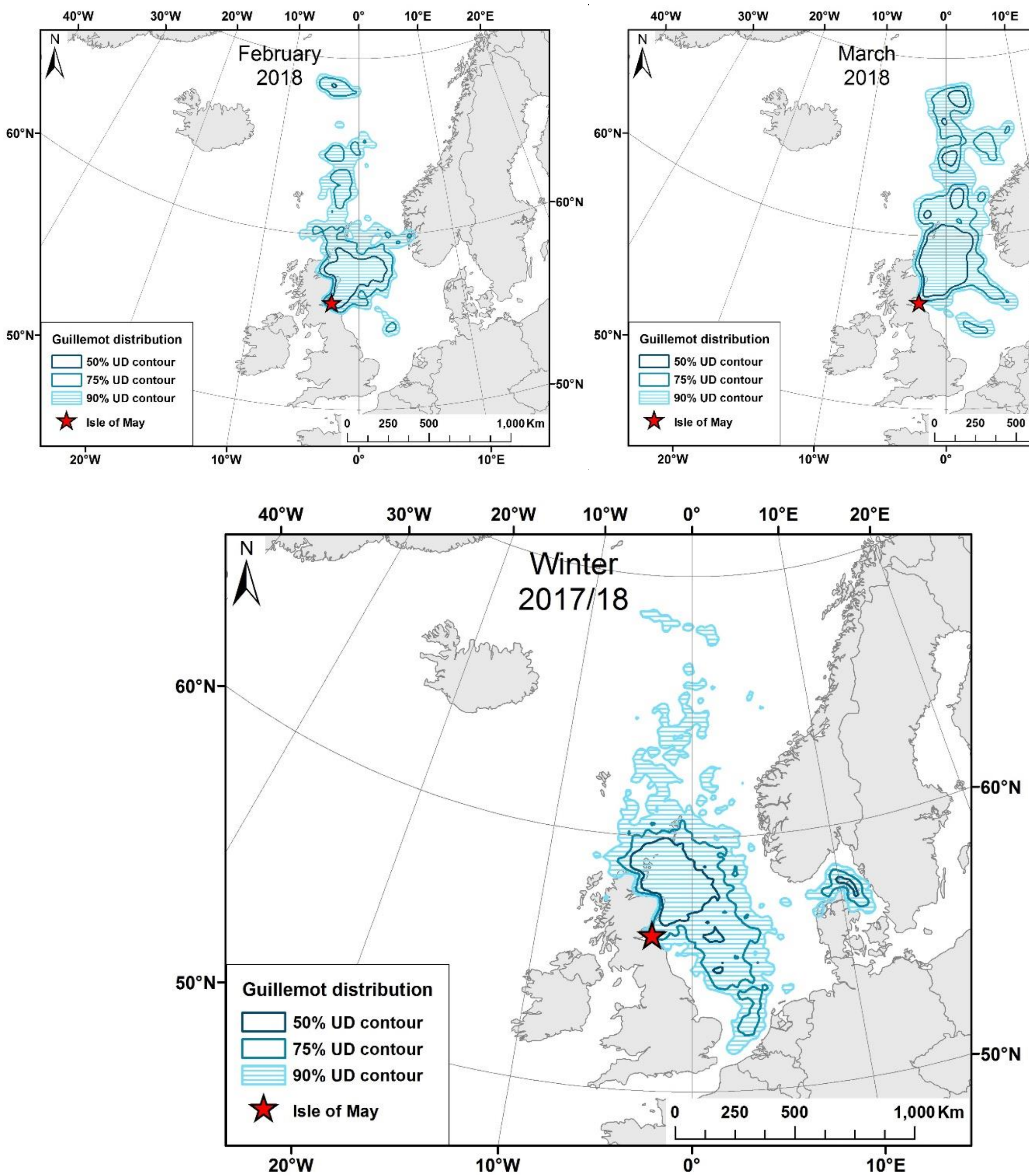


Fig. 6: Utilisation distributions (50%, 75%, 90% contours) for guillemots from Isle of May (n=16) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2017-2018 (August – March).

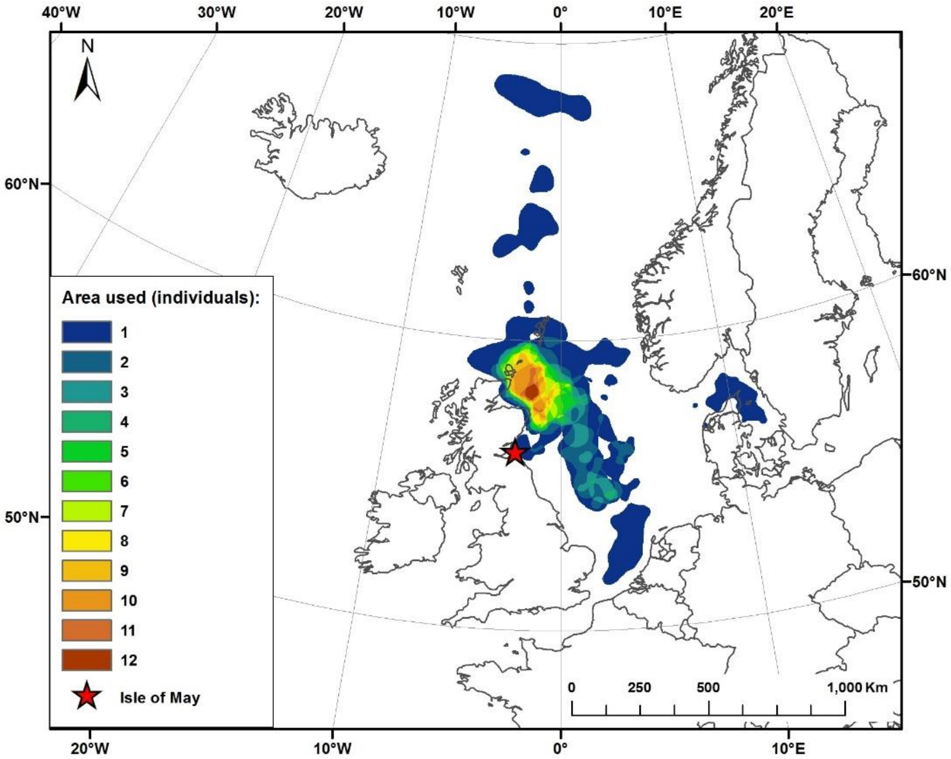
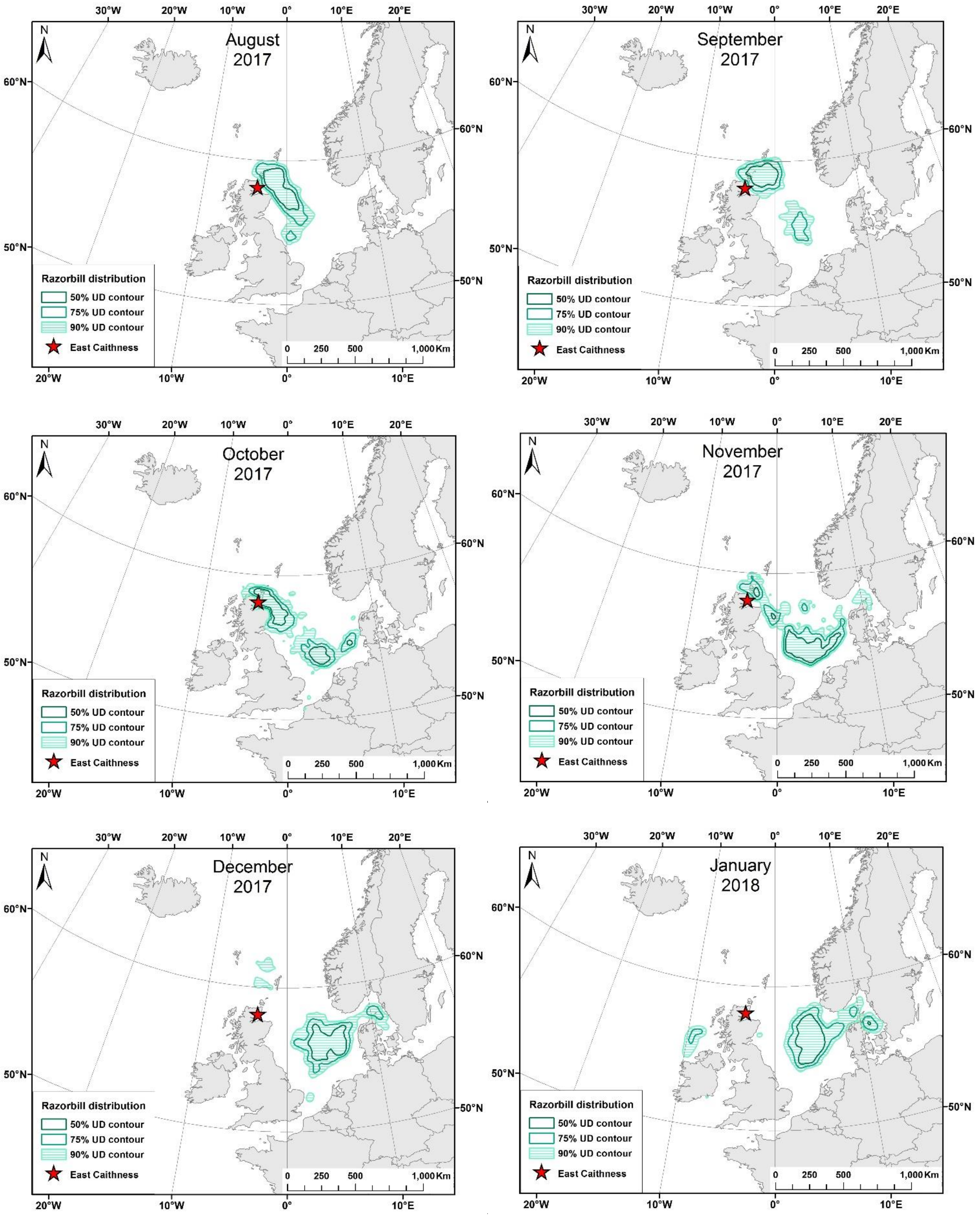


Fig. 7: Consistency in core areas (50% UD contours) of guillemots from Isle of May (n=16) in winter 2017-2018 (August – March).

After the breeding season in 2017, razorbills from East Caithness stayed mainly within the area surrounding the colony (Fig. 8a,b). During October and November, the birds gradually moved to the central North Sea where they remained throughout the winter months (Fig. 8c-g). In January and February, single birds moved to the Skagerrak/Kattegat region and to the north-east Atlantic, Irish and Celtic Seas (Fig. 8 g,h). By March, core areas were concentrated in the central North Sea and the east coast of Scotland including the area around the colony (Fig. 8h).

Overall, during the non-breeding period, the East Caithness razorbills ranged across the North Sea but two key areas were apparent – one in the central North Sea and the other off the east coast of Scotland (Fig. 8i). Accordingly, consistency in individual core areas was highest within these areas, with up to 8-11 out of 15 birds overlapping (Fig. 9).


August 2017
September 2017
October 2017
November 2017
December 2017
January 2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
East Caithness
0 250 500 1,000 Km
30°W 20°W 10°W 0° 10°E 20°E
60°N 50°N

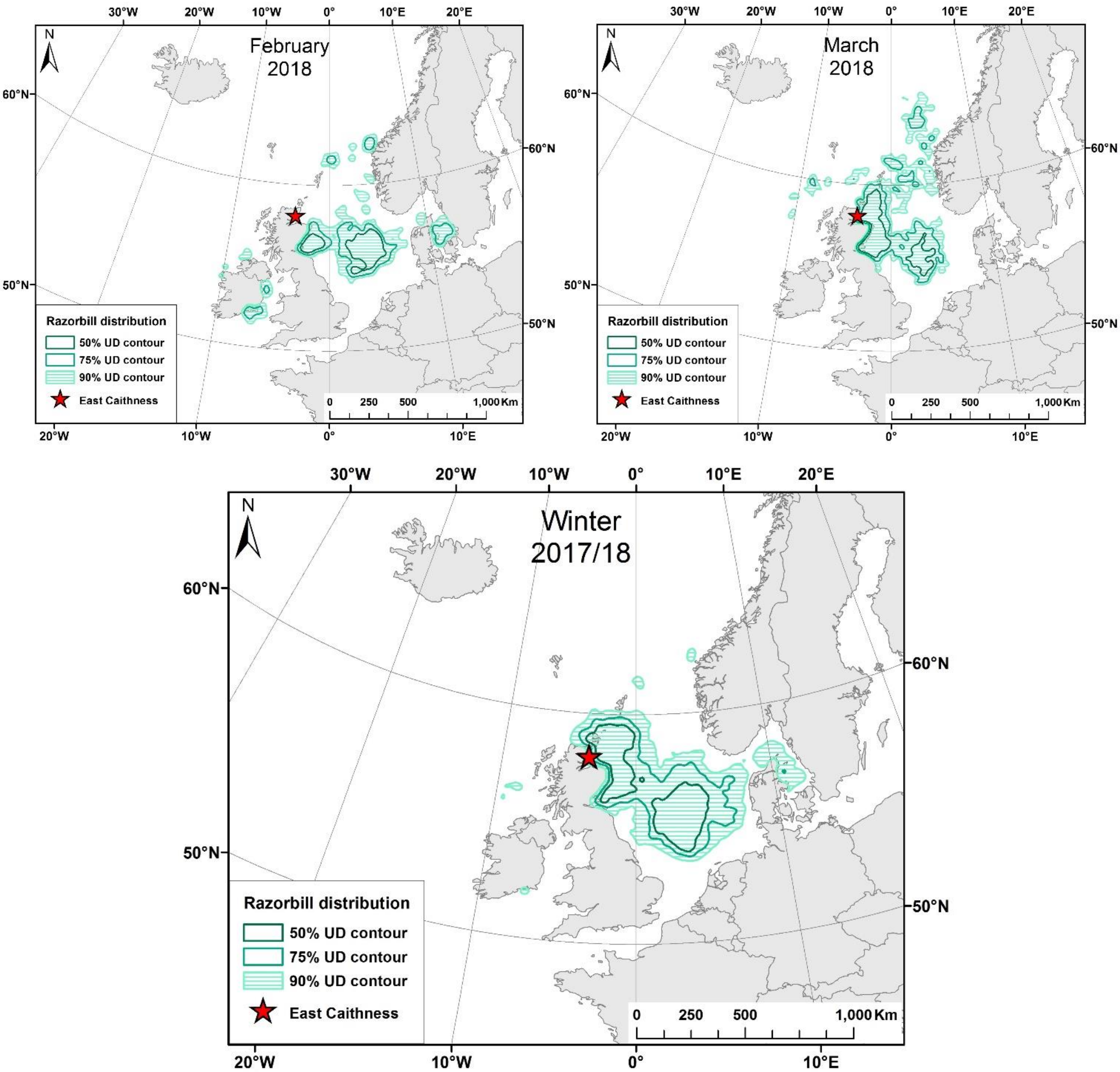


Fig. 8: Utilisation distributions (50%, 75%, 90% contours) for razorbills from East Caithness (n=15) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2017-2018 (August – March).

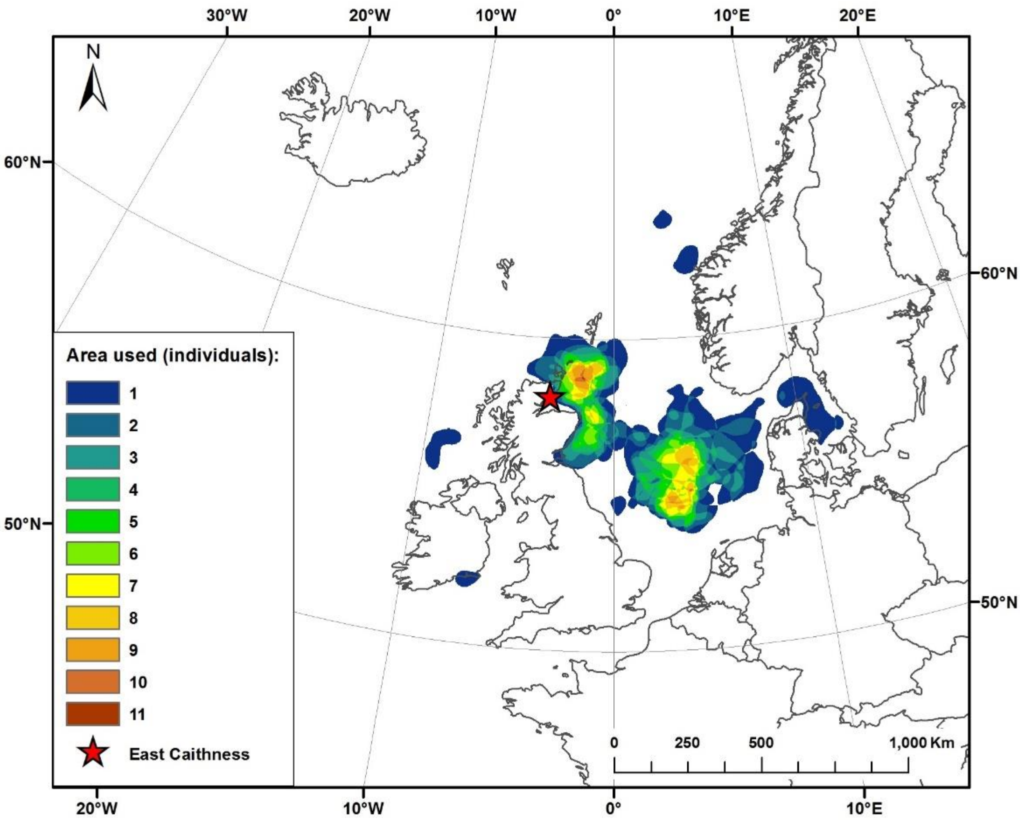
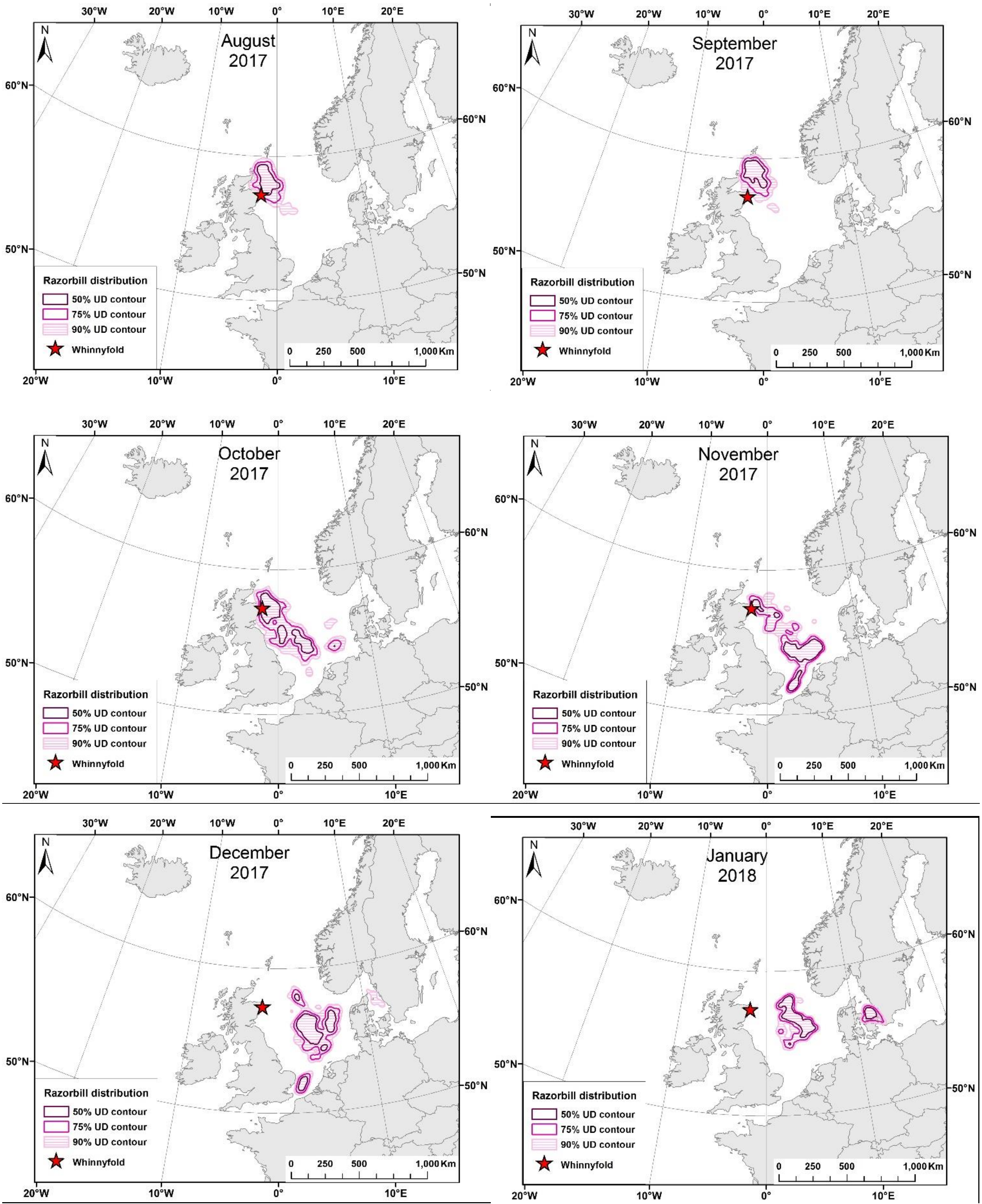


Fig. 9: Consistency in core areas (50% UD contours) of razorbills from East Caithness (n=15) in winter 2017-2018 (August – March).

Results for Buchan Ness to Collieston Coast in 2017 are based on data from few individuals and are likely to be less representative of the population's distribution compared to the other colonies. Similar to East Caithness razorbills, the birds from Buchan Ness to Collieston Coast stayed relatively close to the colony in the post-breeding period (Fig. 10a,b). In October, some of the birds were still in the area around the colony but others moved southward to the central North Sea and the Dogger Bank area (Fig. 10c). During the winter months core areas were located mainly in the central and southern North Sea, with a single bird migrating to the Skagerrak/Kattegat region (Fig. 10d-g). By March core areas were concentrated around the colony and in the central North Sea (Fig. 10h).

Over the whole non-breeding period, two key areas were apparent – one off north-east Scotland (including the area around the colony) and the other in the central North Sea (Fig. 10i). Overlap in individual core areas was highest near the colony (Fig. 11).


August
2017
September
2017
October
2017
November
2017
December
2017
January
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
30°W 20°W 10°W 0° 10°E 20°E
20°W 10°W 0° 10°E
60°N
50°N
N

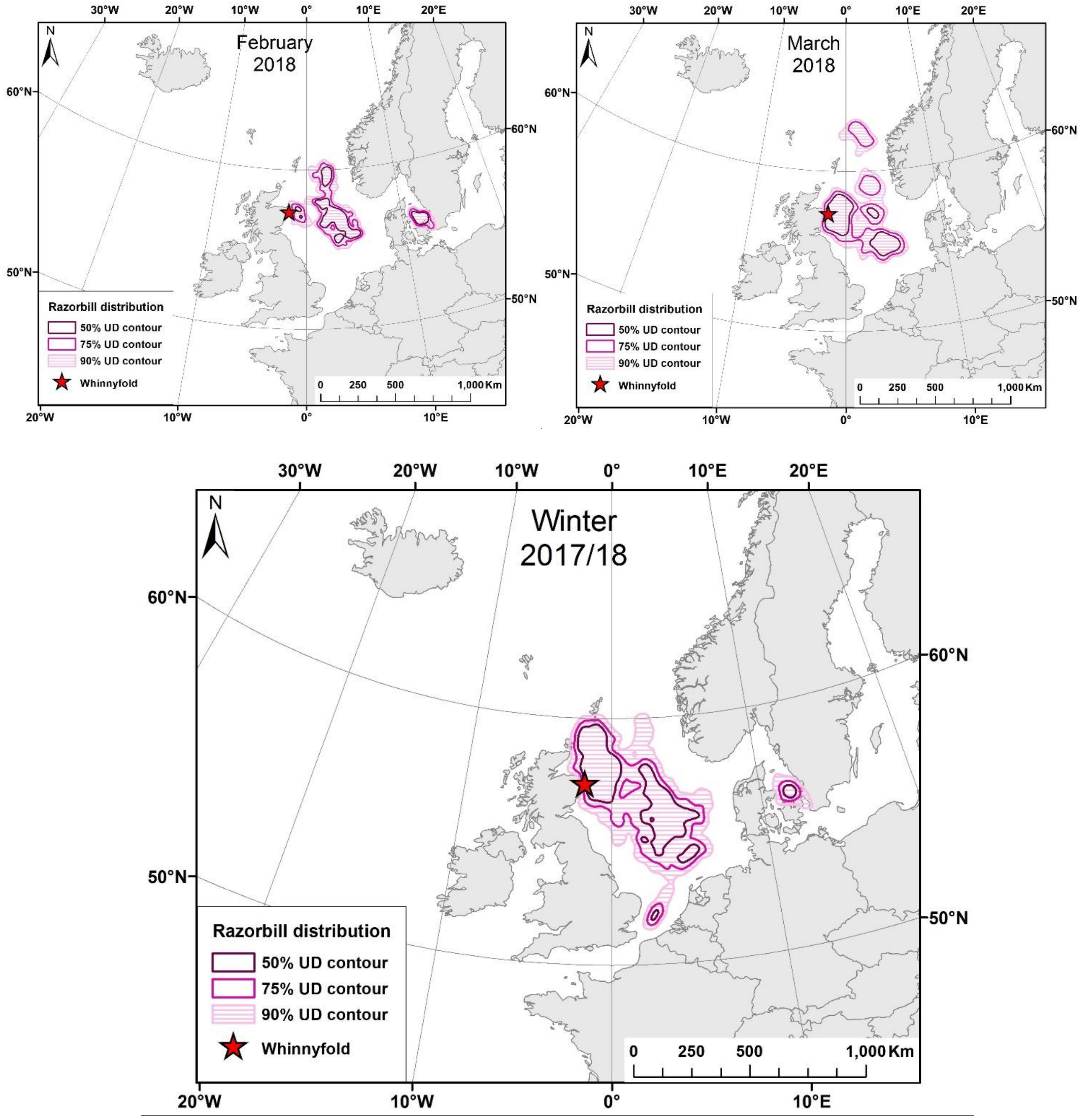


Fig. 10: Utilisation distributions (50%, 75%, 90% contours) for razorbills from Buchan Ness to Collieston Coast (n=5) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2017-2018 (August – March).

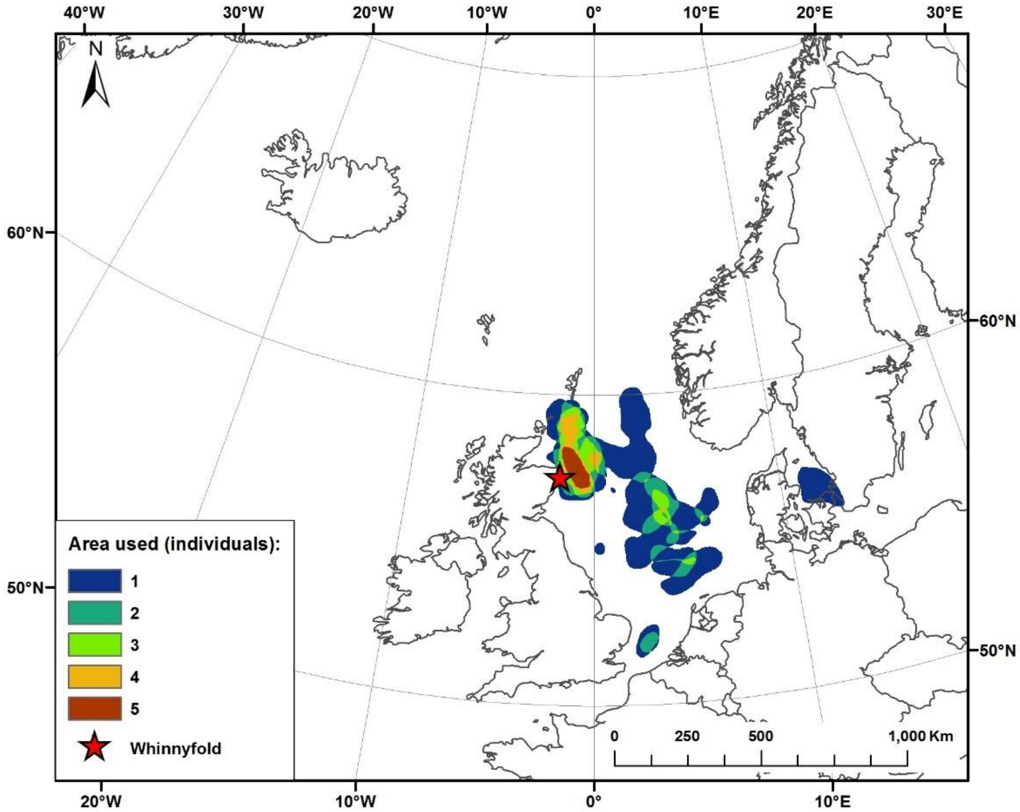
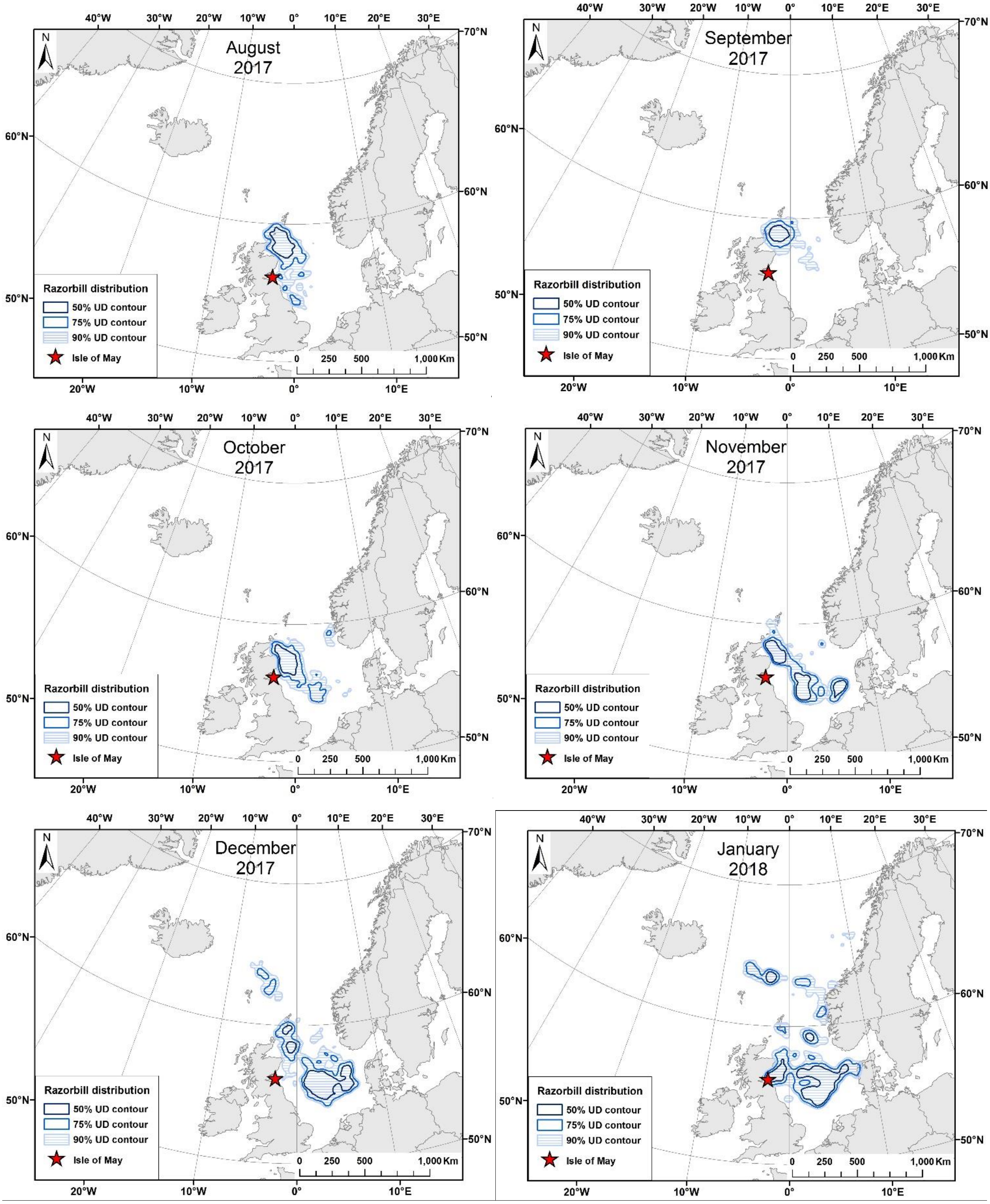


Fig. 11: Consistency in core areas (50% UD contours) of razorbills from Buchan Ness to Collieston Coast (n=5) in winter 2017-2018 (August – March).

After the breeding season, razorbills from the Isle of May stayed in the waters off north-east and east Scotland until November (Fig. 12a-c). In November and December core areas were located mainly in the central and northern North Sea (Fig. 12d,e). In January and February core areas were located around the colony, in the central North Sea and as far north as the Norwegian Sea (although the latter was driven by a single bird; Fig. 12f,g). In March, core areas were concentrated almost exclusively around the colony as the birds returned to breed (Fig. 12h).

Over the whole non-breeding period, razorbills from the Isle of May were distributed across the central and northern North Sea but key areas were located in the waters off east and north-east Scotland and in the Dogger Bank area (Fig. 12i). Consistency in individual core areas was highest around the Scottish coast, with 8-10 out of 11 birds overlapping (Fig. 13).


August
2017
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
September
2017
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
October
2017
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
November
2017
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
December
2017
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
January
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
N
40°W
30°W
20°W
10°W
0°
10°E
20°E
30°E
70°N
60°N
50°N
0
250
500
1,000 Km

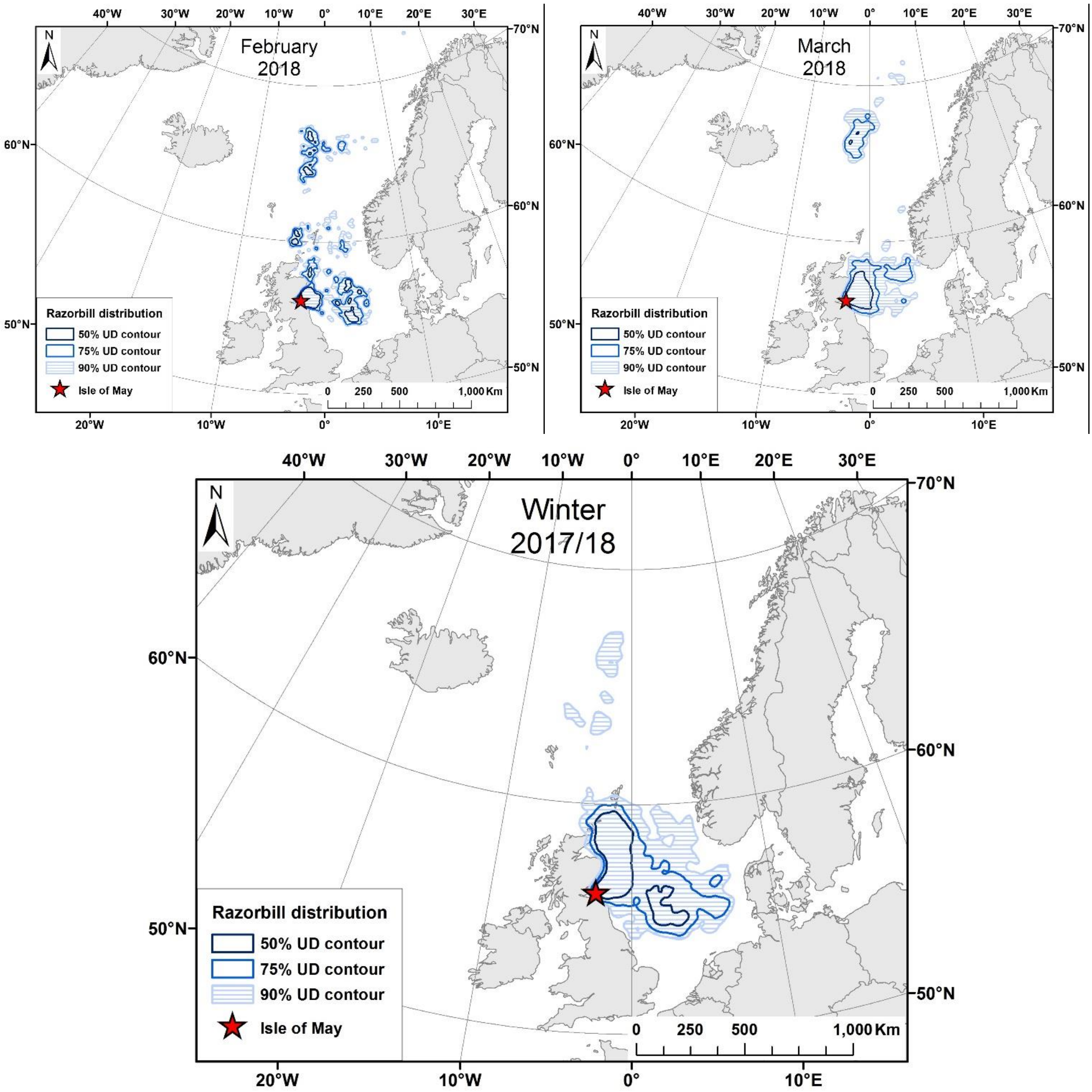


Fig. 12: Utilisation distributions (50%, 75%, 90% contours) for razorbills from Isle of May (n=11) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2017-2018 (August – March).

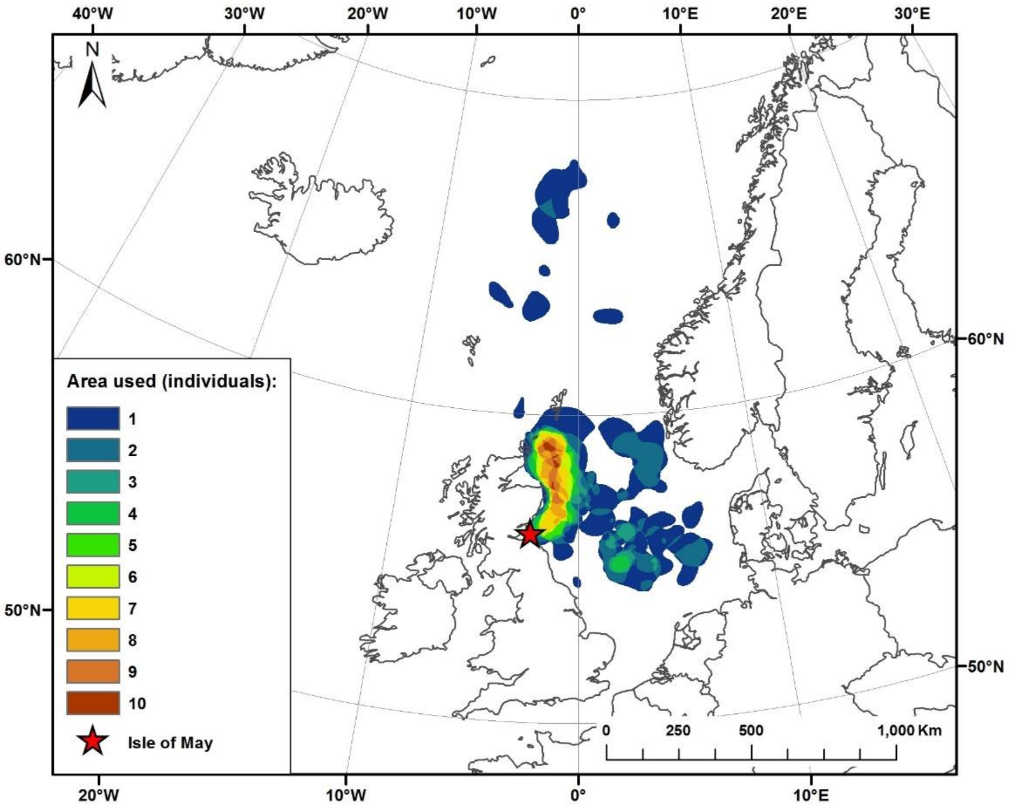


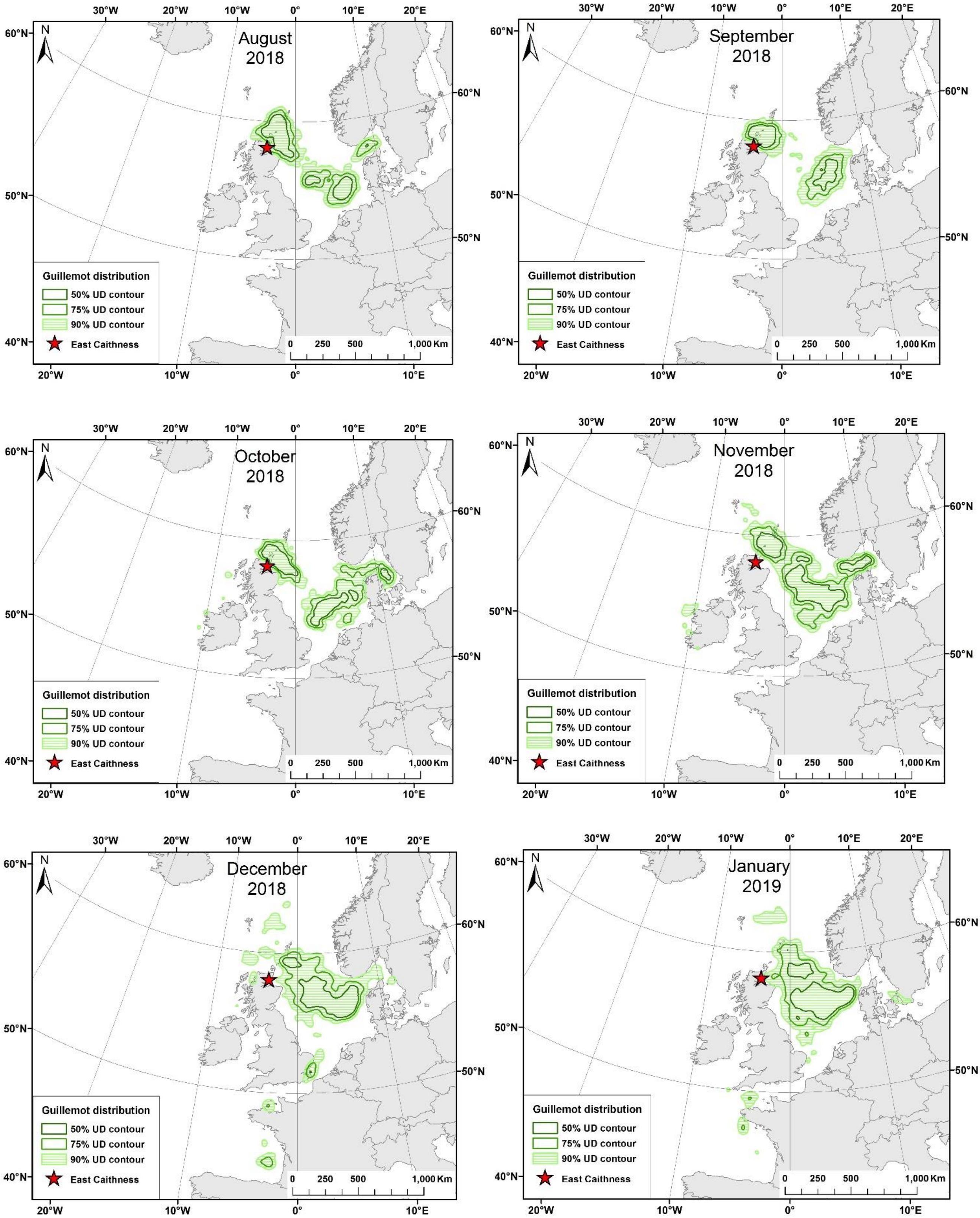
Fig. 13: Consistency in core areas (50% UD contours) of razorbills from Isle of May (n=11) in winter 2017-2018 (August – March).

3.1.1.2 2018-19

Maps of utilisation distributions of guillemots in the second study year are provided in Figures 14-19. Corresponding maps for razorbills are presented in Figures 20-25.

Both the monthly and overall winter distributions of guillemots from East Caithness in 2018-19 were similar to those observed in 2017-18 (Fig. 2 and 14). The only notable differences were the more extensive use of the Skagerrak/Kattegat area in the second year and the intriguing migration of a single bird past the west coast of Ireland to the Celtic Sea, English Channel and Bay of Biscay (Fig. 14).

As in 2017-18, consistency in individual core areas was highest near the colony, with up to 13 out of 25 birds overlapping (Fig. 15). For comparison, key areas in the central North Sea were used by 7-10 out of 25 birds (Fig. 15).


August 2018
September 2018
October 2018
November 2018
December 2018
January 2019
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
East Caithness
0 250 500 1,000 Km
30°W 20°W 10°W 0° 10°E 20°E
60°N 50°N 40°N
20°W 10°W 0° 10°E

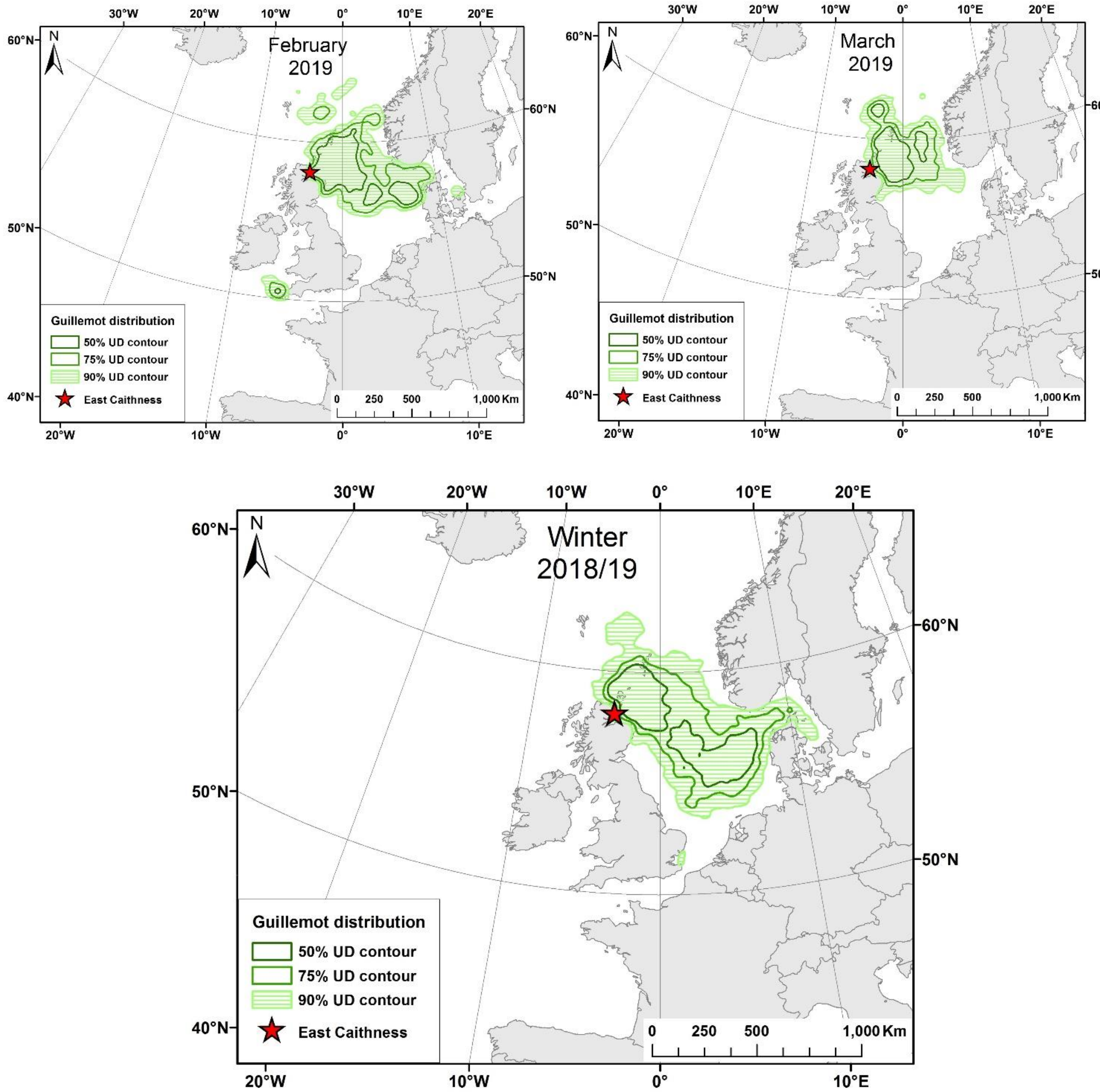


Fig. 14: Utilisation distributions (50%, 75%, 90% contours) for guillemots from East Caithness (n=25) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2018-2019 (August – March).

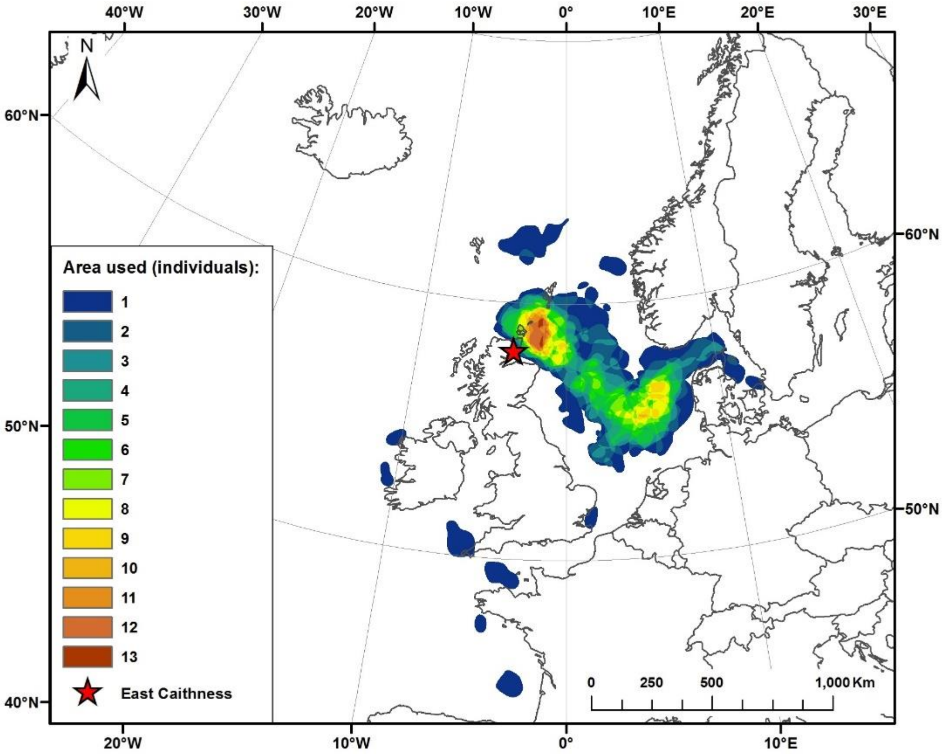
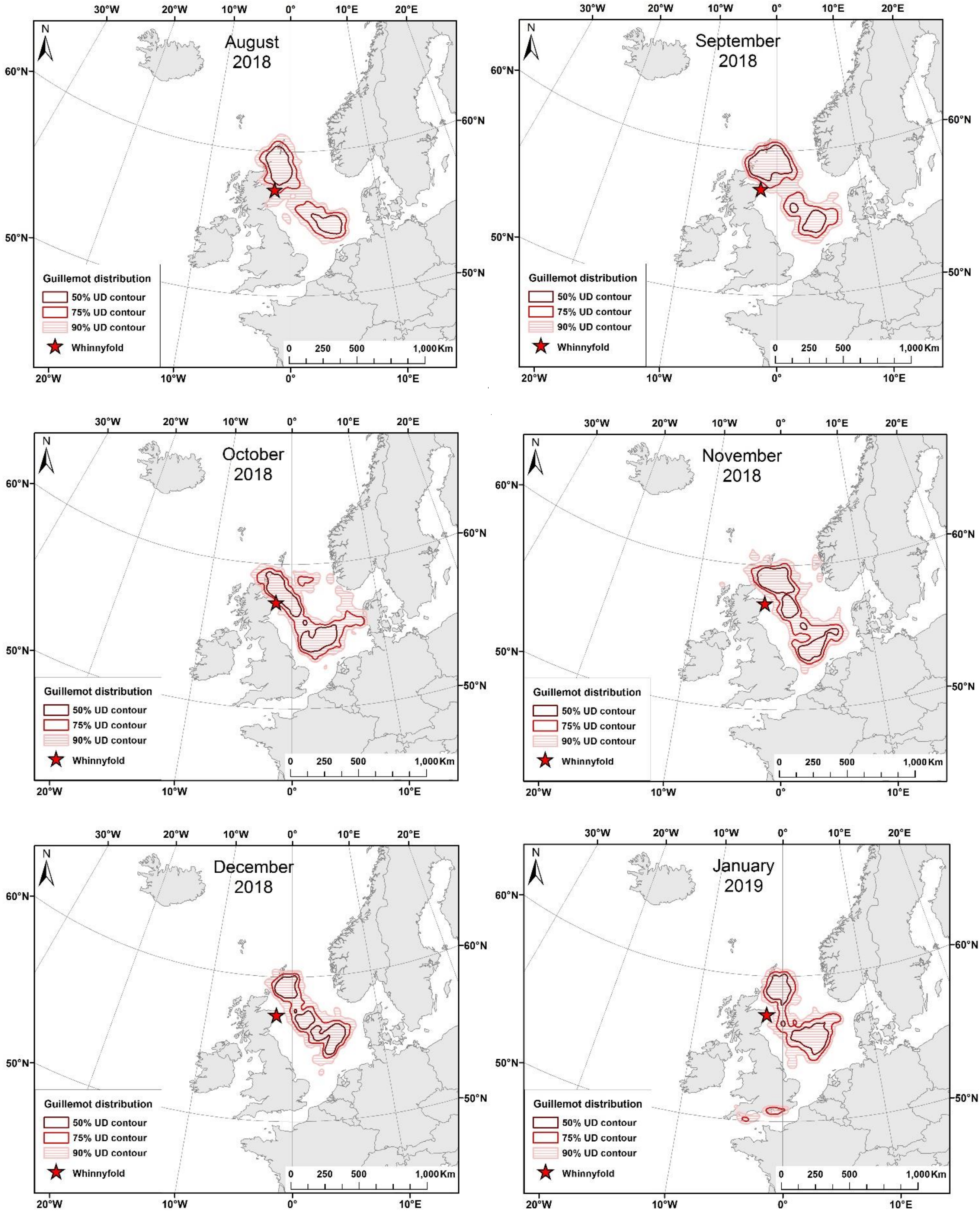


Fig. 15: Consistency in core areas (50% UD contours) of guillemots from East Caithness (n=25) in winter 2018-2019 (August – March).

As in East Caithness guillemots, both the monthly and overall winter distributions of guillemots from Buchan Ness to Collieston Coast in 2018-19 were similar to those in 2017-18 (Fig. 4 and 16). The only exception was the lack of movements towards the Norwegian Sea in February and March, resulting in a more restricted distribution in these months (Fig. 16).

As in 2017-18, consistency in individual core areas was highest near the colony, with up to 18 out of 26 birds overlapping (Fig. 17). However, the area of highest overlap was more restricted than in 2017-18. For comparison, areas in the central North Sea were used by 7-10 out of 26 birds (Fig. 17).


August
2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
September
2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
October
2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
November
2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
December
2018
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
January
2019
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
30°W
20°W
10°W
0°
10°E
20°E
60°N
50°N

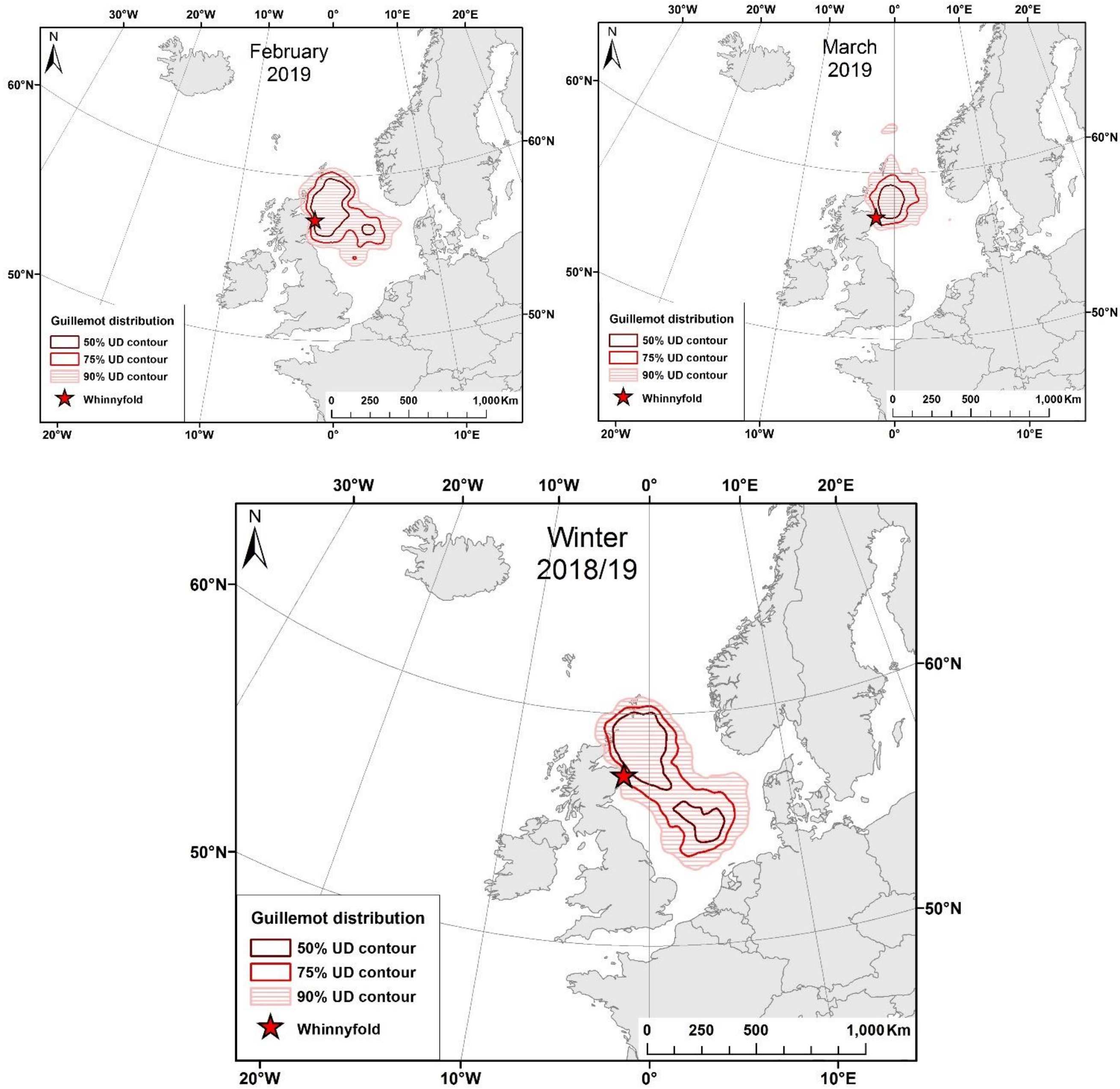


Fig. 16: Utilisation distributions (50%, 75%, 90% contours) for guillemots from Buchan Ness to Collieston Coast (n=26) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2018-2019 (August – March).

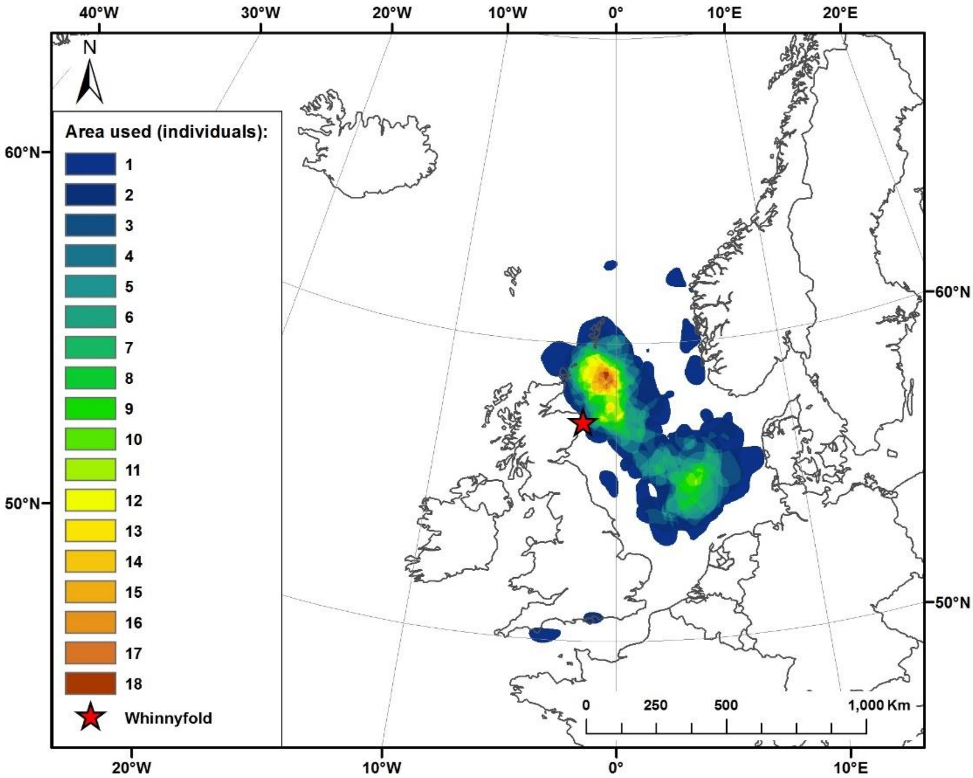
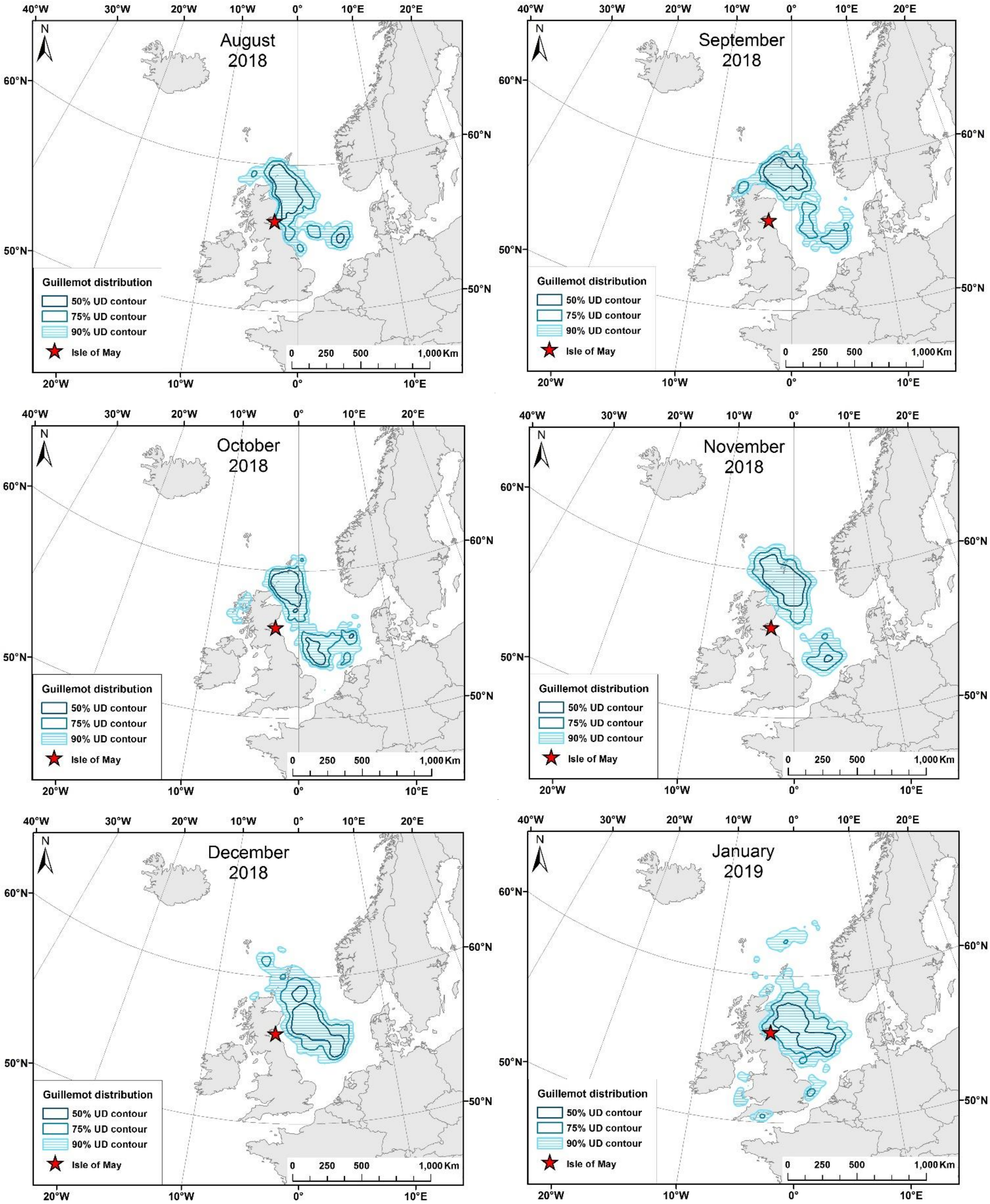


Fig. 17: Consistency in core areas (50% UD contours) of guillemots from Buchan Ness to Collieston Coast (n=26) in winter 2018-2019 (August – March).

As in the other colonies, the monthly and overall winter distributions of guillemots from Isle of May in 2018-19 were similar to those observed in 2017-18 (Fig. 6 and 18). The only notable differences were the absence of movements to the Skagerrak/Kattegat area in the second year and the less extensive use of the Norwegian Sea in February and March, resulting in a more restricted distribution in these months (Fig. 18).

As in 2017-18, consistency in individual core areas was highest in the waters off north-east Scotland, with up to 15 out of 22 birds overlapping (Fig. 19).


August 2018
September 2018
October 2018
November 2018
December 2018
January 2019
Guillemot distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
40°W 30°W 20°W 10°W 0° 10°E 20°E
60°N 50°N
20°W 10°W 0° 10°E

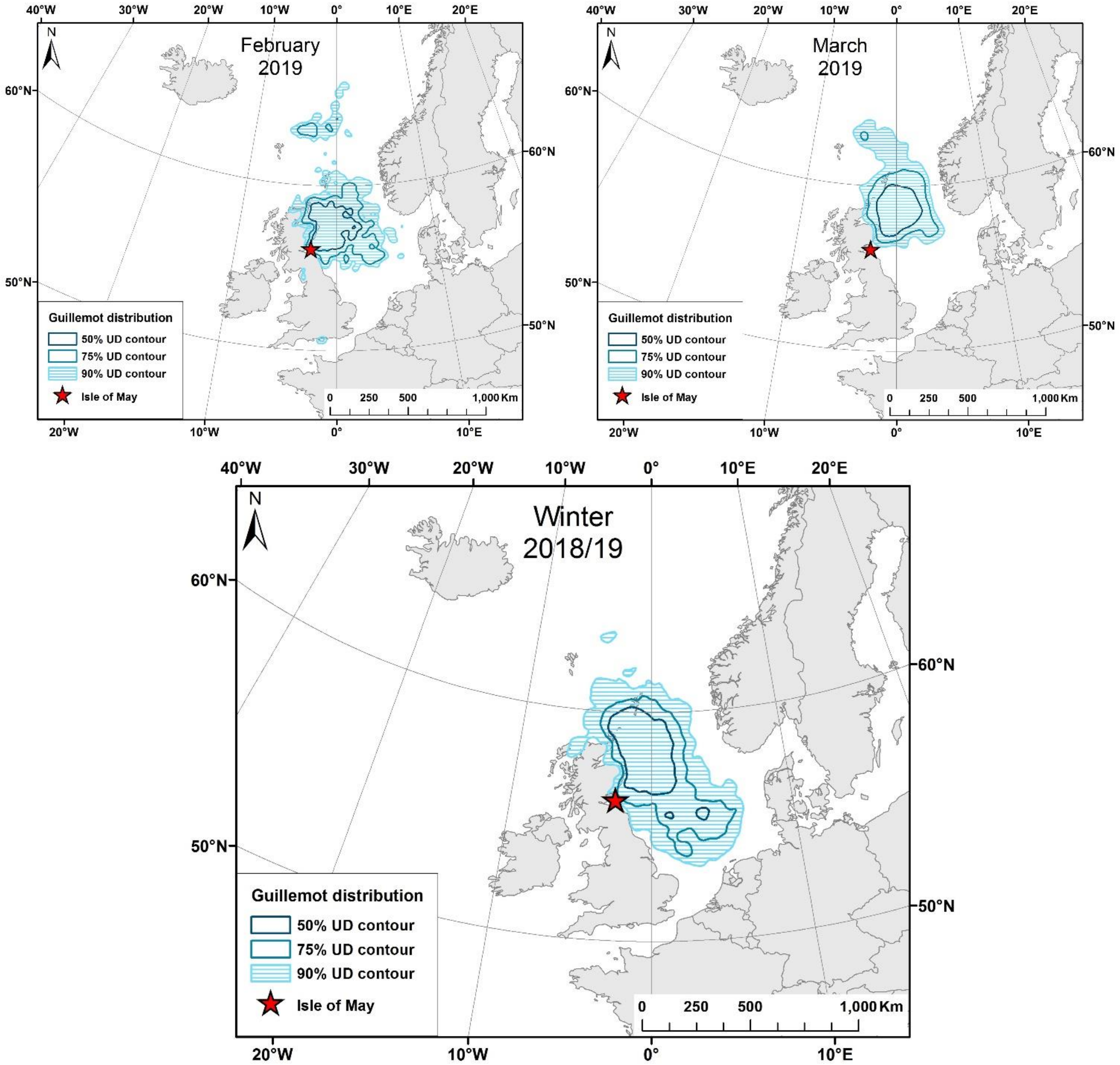


Fig. 18: Utilisation distributions (50%, 75%, 90% contours) for guillemots from Isle of May (n=22) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2018-2019 (August – March).

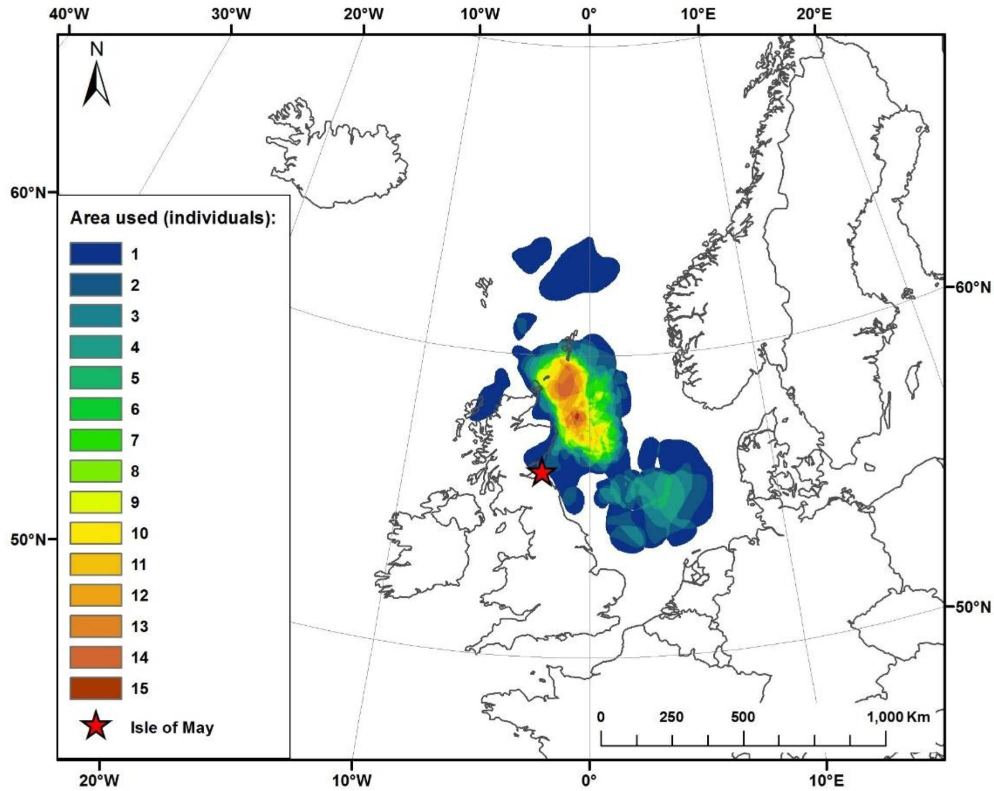
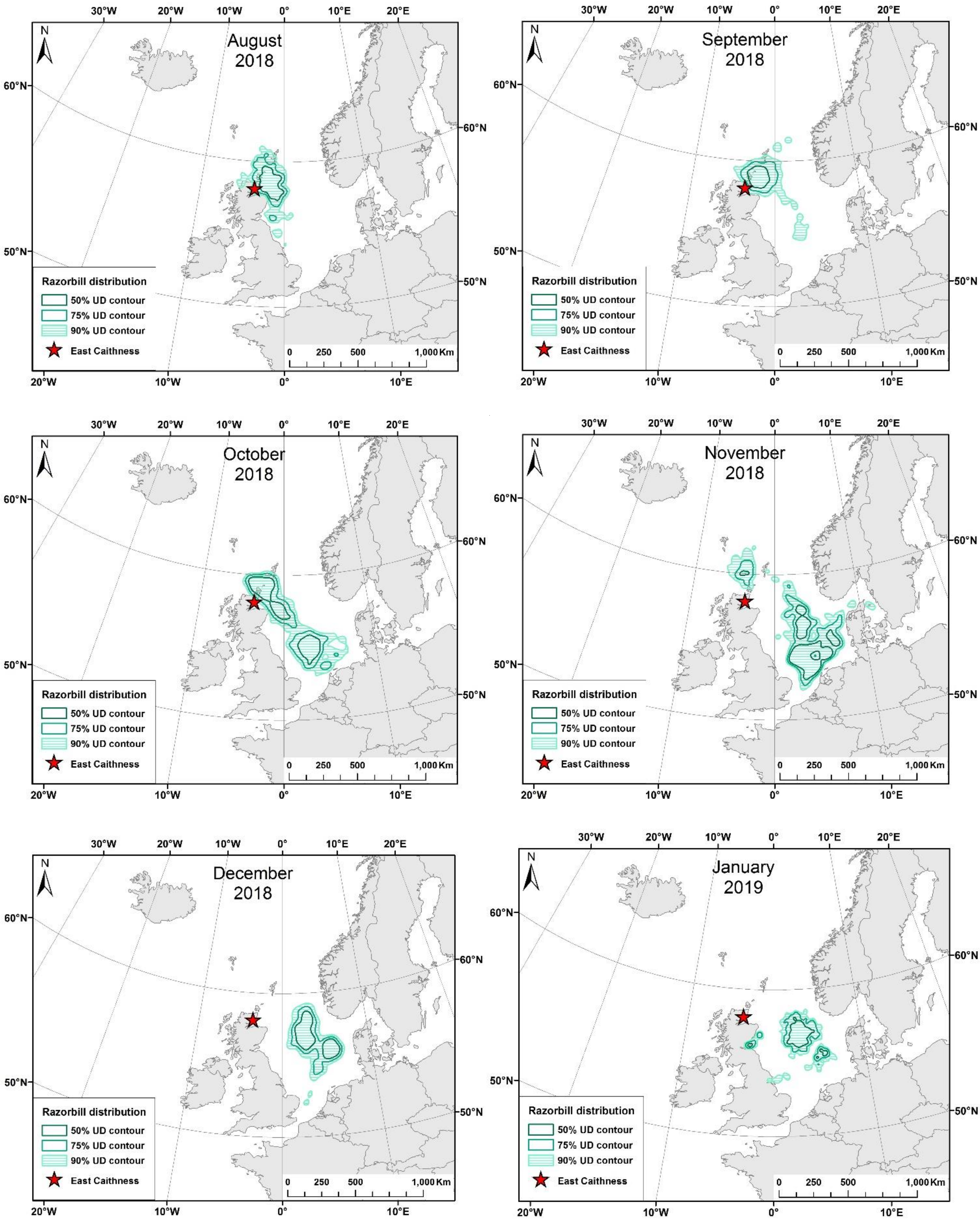


Fig. 19: Consistency in core areas (50% UD contours) of guillemots from Isle of May (n=22) in winter 2018-2019 (August – March).

The monthly and overall winter distributions of razorbills from East Caithness in 2018-19 were generally consistent with those observed in 2017-18 (Fig. 8 and 20). The distribution particularly in January to March was more restricted compared to the first year (Fig. 20), however this may be a consequence of the smaller sample size of birds in the second year.

Highest consistency in individual core areas was observed near the colony, with 5-7 out of 7 birds overlapping (Fig. 21). Consistency was less pronounced in the central parts of the North Sea (Fig. 21).


August
2018
September
2018
October
2018
November
2018
December
2018
January
2019
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
East Caithness
0 250 500 1,000 Km
30°W 20°W 10°W 0° 10°E 20°E
60°N 50°N

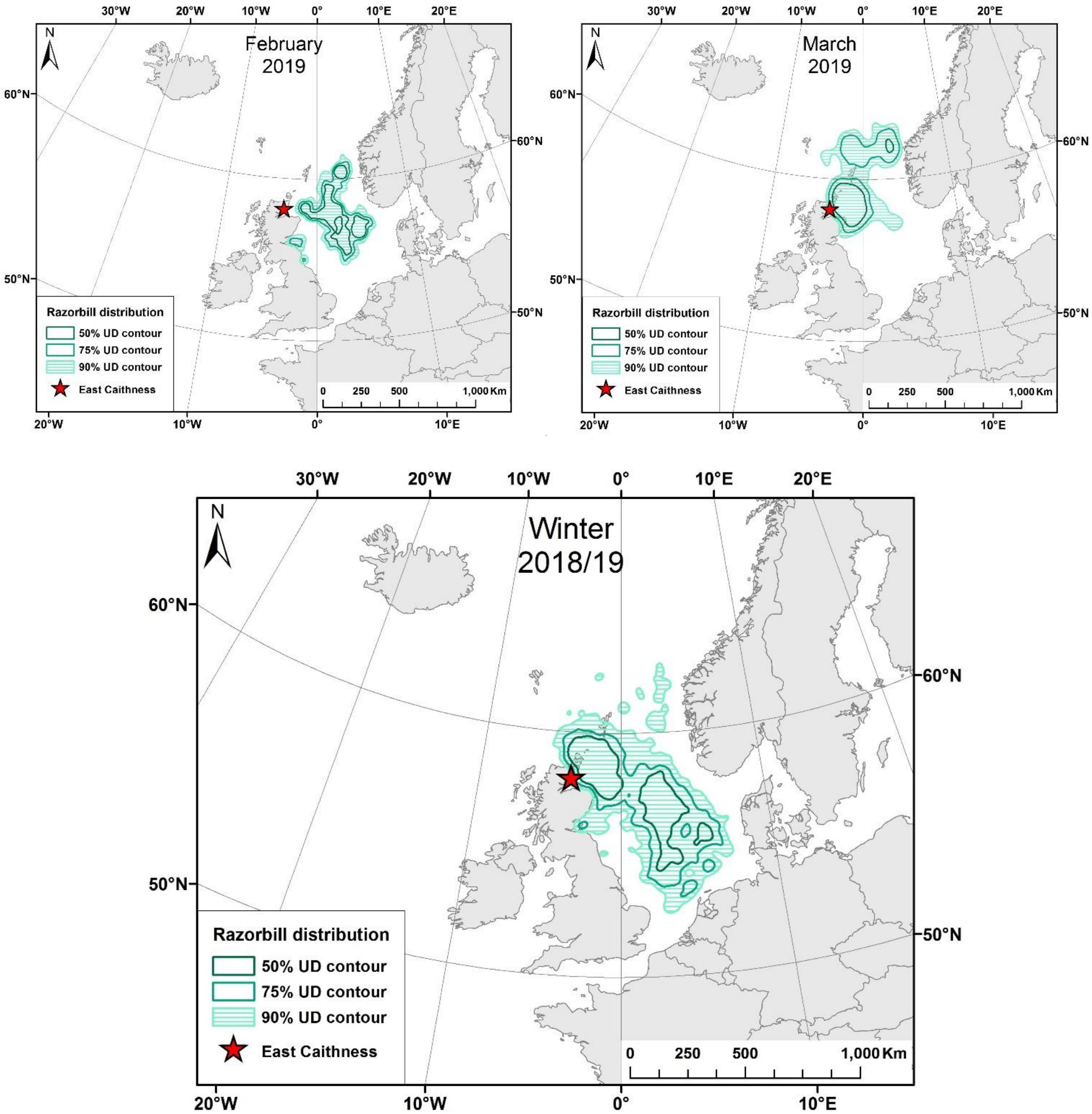


Fig. 20: Utilisation distributions (50%, 75%, 90% contours) for razorbills from East Caithness (n=7) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2018-2019 (August – March).

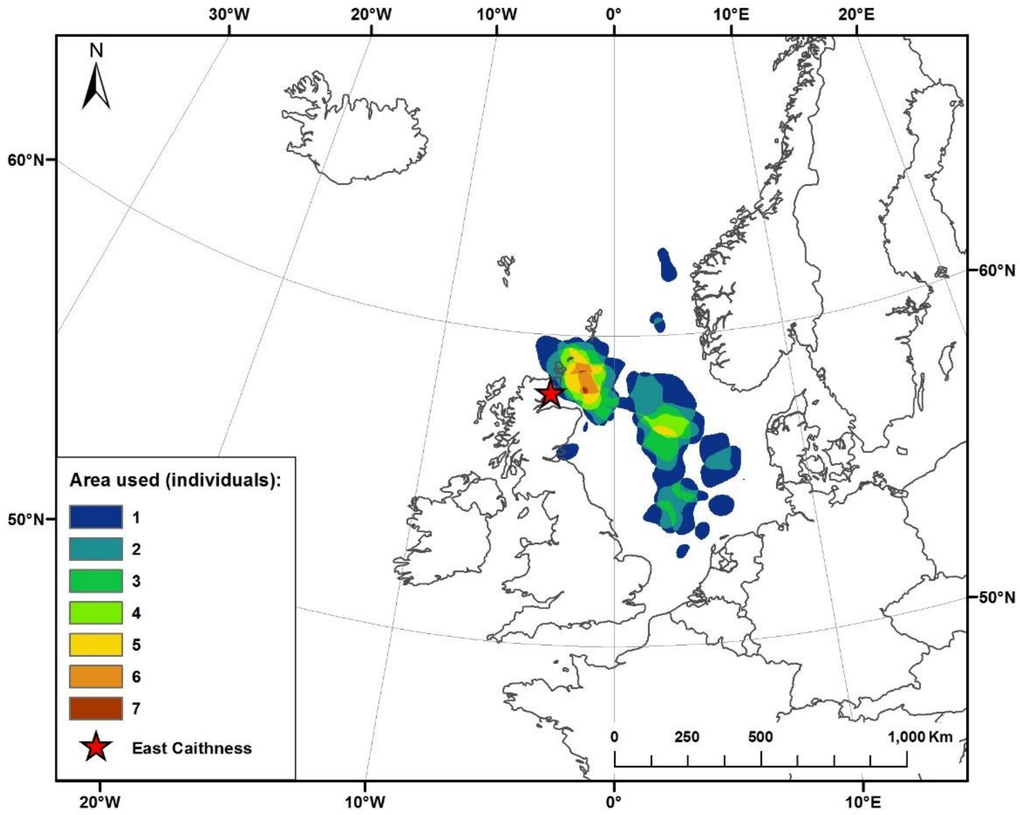
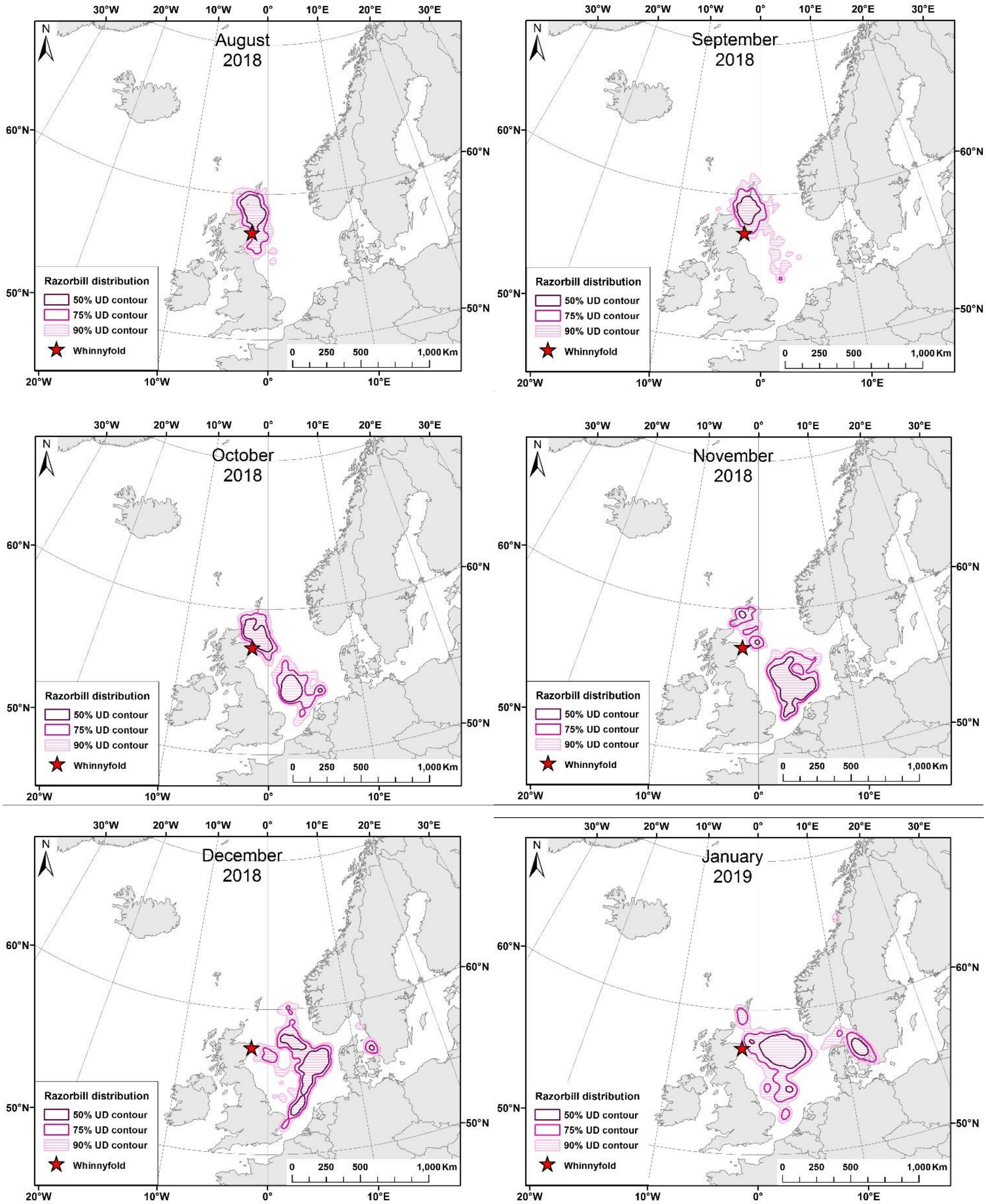


Fig. 21: Consistency in core areas (50% UD contours) of razorbills from East Caithness (n=7) in winter 2018-2019 (August – March).

The sample size of razorbills tracked at Buchan Ness to Collieston Coast in 2018-19 was slightly higher than in 2017-18 but remains relatively small and the results should therefore be treated with caution. Comparisons of the two years showed that the monthly and overall winter distributions were generally consistent (Fig. 10 and 22). Interestingly, a single individual undertook a movement along the coast of Norway, however there is no evidence it reached the Barents Sea as an Isle of May guillemot has previously done.

As in 2017-18, consistency in individual core areas was highest near the colony, with all 7 birds overlapping (Fig. 23).


August 2018
September 2018
October 2018
November 2018
December 2018
January 2019
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Whinnyfold
0 250 500 1,000 Km
N
30°W
20°W
10°W
0°
10°E
20°E
30°E
60°N
50°N

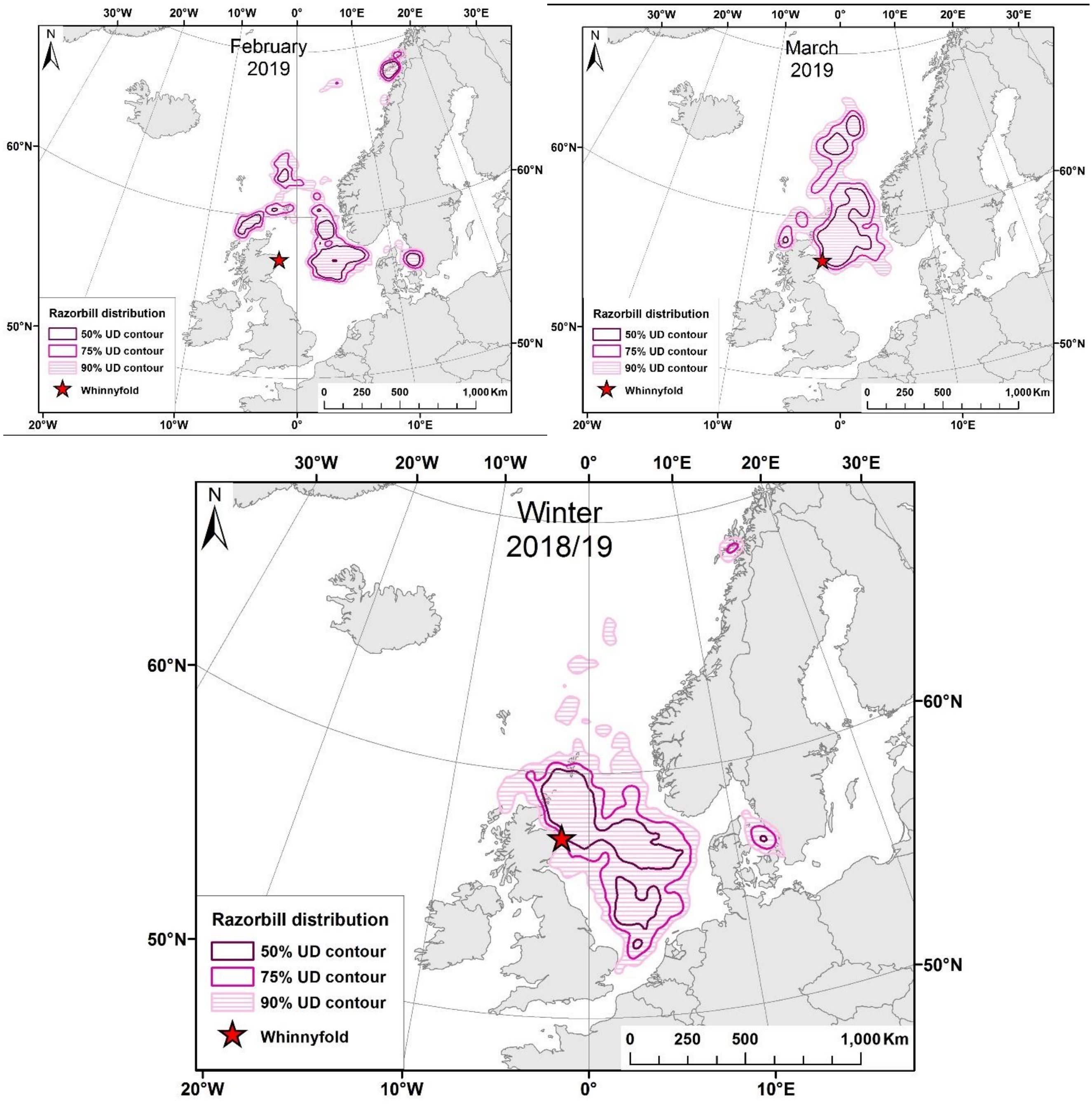


Fig. 22: Utilisation distributions (50%, 75%, 90% contours) for razorbills from Buchan Ness to Collieston Coast (n=8) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2018-2019 (August – March).

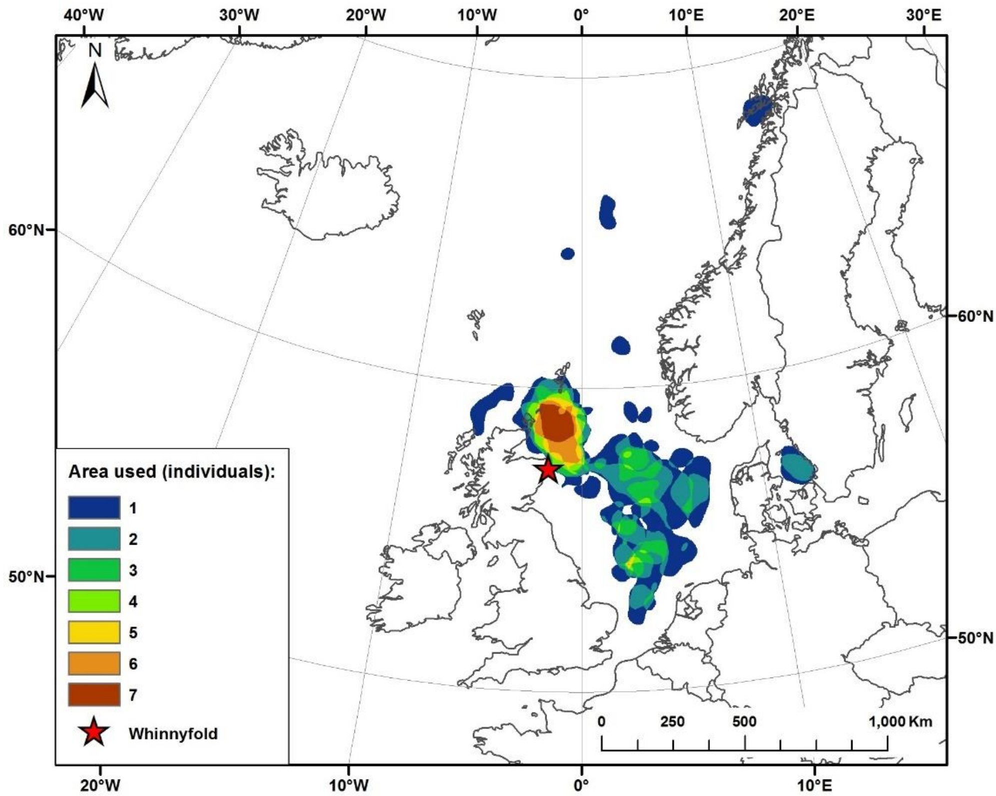
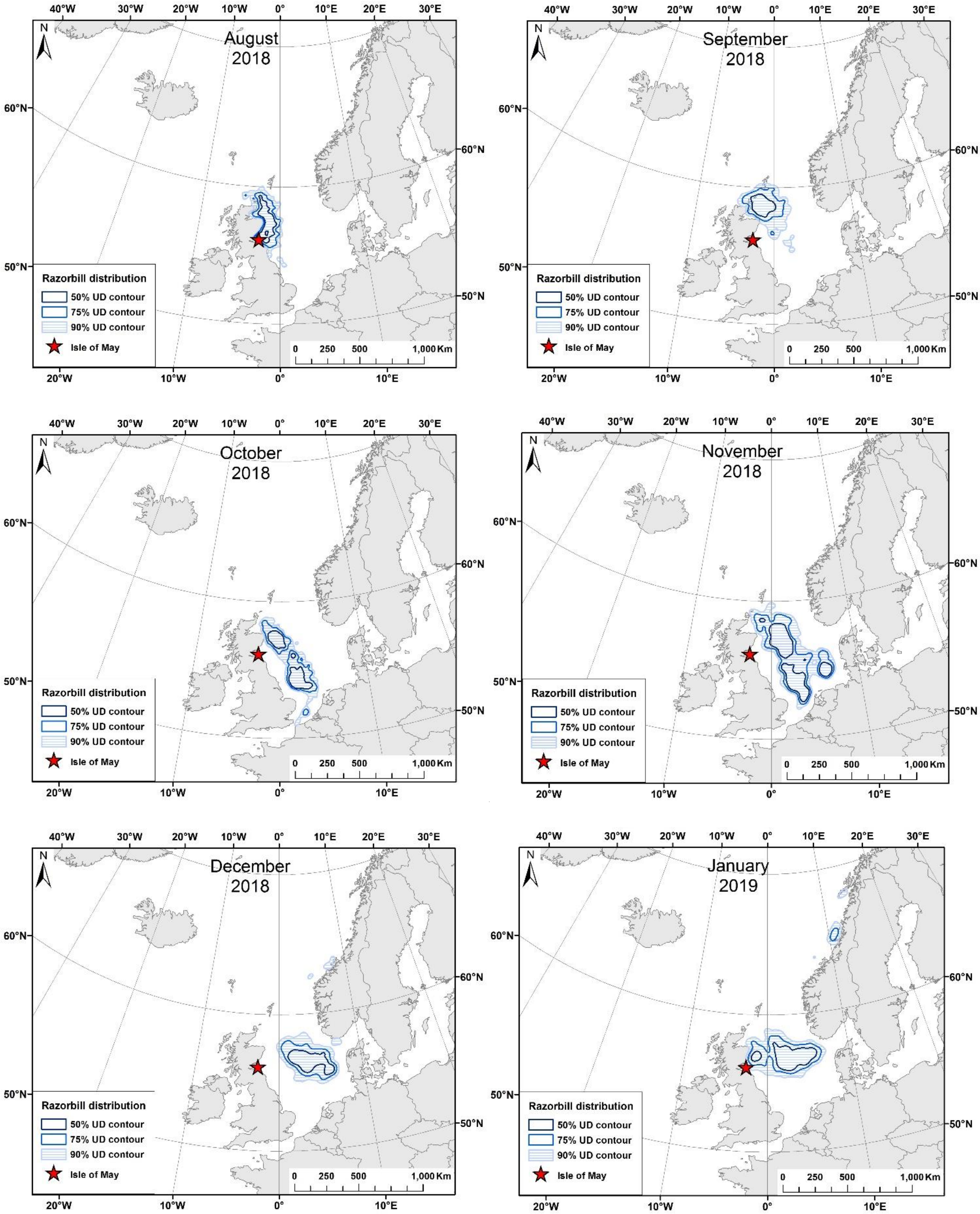


Fig. 23: Consistency in core areas (50% UD contours) of razorbills from Buchan Ness to Collieston Coast (n=8) in winter 2018-2019 (August – March).

The monthly and overall winter distributions of razorbills from Isle of May in 2018-19 were generally consistent with those observed in 2017-18 (Fig. 12 and 24). Similar to the case at Buchan Ness to Collieston Coast, a single bird undertook a movement along the coast of Norway.

Highest consistency in individual core areas was observed in the waters off the east/north-east coast of Scotland, with up to all 11 birds overlapping (Fig. 25). Consistency was less pronounced in the central parts of the North Sea (Fig. 25).


August
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
September
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
October
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
November
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
December
2018
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km
January
2019
Razorbill distribution
50% UD contour
75% UD contour
90% UD contour
Isle of May
0 250 500 1,000 Km

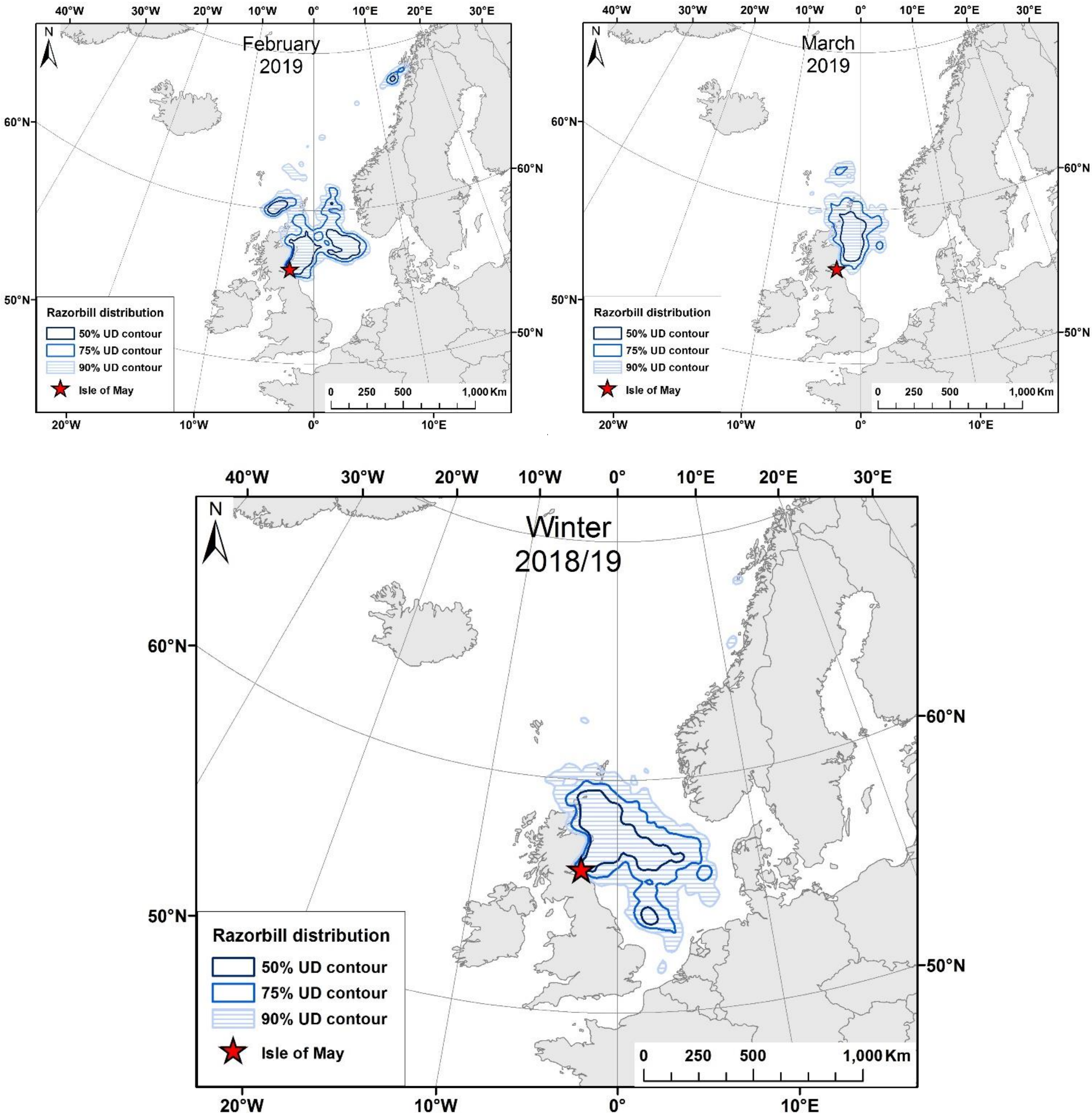


Fig. 24: Utilisation distributions (50%, 75%, 90% contours) for razorbills from Isle of May (n=11) in a) August, b) September, c) October, d) November, e) December, f) January, g) February, h) March and i) winter 2018-2019 (August – March).

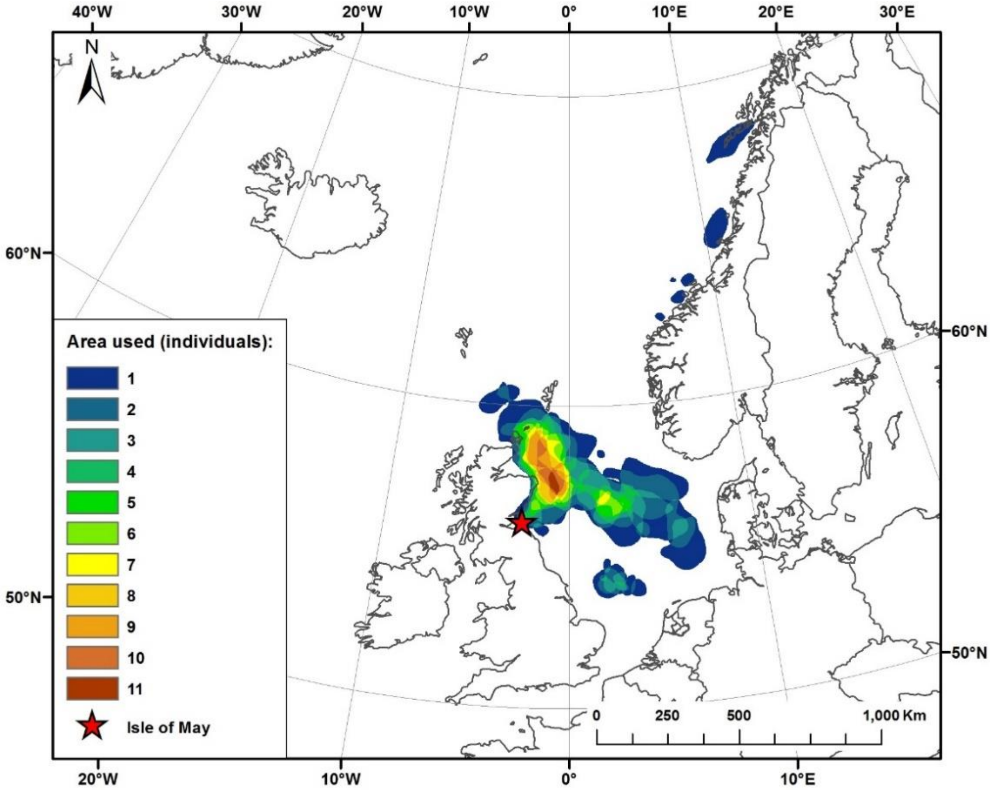


Fig. 25: Consistency in core areas (50% UD contours) of razorbills from Isle of May (n=11) in winter 2018-2019 (August – March).

3.1.2 Overlap in colony utilisation distributions

In both years, over the whole non-breeding period, spatial similarity in the UDs of guillemots from the three study colonies was very high (Table 3).

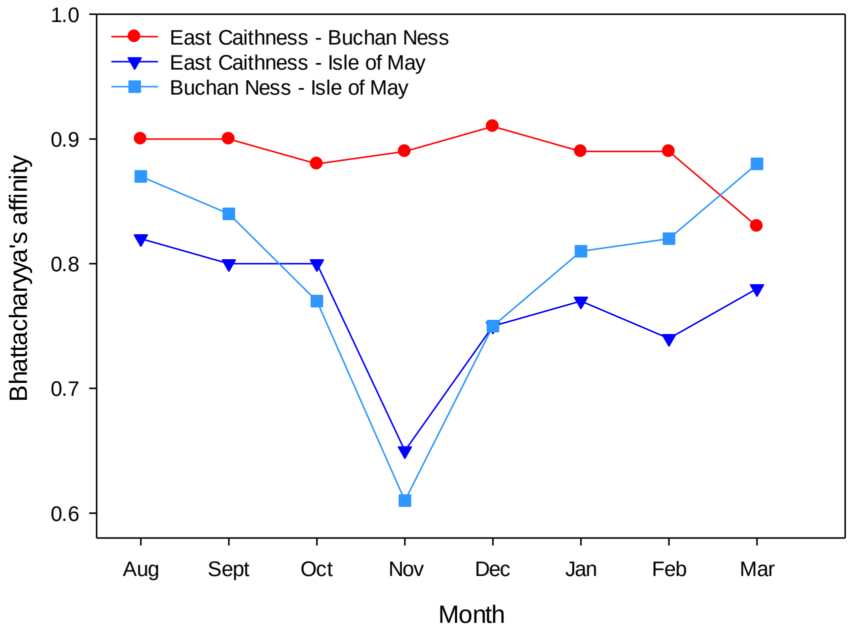
Colony	East Caithness	Buchan Ness to Collieston Coast	Isle of May
a) 2017-18			
East Caithness		0.95	0.86
Buchan Ness	0.95		0.89
Isle of May	0.86	0.89	
b) 2018-19			
East Caithness		0.91	0.88
Buchan Ness	0.91		0.95
Isle of May	0.88	0.95	

Table 3. Whole winter pairwise spatial similarity of UDs of guillemots from the three study colonies in: a) 2017-18; b) 2018-19. Similarity was estimated using Bhattacharyya's affinity measure, ranging from zero (no similarity) to 1 (identical densities).

In 2017-18, pairwise comparisons indicated a moderate to high monthly spatial similarity in UDs of guillemots from the three colonies (Fig. 26a). Throughout the non-breeding period, similarity between East Caithness and Buchan Ness to Collieston Coast was consistently high whereas similarity between these two colonies and the Isle of May was generally lower, particularly in November (Fig. 26a).

In 2018-19, monthly spatial similarity in UDs was high among birds from all three colonies, although slightly lower between East Caithness and Isle of May compared to the other two pairs of colonies (Fig. 26b).

a)



b)

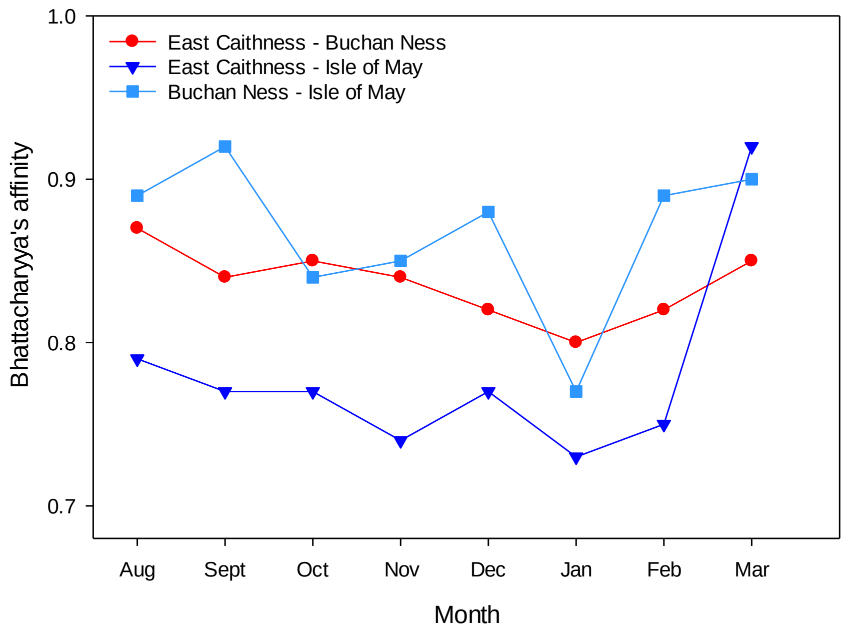


Fig. 26: Monthly pairwise spatial similarity of UDs of guillemots from the three study colonies in: a) 2017-18; b) 2018-19. Similarity was estimated using Bhattacharyya's affinity measure, ranging from zero (no similarity) to 1 (identical densities).

Similar to guillemots, whole winter spatial similarity in the UDs of razorbills between the three study colonies was very high in both years (Table 4).

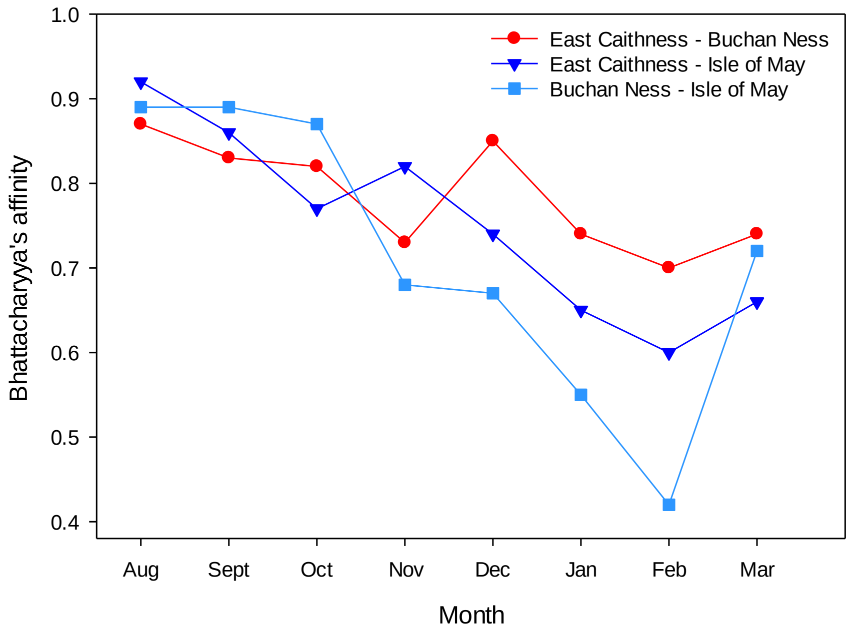
Colony	East Caithness	Buchan Ness to Collieston Coast	Isle of May
a) 2017-18			
East Caithness		0.89	0.87
Buchan Ness	0.89		0.85
Isle of May	0.87	0.85	
b) 2018-19			
East Caithness		0.92	0.92
Buchan Ness	0.92		0.89
Isle of May	0.92	0.89	

Table 4. Whole winter pairwise spatial similarity of UDs of razorbills from the three study colonies in: a) 2017-18; b) 2018-19. Similarity was estimated using Bhattacharyya's affinity measure, ranging from zero (no similarity) to 1 (identical densities).

In 2017-18, monthly spatial similarity in UDs of razorbills from the three colonies was very high in the post-breeding period, then gradually decreased and was lowest in late winter (Fig. 27a). Similarity between East Caithness and Buchan Ness to Collieston Coast was generally highest (Fig. 27a).

In 2018-19, a similar pattern was apparent, with highest similarity in the post-breeding period and lowest in late winter (Fig. 27b).

a)



b)

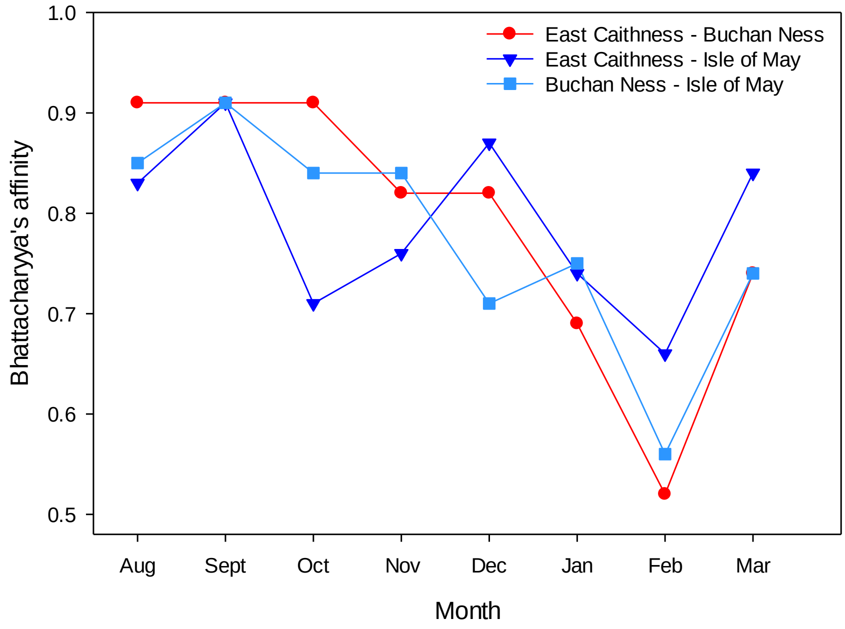


Fig. 27: Monthly pairwise spatial similarity of UDs of razorbills from the three study colonies in: a) 2017-18; b) 2018-19. Similarity was estimated using Bhattacharyya's affinity measure, ranging from zero (no similarity) to 1 (identical densities).

3.1.3 Minimum adequate sample size of tracked birds

3.1.3.1 2017-2018

In guillemots from East Caithness, the resampling procedure using 50% UD contours indicated a gradual increase in the size of core areas used with increasing sample size of birds (Fig. 28a). The increment in cumulative area size was largest with sample size of up to around 6 birds, after which it was less than 5% with each additional bird (Fig. 28b). Randomized samples of 5 and 10 birds covered 57% and 79% of the area identified using all study birds, respectively (Fig. 28b).

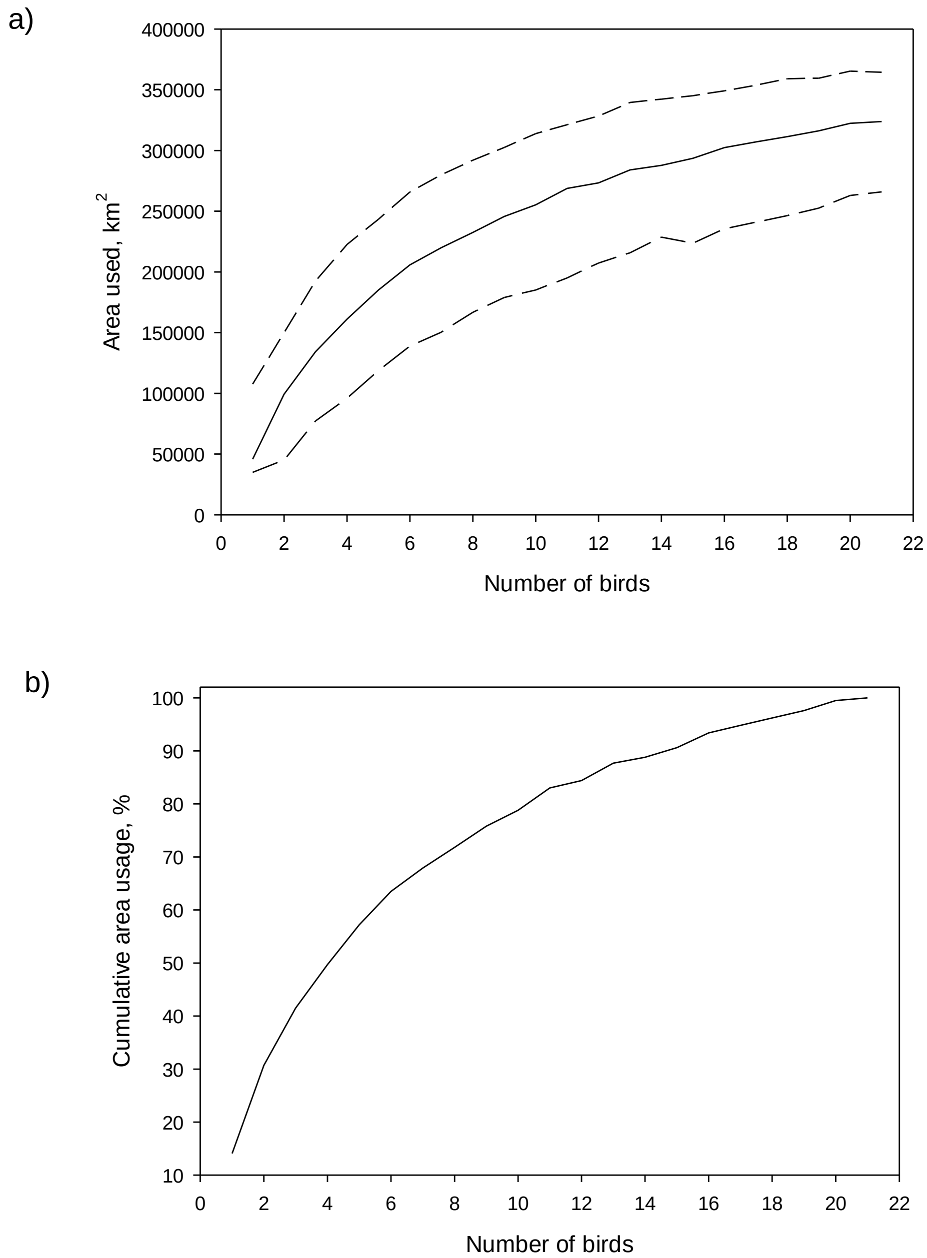
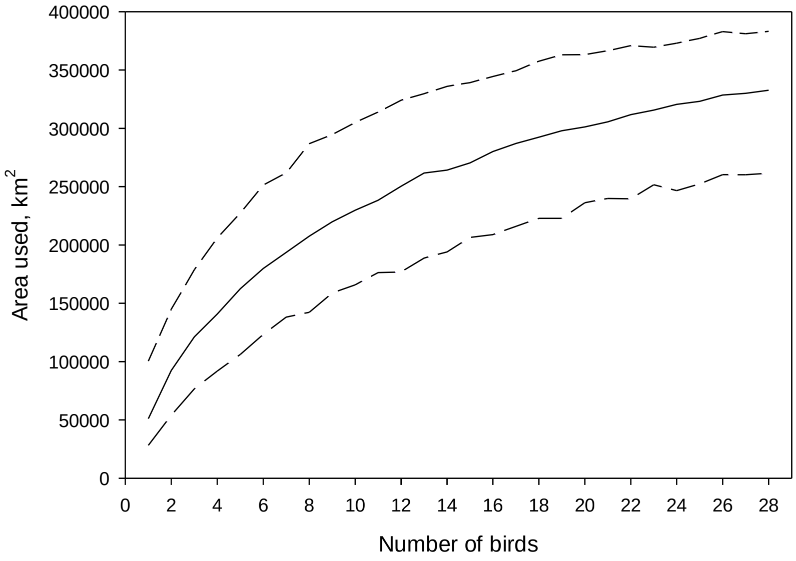


Fig. 28: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in guillemots from East Caithness in 2017-18. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

In guillemots from Buchan Ness to Collieston Coast, a gradual non-linear increase in the size of core areas with increasing sample size of birds was apparent (Fig. 29a). The increment in cumulative area size was largest with sample size of up to 6 birds, after which it was less than 5% with each additional bird; for sample sizes over 14 birds the increment was less than 3% (Fig. 29b). Randomized samples of 5 and 10 birds covered 49% and 69% of the area identified using all study birds, respectively (Fig. 29b).

a)



b)

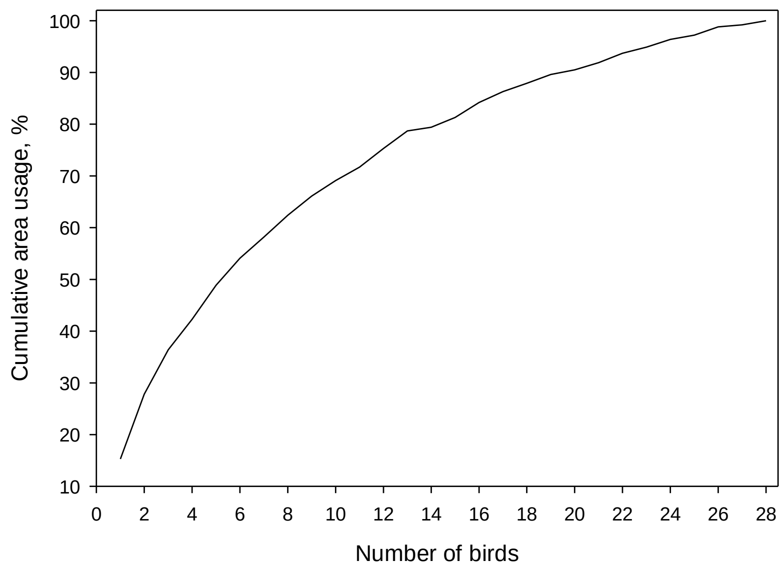
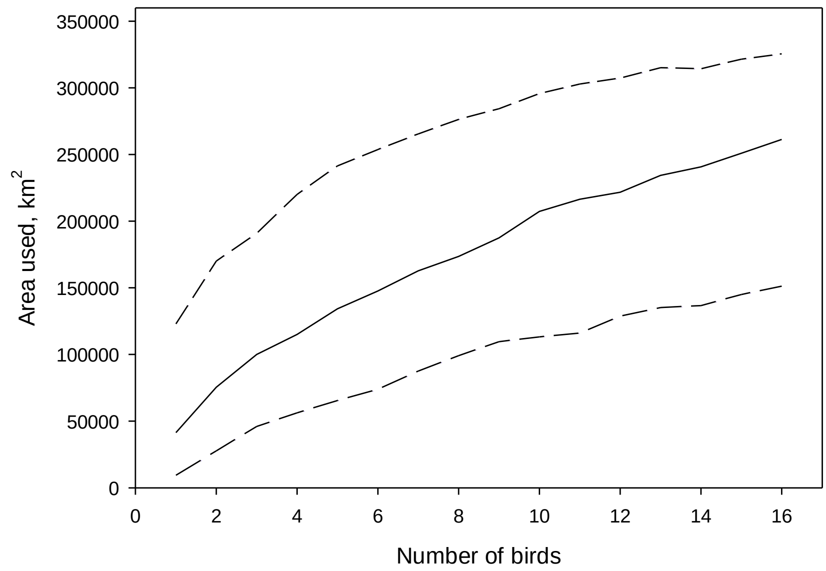


Fig. 29: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in guillemots from Buchan Ness to Collieston Coast in 2017-18. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

In guillemots from the Isle of May, the size of core areas gradually increased with increasing sample size of birds (Fig. 30a). The cumulative curve did not appear to level off, suggesting the minimum adequate sample size was not reached at this colony (Fig. 30b). Randomized samples of 5 and 10 birds covered 51% and 79% of the area identified using all study birds, respectively (Fig. 30b).

a)



b)

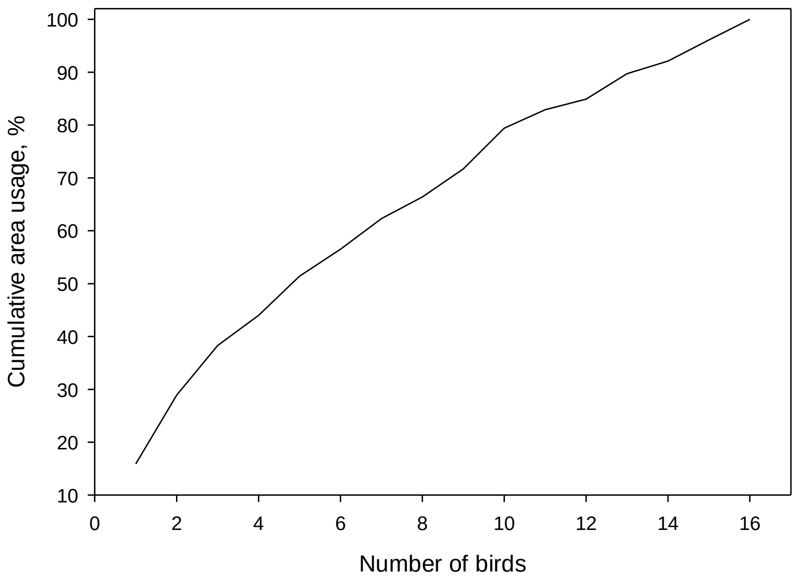
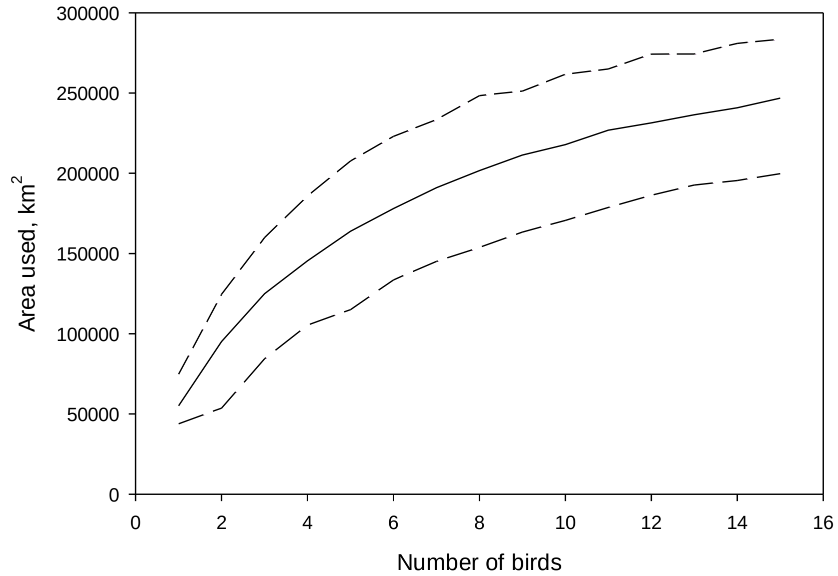


Fig. 30: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in guillemots from Isle of May in 2017-18. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

In razorbills from East Caithness, as with guillemots, the size of core areas increased gradually with increasing sample size of birds (Fig. 31a). The increment in cumulative area size was larger with sample size up to 7 birds, after which it was less than 5% with each additional bird (Fig. 31b). Randomized samples of 5 and 10 birds covered 66% and 88% of the area identified using all study birds, respectively (Fig. 31b).

a)



b)

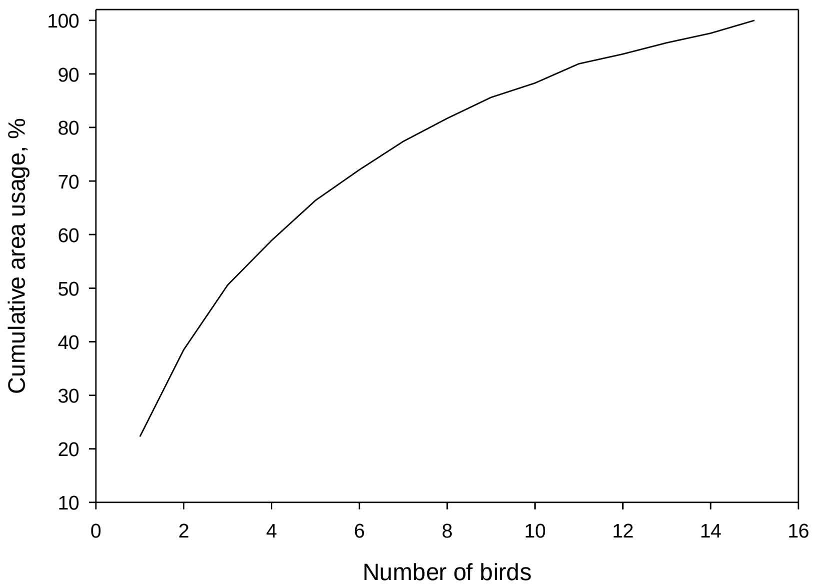
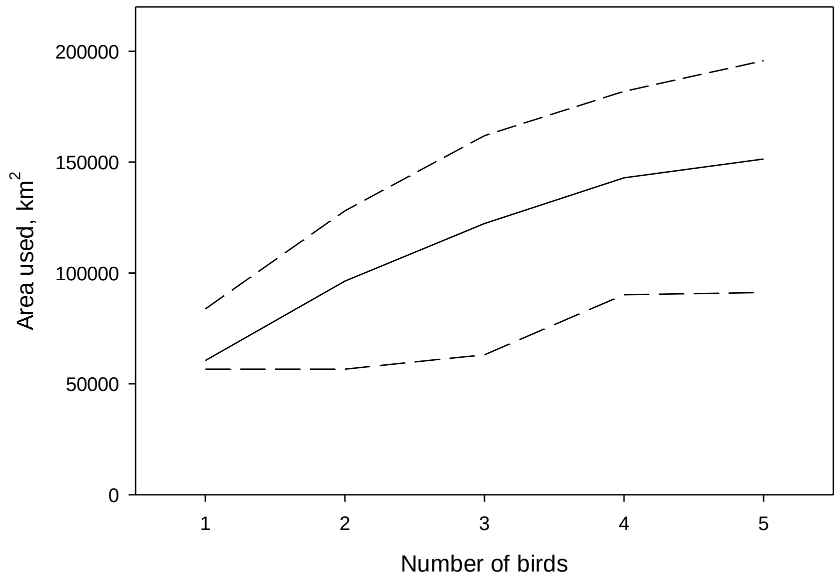


Fig. 31: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in razorbills from East Caithness in 2017-18. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

At Buchan Ness to Collieston Coast only a total of 5 loggers were retrieved from razorbills. A gradual increase in the size of core areas with increasing number of birds was observed as in the other colonies and species (Fig. 32a) but unsurprisingly the cumulative curve did not level off due to the small sample size (Fig. 32b).

a)



b)

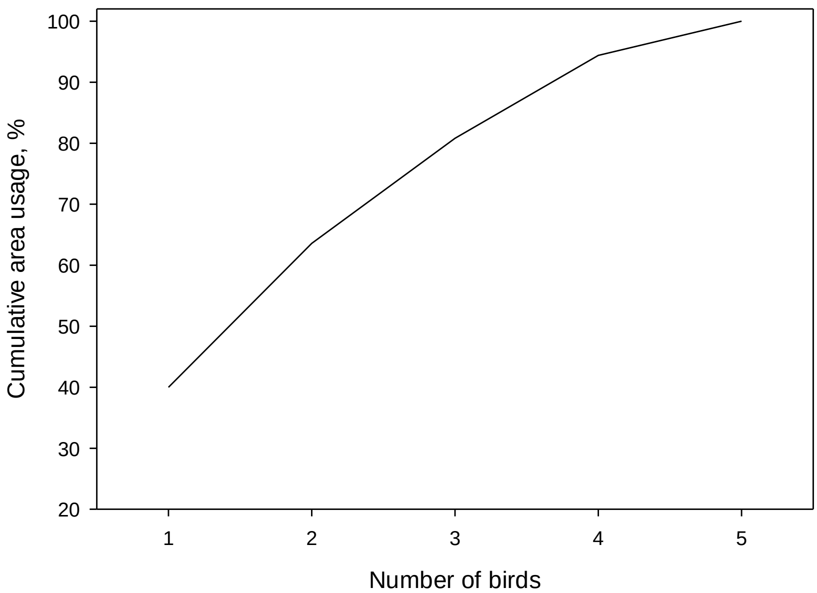
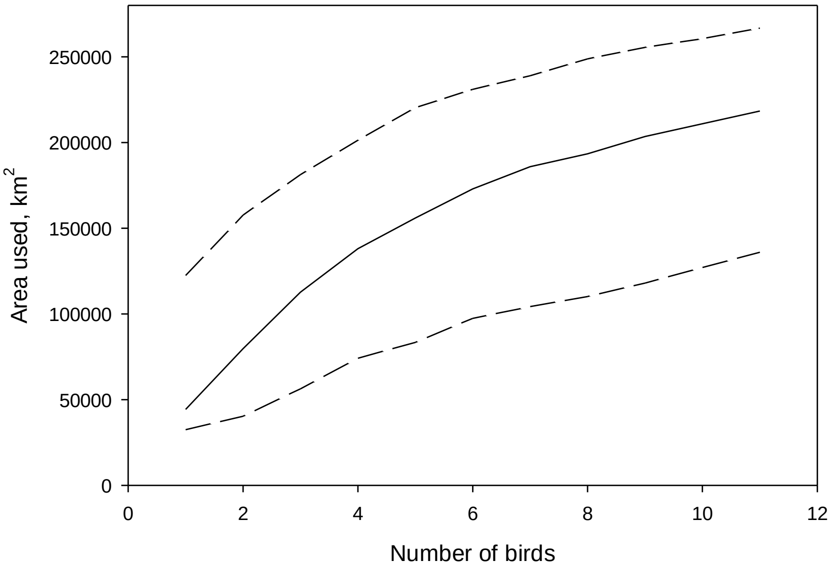


Fig. 32: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in razorbills from Buchan Ness to Collieston Coast in 2017-18. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

The increase in size of core areas with increasing sample size of birds in Isle of May razorbills is shown on Fig. 33a. The increment in cumulative area size was larger with sample size up to around 7 birds, after which it declined to less than 5% with each additional bird (Fig. 33b). Randomized sample of 5 birds covered 71% of the area identified using all study birds (Fig. 33b).

a)



b)

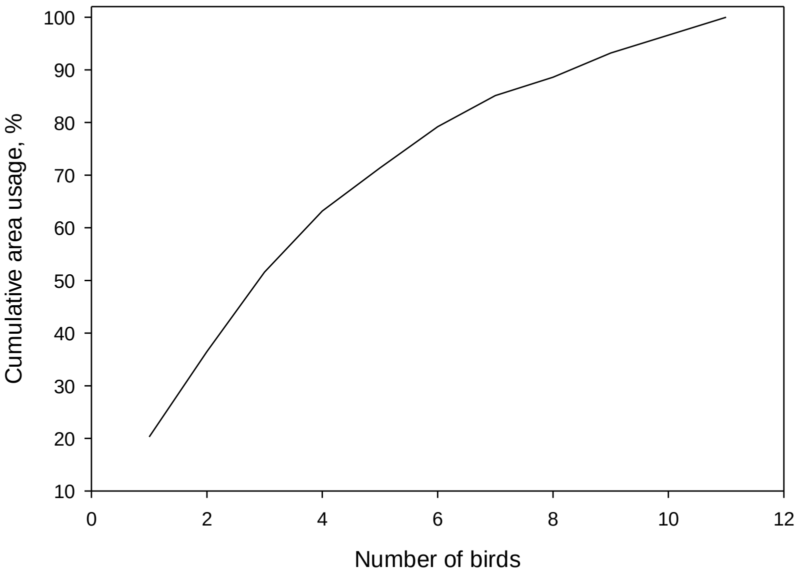


Fig. 33: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in razorbills from Isle of May in 2017-18. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

3.1.3.2 2018-2019

As in 2017-18, East Caithness guillemots showed the typical non-linear increase in size of core areas used with increasing sample size of birds (Fig. 34a). The increment in cumulative area size was larger with sample size up to around 6 birds, after which it was less than 5% with each additional bird. For sample sizes above 12 birds the increment was 1-2% (Fig. 34b). Randomized samples of 5 and 10 birds covered 51% and 72% of the area identified using all study birds, respectively (Fig. 34b).

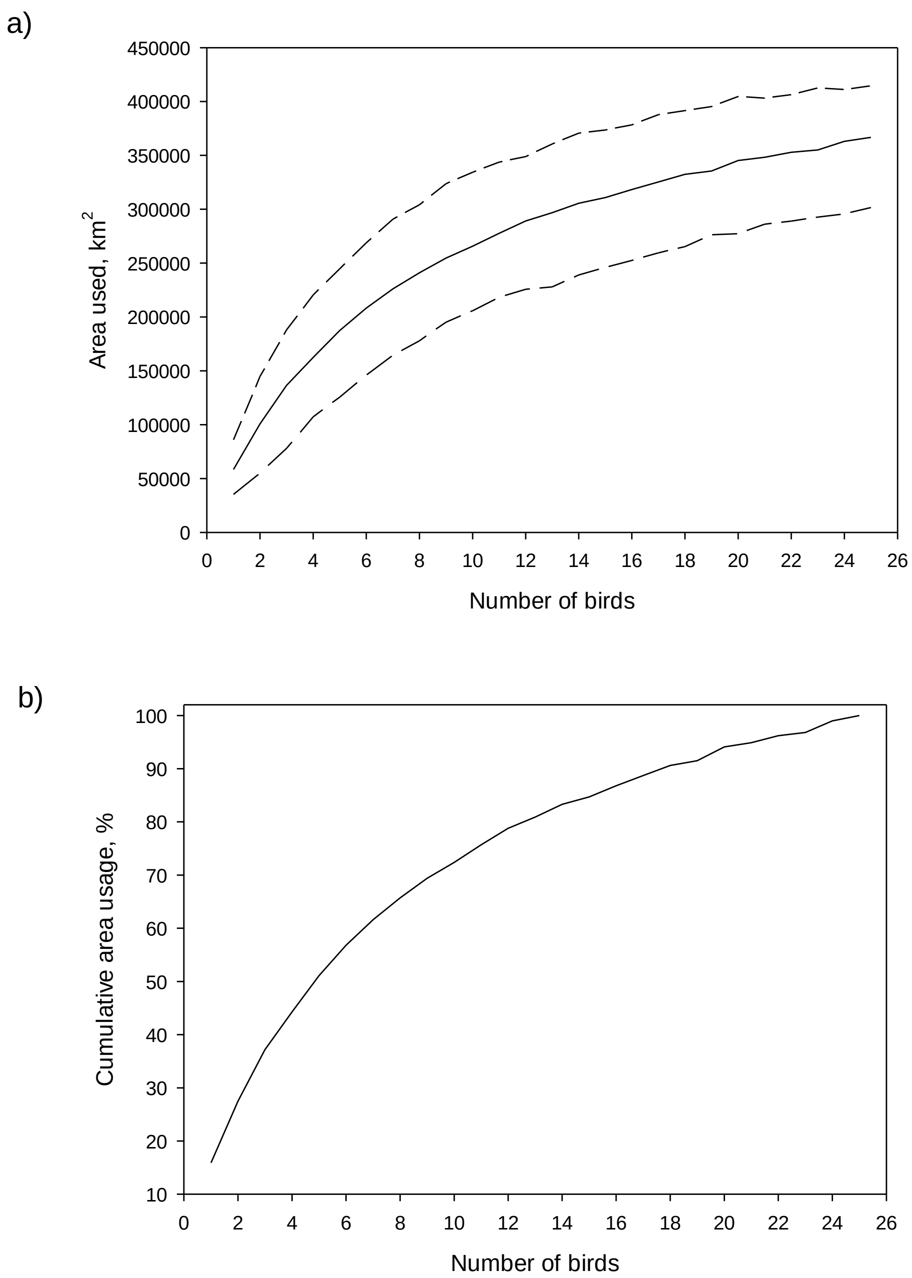
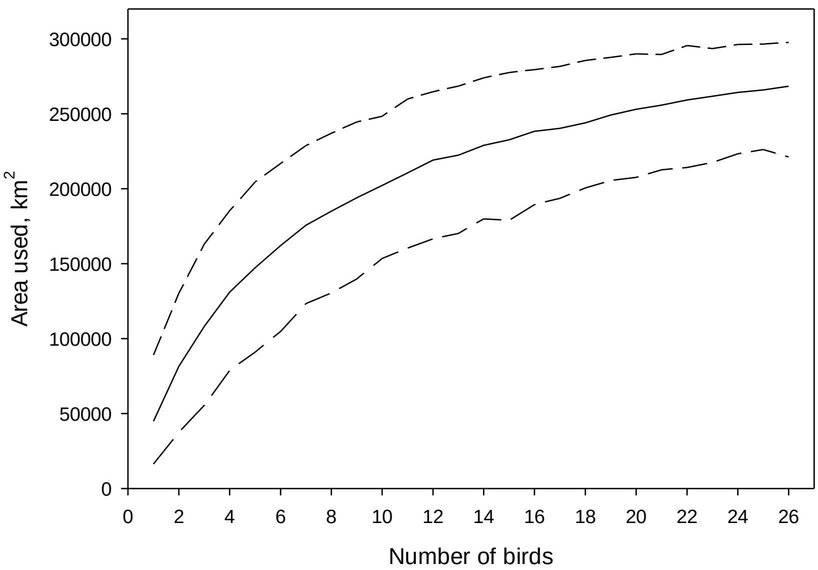


Fig. 34: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in guillemots from East Caithness in 2018-19. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

In guillemots from Buchan Ness to Collieston Coast, a non-linear increase in size of core areas with increasing sample size of birds was evident (Fig. 35a). The increment in cumulative area size was larger with sample size up to around 7 birds, after which it was less than 5% with each additional bird. For sample sizes above 14 birds the increment was 1-2% (Fig. 35b). Randomized samples of 5 and 10 birds covered 55% and 75% of the area identified using all study birds, respectively (Fig. 35b).

a)



b)

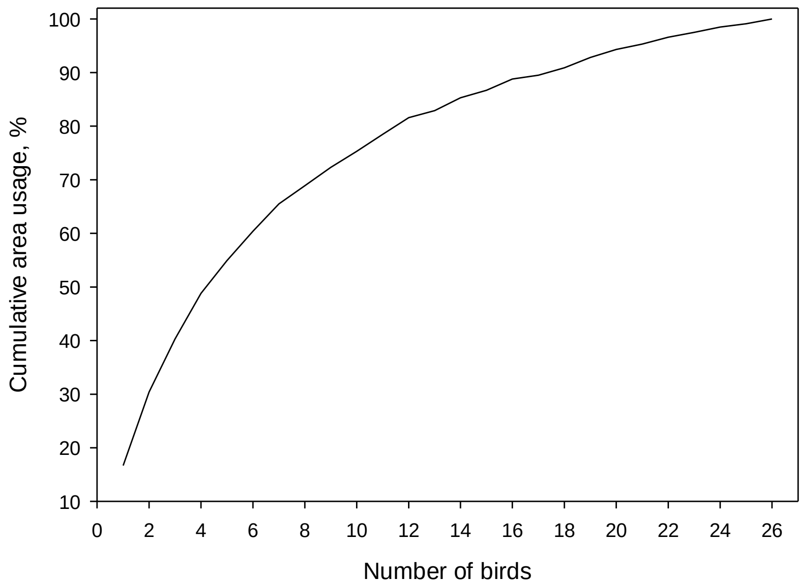
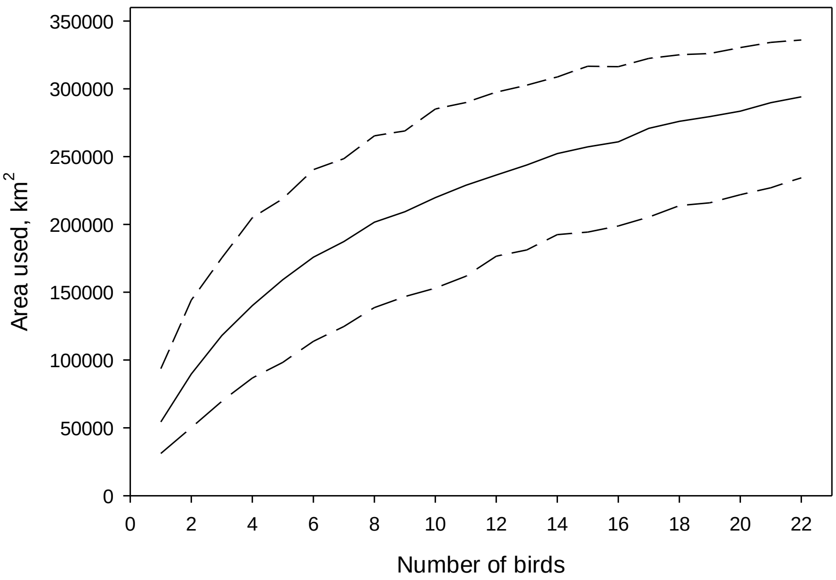


Fig. 35: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in guillemots from Buchan Ness to Collieston Coast in 2018-19. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

As guillemots at the other two colonies, Isle of May guillemots showed the typical non-linear increase in size of core areas with increasing sample size of birds (Fig. 36a). The increment in cumulative area size was larger with sample size up to around 6 birds, after which it was less than 5% with each additional bird (Fig. 36b). Randomized samples of 5 and 10 birds covered 54% and 75% of the area identified using all study birds, respectively (Fig. 36b).

a)



b)

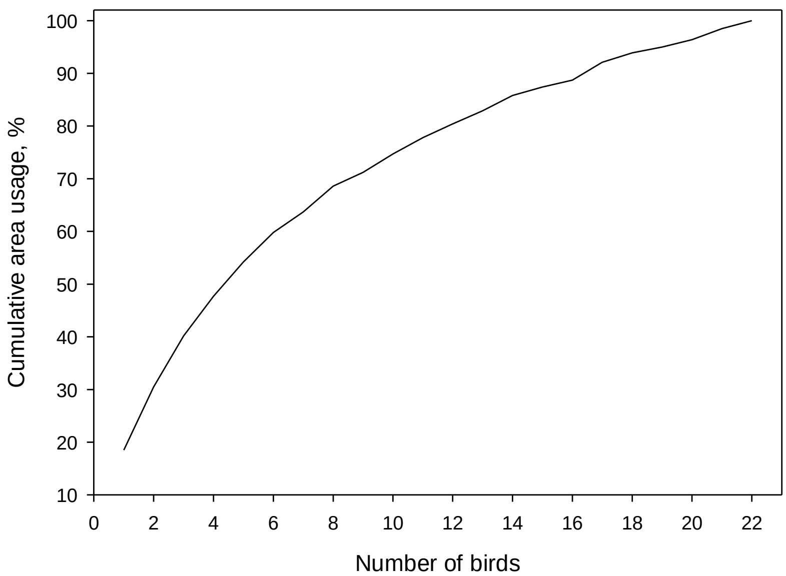


Fig. 36: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in guillemots from Isle of May in 2018-19. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

In razorbills from East Caithness, a non-linear increase in the size of core areas with increasing number of birds was observed as in the other colonies and species (Fig. 37a). However, the cumulative curve did not level off due to the relatively small sample size of birds (Fig. 37b).

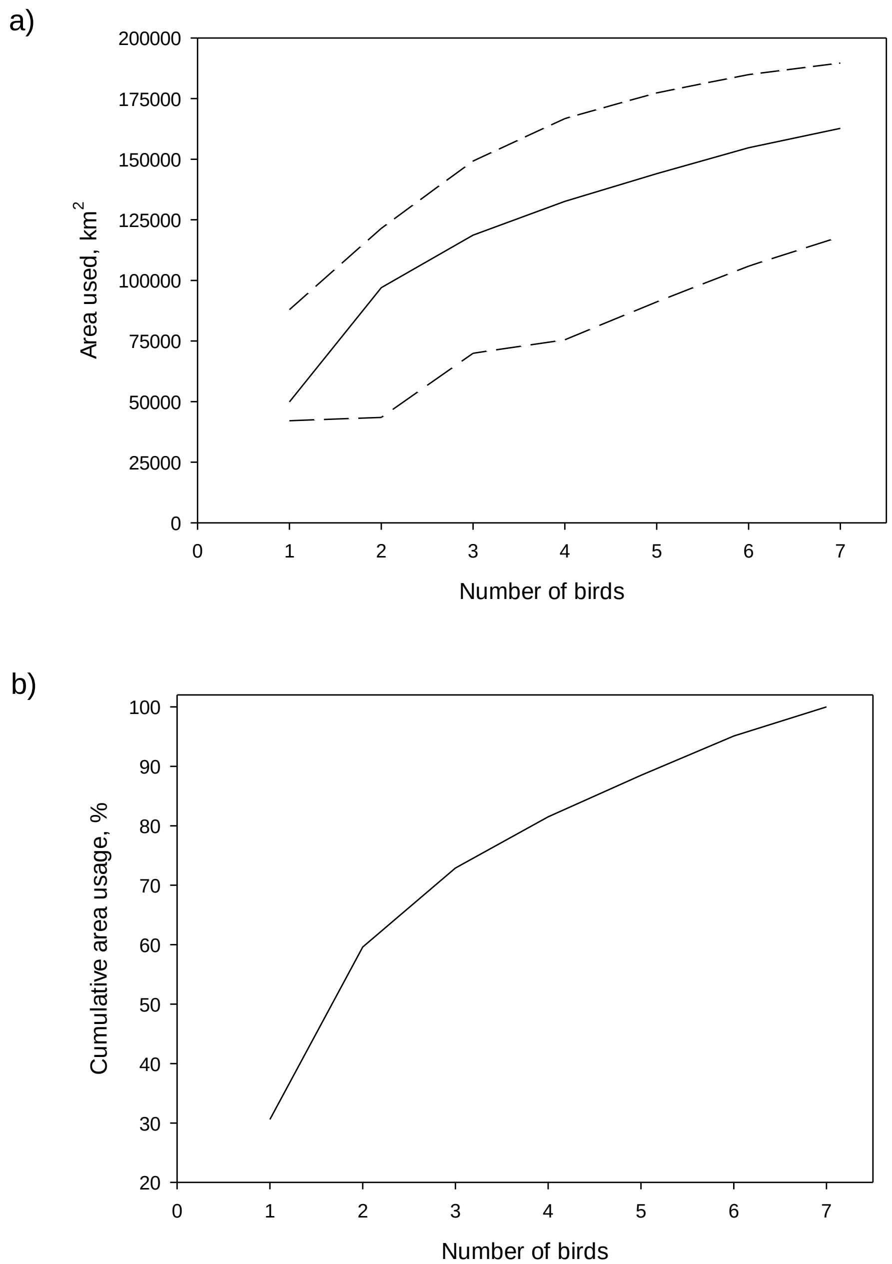
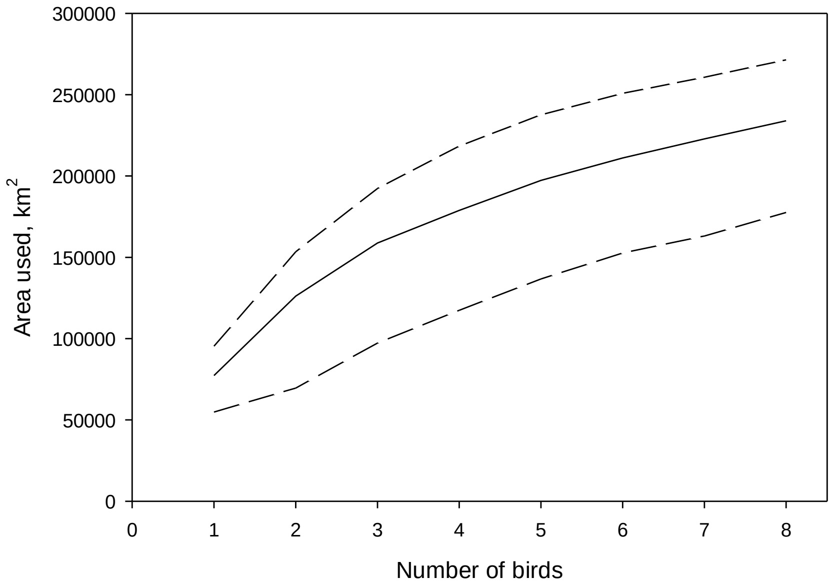


Fig. 37: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in razorbills from East Caithness in 2018-19. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

Razorbills from Buchan Ness to Collieston Coast showed the expected non-linear increase in the size of core areas with increasing number of birds (Fig. 38a) but, similar to East Caithness, the cumulative curve did not level off, reflecting the relatively small sample size of birds (Fig. 38b).

a)



b)

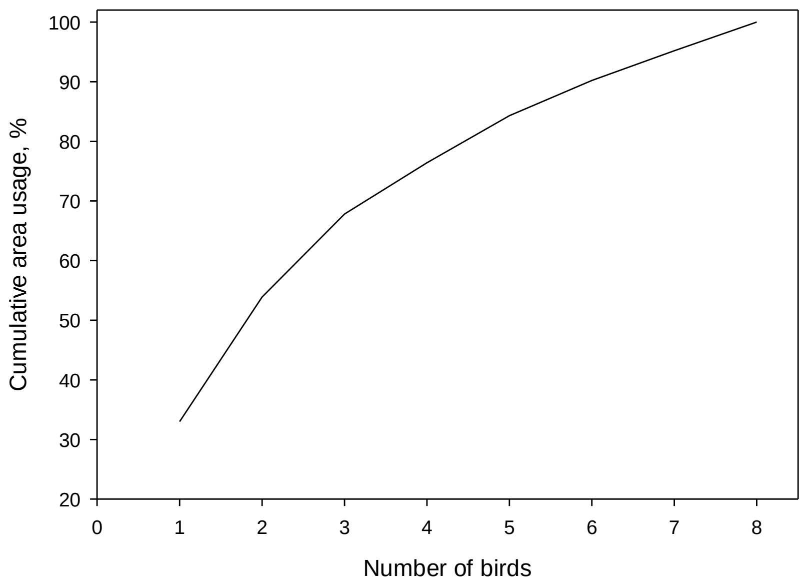


Fig. 38: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in razorbills from Buchan Ness to Collieston Coast in 2018-19. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

The increase in size of core areas with increasing sample size of birds for Isle of May razorbills is shown on Fig. 39a. The increment in cumulative area size was larger with sample size up to around 8 birds, after which it declined to less than 5% with each additional bird (Fig. 39b). Randomized sample of 5 birds covered 74% of the area identified using all study birds (Fig. 39b).

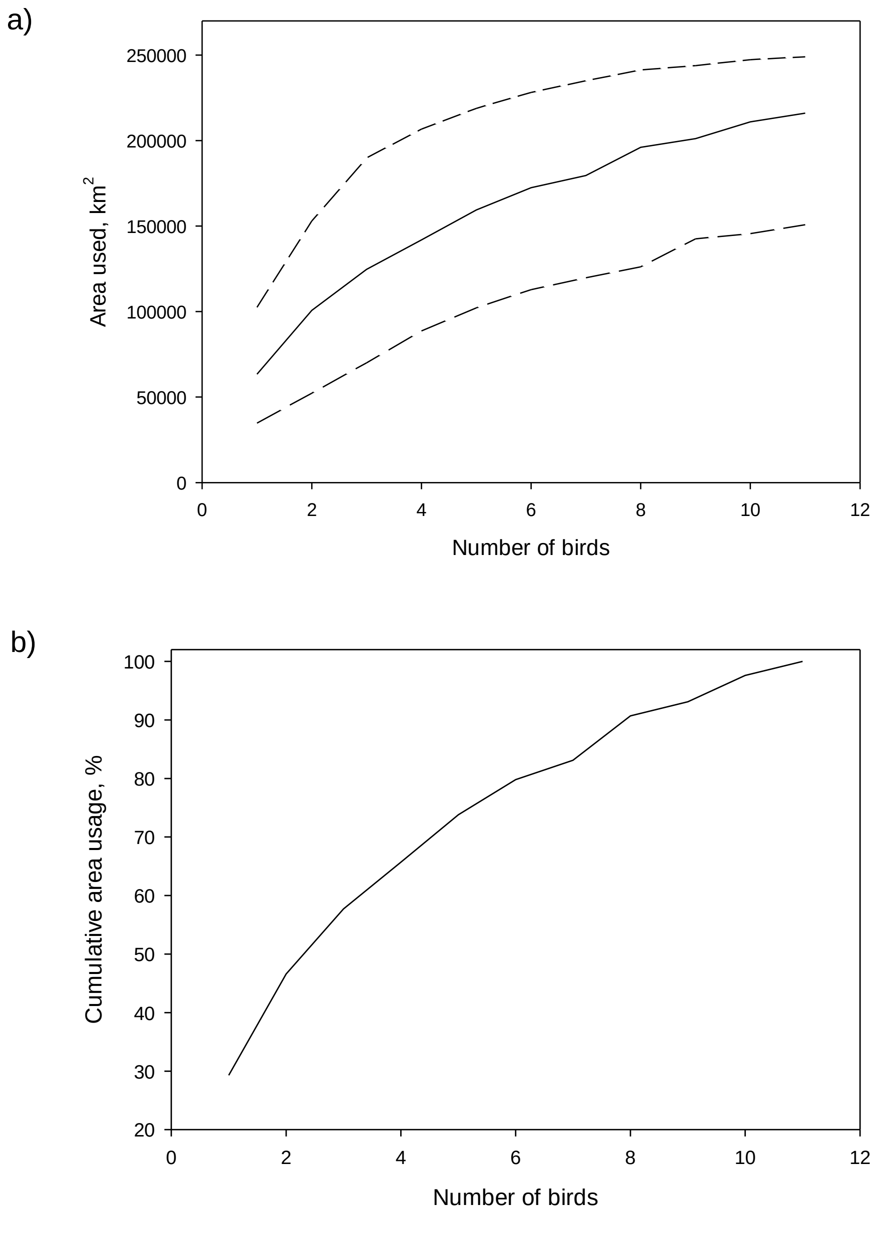


Fig. 39: Relationship between core area used (50% UD contours) and sample size of birds estimated from a resampling procedure in razorbills from Isle of May in 2018-19. a) median area (solid line) and 2.5 and 97.5 percentiles (dashed lines) shown for each randomized sample size; b) cumulative percentage of area used by the population.

3.2 Diet

3.2.1 Breeding season in 2017

We obtained 548 diet observations from East Caithness (n = 422 for guillemot; n=126 for razorbill), 389 diet observations from Buchan Ness to Collieston Coast (n = 298 for guillemot; n=91 for razorbill) and 1,270 diet observations from the Isle of May (n = 1,021 for guillemot; n = 249 for razorbill), giving a total sample across all three colonies of 2,207 in 2017.

At all three colonies, the diet of guillemots as presented as Frequency of Occurrence (i.e. the percentage of diet observations that comprise that prey type) was dominated by clupeids (70% East Caithness; 65% Buchan Ness to Collieston Coast, 86% Isle of May). Guillemots at East Caithness brought back more 1+ group sandeels than at the other two colonies (19%, 9% and 5% respectively), and gadoids were less important on the Isle of May (5%, 7% and 1% respectively). 0 group sandeels were unimportant at all three colonies (Table 5).

The diet of razorbills showed marked among-colony variation, such that 0 group sandeels dominated at East Caithness and Buchan Ness to Collieston Coast (98% East Caithness; 93% Buchan Ness to Collieston Coast, 33% Isle of May) whereas clupeids dominated on the Isle of May (1% East Caithness; 2% Buchan Ness to Collieston Coast, 60% Isle of May; Table 5).

3.2.2 Breeding season in 2018

We obtained 299 diet observations from East Caithness (n = 262 for guillemot; n=37 for razorbill), 528 diet observations from Buchan Ness to Collieston Coast (n = 481 for guillemot; n = 47 for razorbill) and 1,579 diet observations from the Isle of May (n = 1,382 for guillemot; n = 197 for razorbill), giving a total sample across all three colonies of 2,406 in 2018.

A summary of Frequency of Occurrence of each prey type for the two species at the three colonies can be found in Table 5. At all three colonies, the diet of guillemots was dominated by clupeids (76% at East Caithness; 70% Buchan Ness to Collieston Coast, 77% Isle of May; Table 5). Guillemots on the Isle of May brought back fewer 1+ group sandeels than at the other two colonies (19%, 19% and 6% respectively), and gadoids were more important on the Isle of May (1%, 1% and 5% respectively). 0 group sandeels were unimportant at all three colonies. These results accorded closely with those found in 2017 (Table 5).

The diet of razorbills showed marked among-colony variation such that 0 group sandeels dominated at East Caithness and Buchan Ness to Collieston Coast (95% East Caithness; 98% Buchan Ness to Collieston Coast, 10% Isle of May) whereas clupeids dominated on the Isle of May (5% East Caithness; 2% Buchan Ness to Collieston Coast, 80% Isle of May). No 1+ group sandeels were observed in the diet of razorbills. These results accorded closely with those found in 2017 (Table 5), although the importance of clupeids in the diet of Isle of May razorbills was even more marked in 2018.

3.2.3 Breeding season in 2019

We obtained 284 diet observations from East Caithness (n = 207 for guillemot; n=77 for razorbill), 479 diet observations from Buchan Ness to Collieston Coast (n = 417 for guillemot; n = 62 for razorbill) and 1,061 diet observations from the Isle of May (n = 881 for guillemot; n = 180 for razorbill), giving a total sample across all three colonies of 1,824 in 2019.

A summary of Frequency of Occurrence of each prey type for the two species at the three colonies can be found in Table 5. At all three colonies, the diet of guillemots was dominated by clupeids (59% Frequency of Occurrence at East Caithness; 59% Buchan Ness to Collieston Coast, 87% Isle of May; Table 5). Guillemots on the Isle of May brought back fewer 1+ group sandeels than at the other two colonies (29%, 26% and 4% respectively), and gadoids were somewhat more important at Buchan Ness to Collieston Coast (4%, 7% and 3% respectively). 0 group sandeels were unimportant at all three colonies. These results accorded closely with those found in 2017 and 2018 (Table 5).

The diet of razorbills showed among-colony variation, such that 0 group sandeels dominated at East Caithness and Buchan Ness to Collieston Coast (100% East Caithness; 98% Buchan Ness to Collieston Coast, 69% Isle of May). However, this was a much higher Frequency of Occurrence of this prey type on the Isle of May than in the other two years. Unlike in 2017 and 2018, clupeids didn't dominate at any colony (1% East Caithness; 12% Buchan Ness to Collieston Coast, 16% Isle of May). Few 1+ group sandeels were observed in the diet of razorbills.

To summarise the interannual variation, the diet of guillemots was largely consistent with the dominance of clupeids and negligible importance of 0 group sandeels at all colonies, and greater importance of 1+ group sandeels at East Caithness and Buchan Ness to Collieston coast compared with the Isle of May apparent in all three years. As regards razorbill, consistent across all years was the dominance of 0 group sandeels at East Caithness and Buchan Ness to Collieston coast. However, their diet on the Isle of May differed among years, with clupeids dominant in 2017 and 2018 but 0 group sandeels dominant in 2019.

The overall mean across the three years support these conclusions, with the diet of guillemots dominated by clupeids (69% Frequency of Occurrence at East Caithness; 65% Buchan Ness to Collieston Coast, 82% Isle of May). Guillemots on the Isle of May brought back fewer 1+ group sandeels than at the other two colonies across the three years (21%, 19% and 5% respectively), and gadoids were of similar importance at the three colonies overall (4%, 5% and 3% respectively). The overall mean across the three years for razorbills showed that 0 group sandeels dominated at East Caithness and Buchan Ness to Collieston Coast (98% East Caithness; 96% Buchan Ness to Collieston Coast, 36% Isle of May) whereas clupeids dominated on the Isle of May (2% East Caithness; 5% Buchan Ness to Collieston Coast, 54% Isle of May).

2017	Prey type	East Caithness		Buchan Ness to Collieston Coast		Isle of May	
		guillemot	razorbill	guillemot	razorbill	guillemot	razorbill
	0 group sandeel	0.71	97.62	0.67	93.41	0.29	32.53
	1+ group sandeel	19.43	2.38	9.06	2.20	5.09	0.00
	Clupeid	69.91	0.79	65.44	2.20	86.09	59.84
	Gadoid	5.21	0.00	7.05	1.10	1.27	0.00
	Rockling	0.00	0.00	0.00	0.00	0.00	0.00
	Squid	0.00	0.00	0.00	0.00	0.10	0.00
	Crustacean	0.00	0.79	0.00	0.00	0.00	0.00
	Unidentified	4.74	0.79	17.79	2.20	7.15	8.03

2018	Prey type	East Caithness		Buchan Ness to Collieston Coast		Isle of May	
		guillemot	razorbill	guillemot	razorbill	guillemot	razorbill
	0 group sandeel	0.00	94.59	1.25	97.87	0.58	9.64
	1+ group sandeel	18.70	0.00	19.13	0.00	6.22	0.00
	Clupeid	76.34	5.41	69.65	2.13	77.21	79.70
	Gadoid	0.76	0.00	1.66	0.00	4.78	0.00
	Rockling	0.00	0.00	0.00	0.00	0.00	3.05
	Squid	0.00	0.00	0.00	0.00	0.00	0.00
	Crustacean	0.00	0.00	0.00	0.00	0.00	0.00
	Unidentified	4.20	5.41	8.32	2.13	11.79	9.64

2019	Prey type	East Caithness		Buchan Ness to Collieston Coast		Isle of May	
		guillemot	razorbill	guillemot	razorbill	guillemot	razorbill
	0 group sandeel	5.31	100.00	1.20	98.39	0.00	69.44
	1+ group sandeel	29.47	0.00	26.14	1.61	3.75	0.56
	Clupeid	59.42	1.30	58.51	1.61	87.40	16.11
	Gadoid	3.86	0.00	6.95	0.00	3.18	1.11
	Rockling	0.00	0.00	0.00	0.00	0.00	1.67
	Squid	0.00	0.00	0.00	0.00	0.00	0.00
	Crustacean	0.00	0.00	0.00	0.00	0.00	0.00
	Unidentified	1.93	0.00	7.19	0.00	5.68	12.22

Table 5: Frequency of Occurrence of each prey type (expressed as percentage of diet observations that comprise that prey type) delivered by guillemots and razorbills at each colony in 2017, 2018 and 2019.

4 Discussion

4.1 Guillemot and razorbill winter distributions

4.1.1 Within- and between-species variation in winter distributions in relation to colony origin

At a large spatial scale, the distribution of guillemots from East Caithness, Buchan Ness to Collieston Coast and the Isle of May was broadly similar, with key wintering areas located around the colonies, off the north-eastern coast of Scotland and in the central and southern North Sea, as previously demonstrated in Isle of May guillemots (Harris et al. 2015; Dunn et al. 2020). In addition, some East Caithness and Isle of May birds migrated eastwards, to the Skagerrak/Kattegat that form the transient zone between the North Sea and the Baltic Sea. As with guillemots, razorbill distributions were broadly similar among colonies at a large spatial scale. The key wintering area of this species was also in the central and southern North Sea, with some birds from East Caithness and Buchan Ness to Collieston Coast migrating to the Skagerrak/Kattegat. Single individuals from both species also used parts of the Norwegian Sea, as shown previously (Harris et al. 2015). These areas are generally known to be highly productive. For example, the waters around the Dogger Bank have increased productivity associated with the existence of tidal mixing frontal systems (Daewel & Schrum 2013). Similarly, the Skagerrak/Kattegat zone supports high concentrations of immature schooling fish (Knijn et al. 1993, Skov et al. 2000), of which herring has been shown to be of key importance as seabird prey (Skov et al. 2000). Thanks to the favourable feeding conditions, these areas host large multispecies aggregations of wintering seabirds (Skov et al. 1995, 2000).

In both species, however, the similarity in distributions of birds from different colonies varied between months, suggesting there were some differences in the location of areas used during the non-breeding season. This may reflect localised within-species segregation driven by competition (Ratcliffe et al. 2014, McFarlane Tranquilla et al. 2015), although competition is likely to be less pronounced in the winter than during the breeding season when the birds are restricted to forage near the colony (Grémillet et al. 2004, Masello et al. 2010, Wakefield et al. 2013). It may also arise in part because of the cost of reaching winter destinations, which will depend to some extent on colony location (Bogdanova et al. 2017) and may be particularly high in auks due to the high flight costs they incur (Pennycuick 1987, Gaston 2004; Dunn et al. 2020).

Partial overlap was also observed between the wintering areas of guillemots and razorbills from the same colony. This pattern may be linked to differences in diet between the two species as shown previously (Linnebjerg et al. 2013, Glew et al. 2018). Such partial overlap can lead to reduced between-species competition at the wintering grounds, as found in other sympatric species (e.g. Fort et al. 2013, Ratcliffe et al. 2014, McFarlane Tranquilla et al. 2015).

In both species, the birds generally spent the post-breeding moult period (during which they are flightless) relatively close to their colonies, with the exception of some Isle of May guillemots that had moved further north along the east coast of Scotland or to the Skagerrak area prior to moult. This matches previous observations of birds visiting the colony in the autumn (Harris & Wanless 1990). However, there was a substantial overlap in the areas used by the three colonies at this time, suggesting that the large post-breeding aggregations of both species observed in the Hywind Scotland project area (Natural Research Projects Ltd 2015, Statoil 2015) may be formed by birds from all three colonies. We cannot discount the possibility that the area is also used by birds from other breeding colonies that were not part of this study. Our study birds were not sexed so we were unable to determine whether the longer-distance post-breeding movements by some of the Isle of May guillemots were associated with one of the sexes, resulting from differences between males and females in the duration of parental care (Gaston & Jones 1998). As expected, more major movements took place largely during October and February-March. However, among guillemots some birds returned to the colonies already in January. Although razorbills generally wintered away from the colony area, they spent more time in local waters than previously thought. These findings highlight the year-round importance of local areas around the colonies.

4.1.2 Minimum adequate sample size

The analyses of minimum adequate sample size of tracked birds for each species at each of the colonies and years all showed the typical non-linear decline in rate of increase in the size of core area used with increasing sample size. In all cases, the cumulative curves did not reach a horizontal plateau, the point at which adding more birds to the sample would lead to no further increase in the population core wintering area. However, the method we used is relatively conservative since the cumulative area of individual kernel contours is calculated to estimate the size of the population wintering area at each sample size of birds, as opposed to data from all birds within a sample size being pooled and population kernel contours then calculated.

Our results are in line with most tracking studies of seabird at-sea distributions, and reflects the challenge in obtaining the large sample sizes of birds that would be required to achieve a plateau in the cumulative curves (Frederiksen et al. 2012, Fort et al. 2013, Garthe et al. 2016). However, it is encouraging to note that in most cases the shape of the curves indicated that a larger sample size of birds would not have resulted in a dramatically altered size of core wintering areas for these populations. This was particularly the case for guillemots where larger sample sizes were obtained, reflecting the fact that more accessible birds were available and these were easier to recapture than razorbills. As such, the relationship between cumulative area and sample size in this species was approaching a plateau more so than in razorbills.

4.2 Diet variation among colonies and years

We found important differences in diet among the two species and among study colonies. Clupeids dominated the diet of guillemots at all three locations, and 0 group sandeels were unimportant. However, 1+ group sandeels were more important at the two northern colonies than the Isle of May, where clupeids were particularly dominant. The dominance of clupeids in all years suggests consistent availability of this prey across the region over this time period. The long-term study on the Isle of May shows that the dominance of clupieds over 1+ group sandeels has in fact been apparent at this colony since the late 1990s (Wanless et al. 2018). However, our results are in contrast to the only previous study of diet at Buchan Ness to Collieston Coast. In 2006, observers at the colony recorded a low proportion of 1+ group sandeels, as we found, but the principal prey was gadids as opposed to clupeids (Anderson et al. 2014). These differences likely reflect changes in the availability of these two prey types over this 10-

year period. However, it is not possible to verify this because of the lack of direct data on prey distributions.

For razorbills, there were marked among-colony and among-year differences whereby clupeids dominated on the Isle of May in two out of three years, whereas 0 group sandeels dominated at the other two colonies in all three years, but only in 2019 on the Isle of May. The among-colony differences could have an important effect on provisioning of offspring since clupeids are generally larger and more nutritious than 0 group sandeels (Harris et al. 2008), which may not be compensated for by the typically large number of prey items that are delivered with the latter. The relative profitability of the two prey types also depends on the relative costs in obtaining them. It is challenging to ascertain why these differences exist among colonies, and among years for the Isle of May since, as with guillemot diet, direct data on prey distribution are not available. However, the most parsimonious explanation is that razorbills are responding to what prey are available close to the colony, and that clupeids were more available to razorbills on the Isle of May in 2017 and 2018, while in 2019 at that colony and at the other two colonies in all three years there was likely a greater availability of 0 group sandeels.

It is important to note that while the diet sample sizes were sufficient to be confident that they provide a representative summary of diet over the sampling period, that diet may have differed outside these periods e.g. during incubation.

4.3 Conclusions: winter ecology of guillemots and razorbills from the three colonies and implications for offshore renewable developments

Seabirds are long-lived species whose population dynamics are largely determined by adult survival rates. Adult mortality typically occurs outside the breeding season, so conditions at the wintering grounds can have a profound impact on population trajectories (Reynolds et al. 2011). The extent of winter mixing of birds from different breeding populations, and therefore the potential for shared experiences of poor conditions or interactions with human developments, can have important conservation implications (Frederiksen et al. 2012). Our results show that the three populations of guillemots and razorbills showed a similar overall distribution, with extensive use of the central and southern North Sea and areas around the breeding colonies. However, in both species there were important differences among colonies in the location of hotspots during the non-breeding period. These differences likely reflect the considerable amount of time that birds were spending close to their colonies outside the breeding season, and suggest that they may show different population dynamic responses to environmental conditions operating at local scales.

Offshore renewable developments must consider potential consequences of impacts on protected seabird populations. In the case of guillemots and razorbills, the principal concern is displacement and barrier effects (Masden et al. 2010; Dierschke et al. 2016). These effects could be particularly important in the case of multiple developments, as the potential for cumulative negative impacts increases (e.g. Busch et al. 2013). Our study provides important insights into the year-round space use of these two key species at three important colonies on the east coast of Scotland, and therefore the extent to which birds from multiple colonies may be affected by particular single or multiple developments at different periods of the year.

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7 Appendix: Deployment details

Tables A1a, A1b and A1c provide deployment details at East Caithness, Buchan Ness to Collieston Coast and the Isle of May, respectively, in 2017.

Tables A2a, A2b and A2c provide deployment details at East Caithness, Buchan Ness to Collieston Coast and the Isle of May, respectively, in 2018.

Table A1a: GLS logger deployment details for East Caithness in 2017. Start date and start time denote the date the logger commenced data collection.

n	Species	Site	BTO ring	Logger ID	Start date	Start time	Deployment date	Deployment Time	Nest Status	Year retrieved	Deployment successful
1	Guillemot	1a	R99313	2561	11-Jun-17	15:37	12-Jun-17	09:50	Brooding chick	NA	NA
2	Guillemot	1a	R99314	2560	11-Jun-17	15:36	12-Jun-17	09:56	Incubating egg	2018	Yes
3	Guillemot	1b	R99315	2556	11-Jun-17	15:33	12-Jun-17	10:10	Brooding chick	2018	Yes
4	Guillemot	1b	R99316	2564	11-Jun-17	15:38	12-Jun-17	10:13	Brooding chick	2018	Yes
5	Guillemot	1b	R99317	2531	11-Jun-17	15:22	12-Jun-17	10:15	Brooding chick	2018	No
6	Guillemot	1b	R99318	2544	11-Jun-17	15:28	12-Jun-17	10:18	Brooding chick	2018	Yes
7	Guillemot	1b	R99319	2542	11-Jun-17	15:27	12-Jun-17	10:20	Brooding chick	2018	Yes
8	Guillemot	1b	R99320	2533	11-Jun-17	15:23	12-Jun-17	10:22	Brooding chick	2018	Yes
9	Guillemot	1b	T15286	2552	11-Jun-17	15:31	12-Jun-17	10:25	Brooding chick	NA	NA
10	Guillemot	1b	T15287	2535	11-Jun-17	15:29	12-Jun-17	10:28	Brooding chick	NA	NA
11	Guillemot	1b	T15288	2555	11-Jun-17	15:32	12-Jun-17	10:32	Incubating egg	2018	Yes
12	Guillemot	1b	T15289	2551	11-Jun-17	15:31	12-Jun-17	10:35	Brooding chick	2018	Yes
13	Guillemot	1b	T15290	2554	11-Jun-17	15:32	12-Jun-17	10:37	Brooding chick	2019	Yes
14	Guillemot	1b	T15291	2550	11-Jun-17	15:30	12-Jun-17	10:39	Brooding chick	2019	No
15	Guillemot	1b	T15292	2539	11-Jun-17	15:26	12-Jun-17	10:44	Brooding chick	NA	NA
16	Guillemot	1b	T15293	2534	11-Jun-17	15:24	12-Jun-17	10:46	Brooding chick	2018	Yes
17	Guillemot	1b	T15294	2545	11-Jun-17	15:29	12-Jun-17	10:48	Brooding chick	2018	No
18	Guillemot	1b	T15295	2538	11-Jun-17	15:25	12-Jun-17	10:50	Incubating egg	2018	Yes
19	Guillemot	1b	T15296	2565	11-Jun-17	15:38	12-Jun-17	10:53	Brooding chick	NA	NA
20	Guillemot	1b	T15297	2559	11-Jun-17	15:36	12-Jun-17	11:11	Brooding chick	2018	Yes
21	Razorbill	1b	M78952	2641	11-Jun-17	14:54	12-Jun-17	10:06	Brooding chick	NA	NA
22	Razorbill	1b	M78954	2646	11-Jun-17	14:57	12-Jun-17	10:56	Incubating egg	NA	NA
23	Razorbill	1b	M78955	2647	11-Jun-17	14:58	12-Jun-17	11:00	Incubating egg	NA	NA
24	Razorbill	1b	M78956	2645	11-Jun-17	14:56	12-Jun-17	11:02	Brooding chick	NA	NA
25	Razorbill	1b	M78957	2640	11-Jun-17	14:54	12-Jun-17	11:05	Unknown	2018	Yes
26	Razorbill	1b	M78958	2648	11-Jun-17	14:58	12-Jun-17	11:14	Brooding chick	NA	NA
27	Razorbill	1b	M78959	2642	11-Jun-17	14:55	12-Jun-17	11:21	Incubating egg	2019	Yes
28	Razorbill	1b	M78990	2643	11-Jun-17	14:56	12-Jun-17	15:13	Brooding chick	2018	Yes
29	Razorbill	1b	M78991	2666	11-Jun-17	15:06	12-Jun-17	15:16	Unknown	NA	NA
30	Guillemot	2	T15298	2541	11-Jun-17	15:27	12-Jun-17	11:51	Incubating egg	2018	Yes
31	Guillemot	2	T15299	2568	11-Jun-17	15:40	12-Jun-17	11:54	Incubating egg	NA	NA
32	Guillemot	2	T15300	2529	11-Jun-17	15:20	12-Jun-17	11:56	Brooding chick	2018	Yes
33	Guillemot	2	T15301	2528	11-Jun-17	15:19	12-Jun-17	11:58	Brooding chick	NA	NA
34	Guillemot	2	T15302	2537	11-Jun-17	15:25	12-Jun-17	12:00	Brooding chick	2018	Yes
35	Guillemot	2	T15303	2543	11-Jun-17	15:28	12-Jun-17	12:02	Incubating egg	2019	Yes
36	Guillemot	2	T15304	2558	11-Jun-17	15:34	12-Jun-17	12:04	Brooding chick	2019	Yes
37	Guillemot	2	T15305	2530	11-Jun-17	15:20	12-Jun-17	12:06	Brooding chick	NA	NA
38	Guillemot	2	T15306	2557	11-Jun-17	15:33	12-Jun-17	12:08	Brooding chick	NA	NA
39	Guillemot	2	T15307	2547	11-Jun-17	15:29	12-Jun-17	12:10	Brooding chick	NA	NA
40	Guillemot	2	T15308	2532	11-Jun-17	15:23	12-Jun-17	12:14	Brooding chick	NA	NA
41	Guillemot	2	T15309	2548	11-Jun-17	15:29	12-Jun-17	12:16	Brooding chick	NA	NA
42	Guillemot	2	T15310	2549	11-Jun-17	15:30	12-Jun-17	12:18	Brooding chick	2018	Yes
43	Guillemot	2	T15311	2562	11-Jun-17	15:37	12-Jun-17	12:20	Brooding chick	2018	Yes
44	Guillemot	2	T15312	2540	11-Jun-17	15:26	12-Jun-17	12:22	Brooding chick	NA	NA
45	Guillemot	2	T15313	2536	11-Jun-17	15:24	12-Jun-17	12:24	Brooding chick	NA	NA
46	Guillemot	2	T15314	2567	11-Jun-17	15:39	12-Jun-17	12:26	Brooding chick	2019	Yes
47	Guillemot	2	T15315	2566	11-Jun-17	15:39	12-Jun-17	12:28	Brooding chick	2018	No
48	Guillemot	2	T15316	2553	11-Jun-17	15:32	12-Jun-17	12:30	Brooding chick	NA	NA
49	Guillemot	2	T15317	2563	11-Jun-17	15:37	12-Jun-17	12:32	Brooding chick	2018	Yes
50	Razorbill	3	M78980	2650	11-Jun-17	15:00	12-Jun-17	14:12	Brooding chick	2018	Yes
51	Razorbill	3	M78981	2657	11-Jun-17	15:02	12-Jun-17	14:13	Brooding chick	2018	Yes
52	Razorbill	3	M78982	2649	11-Jun-17	14:59	12-Jun-17	14:21	Brooding chick	NA	NA
53	Razorbill	3	M78983	2655	11-Jun-17	15:02	12-Jun-17	14:24	Incubating egg	NA	NA
54	Razorbill	3	M78984	2662	11-Jun-17	15:05	12-Jun-17	14:26	Brooding chick	2018	Yes
55	Razorbill	3	M78985	2665	11-Jun-17	15:06	12-Jun-17	14:30	Brooding chick	NA	NA
56	Razorbill	3	M78986	2652	11-Jun-17	15:01	12-Jun-17	14:37	Brooding chick	NA	NA
57	Razorbill	3	M78987	2663	11-Jun-17	15:05	12-Jun-17	14:51	Brooding chick	NA	NA
58	Razorbill	3	M78988	2644	11-Jun-17	14:56	12-Jun-17	14:54	Brooding chick	2018	Yes
59	Razorbill	3	M78989	2667	11-Jun-17	15:07	12-Jun-17	14:58	Incubating egg	2018	Yes
60	Razorbill	4	M72416	2656	11-Jun-17	15:02	12-Jun-17	10:31	Brooding chick	NA	NA
61	Razorbill	4	M72417	2669	11-Jun-17	15:07	12-Jun-17	10:39	Brooding chick	2018	Yes
62	Razorbill	4	M72418	2668	11-Jun-17	15:07	12-Jun-17	11:00	Incubating egg	2018	Yes
63	Razorbill	4	M72419	2658	11-Jun-17	15:03	12-Jun-17	11:06	Incubating egg	NA	NA
64	Razorbill	4	M72421	2664	11-Jun-17	15:05	12-Jun-17	11:19	Brooding chick	NA	NA
65	Razorbill	4	M72420	2653	11-Jun-17	15:01	12-Jun-17	11:25	Brooding chick	2018	Yes
66	Razorbill	4	M72422	2661	11-Jun-17	15:04	12-Jun-17	11:34	Brooding chick	2019	Yes
67	Razorbill	4	M72423	2660	11-Jun-17	15:04	12-Jun-17	11:40	Brooding chick	2018	Yes
68	Razorbill	4	M72424	2659	11-Jun-17	15:03	12-Jun-17	12:13	Brooding chick	2018	Yes
69	Razorbill	4	M72425	2654	11-Jun-17	15:01	12-Jun-17	12:20	Incubating egg	NA	NA
70	Razorbill	4	M72426	2651	11-Jun-17	15:00	12-Jun-17	12:34	Incubating egg	2018	Yes

Table A1b: GLS logger deployment details for Buchan Ness to Collieston Coast SPA in 2017. Start date and start time denote the start of data collection.

n	Species	Site	BTO ring	Logger ID	Start date	Start time	Deployment date	Deployment Time	Nest Status	Year retrieved	Deployment successful
1	Guillemot	1	T23784	2587	13-Jun-17	05:22	14-Jun-17	18:42	Brooding chick	2019	Yes
2	Guillemot	1	T23785	2579	13-Jun-17	05:18	14-Jun-17	18:46	Brooding chick	2018	Yes
3	Guillemot	1	T23786	2585	13-Jun-17	05:21	14-Jun-17	18:50	Incubating egg	2018	Yes
4	Guillemot	1	T70810	2606	13-Jun-17	05:31	14-Jun-17	18:52	Brooding chick	2018	Yes
5	Guillemot	1	T23787	2577	13-Jun-17	05:18	14-Jun-17	18:54	Brooding chick	2018	Yes
6	Guillemot	1	T23288	2575	13-Jun-17	05:17	14-Jun-17	18:57	Brooding chick	NA	NA
7	Guillemot	1	T23789	2571	13-Jun-17	05:15	14-Jun-17	19:00	Brooding chick	2018	Yes
8	Guillemot	1	T23790	2586	13-Jun-17	05:22	14-Jun-17	19:02	Brooding chick	2018	Yes
9	Guillemot	1	T70756	2590	13-Jun-17	05:23	14-Jun-17	19:04	Brooding chick	NA	NA
10	Guillemot	1	T23791	2569	13-Jun-17	05:14	14-Jun-17	19:06	Brooding chick	2019	Yes
11	Guillemot	1	T23793	2598	13-Jun-17	05:27	14-Jun-17	19:09	Brooding chick	2018	Yes
12	Guillemot	1	T23794	2594	13-Jun-17	05:25	14-Jun-17	19:13	Brooding chick	2018	Yes
13	Guillemot	1	T23795	2602	13-Jun-17	05:29	14-Jun-17	19:14	Brooding chick	2018	Yes
14	Guillemot	1	T23796	2584	13-Jun-17	05:21	14-Jun-17	19:16	Brooding chick	2019	Yes
15	Guillemot	1	T70809	2608	13-Jun-17	05:31	14-Jun-17	19:18	Brooding chick	NA	NA
16	Guillemot	1	T23761	2592	13-Jun-17	05:24	14-Jun-17	19:20	Brooding chick	NA	NA
17	Guillemot	1	T23797	2572	13-Jun-17	05:15	14-Jun-17	19:22	Incubating egg	2018	Yes
18	Guillemot	1	T23799	2599	13-Jun-17	05:28	14-Jun-17	19:25	Brooding chick	NA	NA
19	Guillemot	1	T23798	2588	13-Jun-17	05:22	14-Jun-17	19:26	Brooding chick	2018	Yes
20	Guillemot	1	T23800	2576	13-Jun-17	05:17	14-Jun-17	19:28	Brooding chick	2018	Yes
21	Guillemot	1	T70901	2605	13-Jun-17	05:30	14-Jun-17	19:30	Brooding chick	2018	Yes
22	Guillemot	1	T70902	2607	13-Jun-17	05:31	14-Jun-17	19:32	Brooding chick	2019	Yes
23	Guillemot	1	T70903	2593	13-Jun-17	05:25	14-Jun-17	20:05	Brooding chick	2018	Yes
24	Guillemot	1	T70904	2580	13-Jun-17	05:19	14-Jun-17	20:19	Brooding chick	2018	Yes
25	Guillemot	1	T70906	2595	13-Jun-17	05:26	14-Jun-17	20:21	Brooding chick	2018	Yes
26	Guillemot	1	T70905	2601	13-Jun-17	05:29	14-Jun-17	20:23	Brooding chick	2018	Yes
27	Guillemot	1	T70908	2581	13-Jun-17	05:19	14-Jun-17	20:26	Brooding chick	NA	NA
28	Guillemot	1	T70907	2589	13-Jun-17	05:23	14-Jun-17	20:28	Brooding chick	NA	NA
29	Guillemot	1	T70961	2573	13-Jun-17	05:16	14-Jun-17	20:29	Brooding chick	2018	Yes
30	Guillemot	1	T70909	2578	13-Jun-17	05:18	14-Jun-17	20:31	Brooding chick	NA	NA
31	Guillemot	1	T23778	2604	13-Jun-17	05:30	14-Jun-17	20:33	Brooding chick	2018	Yes
32	Guillemot	1	T23776	2600	13-Jun-17	05:28	14-Jun-17	20:34	Brooding chick	NA	NA
33	Guillemot	1	T70962	2597	13-Jun-17	05:27	14-Jun-17	20:36	Brooding chick	2018	Yes
34	Guillemot	1	T70910	2596	13-Jun-17	05:26	14-Jun-17	20:38	Brooding chick	NA	NA
35	Guillemot	1	T70911	2603	13-Jun-17	05:29	14-Jun-17	20:39	Brooding chick	2018	Yes
36	Guillemot	1	T70956	2582	13-Jun-17	05:20	14-Jun-17	20:41	Brooding chick	2018	Yes
37	Guillemot	1	T23764	2574	13-Jun-17	05:16	14-Jun-17	20:43	Brooding chick	2018	Yes
38	Guillemot	1	T70912	2570	13-Jun-17	05:15	14-Jun-17	20:45	Brooding chick	2018	Yes
39	Guillemot	1	T70913	2591	13-Jun-17	05:24	14-Jun-17	20:46	Brooding chick	NA	NA
40	Guillemot	1	T70914	2583	13-Jun-17	05:20	14-Jun-17	20:48	Brooding chick	NA	NA
41	Razorbill	2	M88601	2678	13-Jun-17	05:04	15-Jun-17	10:02	Incubating egg	NA	NA
42	Razorbill	3	M88602	2687	13-Jun-17	05:08	23-Jun-17	19:34	Unknown	NA	NA
43	Razorbill	3	M88603	2688	13-Jun-17	05:08	23-Jun-17	19:32	Brooding chick	2019	Yes
44	Razorbill	3	M88604	2684	13-Jun-17	05:06	23-Jun-17	19:43	Brooding chick	NA	NA
45	Razorbill	3	M88605	2671	13-Jun-17	05:01	23-Jun-17	19:54	Incubating egg	NA	NA
46	Razorbill	3	M88606	2676	13-Jun-17	05:03	23-Jun-17	19:57	Brooding chick	NA	NA
47	Razorbill	3	M88607	2681	13-Jun-17	05:05	23-Jun-17	20:00	Brooding chick	NA	NA
48	Razorbill	3	M88608	2683	13-Jun-17	05:06	23-Jun-17	20:05	Brooding chick	2019	Yes
49	Razorbill	3	M88609	2679	13-Jun-17	05:02	23-Jun-17	20:09	Brooding chick	2018	Yes
50	Razorbill	3	M88610	2677	13-Jun-17	05:04	23-Jun-17	20:18	Incubating egg	2019	Yes
51	Razorbill	3	M88611	2680	13-Jun-17	05:05	23-Jun-17	20:25	Brooding chick	NA	NA
52	Razorbill	3	M88612	2675	13-Jun-17	05:03	23-Jun-17	20:38	Brooding chick	2018	Yes
53	Razorbill	3	M88613	2674	13-Jun-17	05:02	23-Jun-17	20:43	Brooding chick	NA	NA
54	Razorbill	3	M88614	2672	13-Jun-17	05:02	23-Jun-17	20:54	Brooding chick	NA	NA
55	Razorbill	3	M88615	2689	13-Jun-17	05:09	23-Jun-17	21:05	Brooding chick	NA	NA
56	Razorbill	2	M88616	2686	13-Jun-17	05:07	24-Jun-17	14:05	Brooding chick	NA	NA
57	Razorbill	4	M88617	2673	13-Jun-17	05:02	24-Jun-17	16:02	Brooding chick	NA	NA
58	Razorbill	4	M88618	2682	13-Jun-17	05:06	24-Jun-17	16:05	Incubating egg	NA	NA
59	Razorbill	4	M88619	2685	13-Jun-17	05:07	24-Jun-17	16:27	Brooding chick	NA	NA
60	Razorbill	4	M88620	2670	13-Jun-17	05:00	24-Jun-17	16:41	Brooding chick	NA	NA

Table A1c: GLS logger deployment details for Isle of May NNR in 2017. Start date and start time denote the start of data collection.

n	Species	Site	BTO ring	Logger ID	Start date	Start time	Deployment date	Deployment Time	Nest Status	Year retrieved	Deployment successful
1	Razorbill	1	M82449	2614	08-Jun-17	13:43	20-Jun-17	20:00	Brooding chick	2018	Yes
2	Razorbill	2	M82440	2622	08-Jun-17	13:47	19-Jun-17	11:05	Brooding chick	2018	Yes
3	Razorbill	3	M84627	2609	08-Jun-17	13:40	14-Jun-17	09:00	Brooding chick	NA	NA
4	Razorbill	4	M84628	2611	08-Jun-17	13:42	17-Jun-17	10:40	Brooding chick	NA	NA
5	Razorbill	4	M84629	2610	08-Jun-17	13:41	17-Jun-17	10:50	Brooding chick	NA	NA
6	Razorbill	4	M84630	2612	08-Jun-17	13:42	17-Jun-17	11:02	Brooding chick	2018	Yes
7	Razorbill	4	M84631	2613	08-Jun-17	13:43	19-Jun-17	10:40	Brooding chick	NA	NA
8	Razorbill	1	M84632	2615	08-Jun-17	13:44	19-Jun-17	11:13	Brooding chick	NA	NA
9	Razorbill	1	M84633	2616	08-Jun-17	13:45	19-Jun-17	11:23	Brooding chick	2018	Yes
10	Razorbill	3	M84634	2617	08-Jun-17	13:45	19-Jun-17	11:41	Brooding chick	NA	NA
11	Razorbill	3	M84635	2618	08-Jun-17	13:45	19-Jun-17	11:50	Brooding chick	NA	NA
12	Razorbill	5	M84636	2619	08-Jun-17	13:46	20-Jun-17	08:45	Brooding chick	2018	Yes
13	Razorbill	5	M84637	2620	08-Jun-17	13:46	20-Jun-17	09:00	Brooding chick	NA	NA
14	Razorbill	3	M84640	2621	08-Jun-17	13:46	20-Jun-17	09:20	Brooding chick	NA	NA
15	Razorbill	2	M84641	2623	08-Jun-17	13:47	20-Jun-17	20:30	Brooding chick	2018	Yes
16	Razorbill	2	M84642	2624	08-Jun-17	13:48	20-Jun-17	20:40	Brooding chick	NA	NA
17	Razorbill	3	M84643	2625	08-Jun-17	13:48	21-Jun-17	10:30	Brooding chick	2018	Yes
18	Razorbill	6	M84644	2626	08-Jun-17	13:48	21-Jun-17	16:40	Brooding chick	2018	Yes
19	Razorbill	6	M84645	2627	08-Jun-17	13:49	21-Jun-17	16:50	Brooding chick	NA	NA
20	Razorbill	2	M84646	2628	08-Jun-17	13:49	21-Jun-17	17:10	Brooding chick	NA	NA
21	Razorbill	7	M84647	2629	08-Jun-17	13:50	21-Jun-17	17:30	Brooding chick	2018	Yes
22	Razorbill	8	M84648	2630	08-Jun-17	13:50	22-Jun-17	08:10	Brooding chick	NA	NA
23	Razorbill	8	M84649	2631	08-Jun-17	13:50	22-Jun-17	08:20	Brooding chick	NA	NA
24	Razorbill	8	M84650	2632	08-Jun-17	13:51	22-Jun-17	08:30	Brooding chick	NA	NA
25	Razorbill	6	M84651	2633	08-Jun-17	13:51	22-Jun-17	08:40	Brooding chick	NA	NA
26	Razorbill	1	M84652	2634	08-Jun-17	13:52	22-Jun-17	17:02	Brooding chick	2018	Yes
27	Razorbill	1	M84653	2635	08-Jun-17	13:52	22-Jun-17	17:17	Brooding chick	NA	NA
28	Razorbill	1	M84654	2636	08-Jun-17	13:52	22-Jun-17	17:24	Brooding chick	2018	Yes
29	Razorbill	4	M84655	2639	08-Jun-17	13:53	23-Jun-17	09:00	Brooding chick	NA	NA
30	Razorbill	6	M84656	2637	08-Jun-17	13:53	23-Jun-17	09:30	Brooding chick	NA	NA

Table A2a: geolocator deployment details for East Caithness in 2018. Start date and start time denote the start of data collection.

n	Species	Site	BTO ring	Logger ID	Start date	Start time	Deployment date	Deployment Time	Nest Status	Year retrieved	Deployment successful
1	Guillemot	1a	R99314	B3853	12-Jun-18	19:23	17-Jun-18	12:04	Incubating egg	2019	Yes
2	Guillemot	1b	R99315	B3850	12-Jun-18	19:21	17-Jun-18	14:52	Unknown	2019	Yes
3	Guillemot	1b	R99316	B3818	12-Jun-18	19:07	17-Jun-18	10:48	Incubating egg	2019	Yes
4	Guillemot	1b	R99317	B3827	12-Jun-18	19:13	17-Jun-18	10:59	Brooding chick	NA	NA
5	Guillemot	1b	R99318	B3830	12-Jun-18	19:14	18-Jun-18	16:25	Brooding chick	2019	Yes
6	Guillemot	1b	R99319	B3832	12-Jun-18	19:15	17-Jun-18	11:46	Brooding chick	2019	Yes
7	Guillemot	1b	R99320	B3851	12-Jun-18	19:22	17-Jun-18	11:40	Brooding chick	2019	Yes
8	Guillemot	1b	T15288	B3843	12-Jun-18	19:19	17-Jun-18	11:13	Brooding chick	2019	Yes
9	Guillemot	1b	T15289	B3823	12-Jun-18	19:11	17-Jun-18	11:07	Incubating egg	NA	NA
10	Guillemot	1b	T15293	B3811	12-Jun-18	19:06	17-Jun-18	12:08	Incubating egg	NA	NA
11	Guillemot	1b	T15294	B3847	12-Jun-18	19:21	17-Jun-18	11:18	Unknown	NA	NA
12	Guillemot	1b	T15295	B3834	12-Jun-18	19:16	17-Jun-18	10:52	Incubating egg	NA	NA
13	Guillemot	1b	T15297	B3824	12-Jun-18	19:12	17-Jun-18	11:21	Brooding chick	2019	Yes
14	Razorbill	1b	M78957	BN100	13-Jun-18	06:56	18-Jun-18	11:12	Brooding chick	2019	Yes
15	Razorbill	1b	M78990	BN097	13-Jun-18	04:14	17-Jun-18	14:48	Brooding chick	NA	NA
16	Guillemot	2	T15298	B3829	12-Jun-18	19:14	18-Jun-18	15:30	Brooding chick	NA	NA
17	Guillemot	2	T15300	B3835	12-Jun-18	19:16	18-Jun-18	15:05	Incubating egg	NA	NA
18	Guillemot	2	T15302	B3837	12-Jun-18	19:17	17-Jun-18	13:37	Incubating egg	2019	Yes
19	Guillemot	2	T15310	B3840	12-Jun-18	19:18	18-Jun-18	13:55	Incubating egg	NA	NA
20	Guillemot	2	T15311	B3842	12-Jun-18	19:18	19-Jun-18	12:55	Brooding chick	NA	NA
21	Guillemot	2	T15315	B3848	12-Jun-18	19:21	18-Jun-18	13:41	Unknown	2019	Yes
22	Guillemot	2	T15317	B3817	12-Jun-18	19:09	18-Jun-18	15:50	Brooding chick	NA	NA
23	Razorbill	3	M78980	BN055	13-Jun-18	05:51	17-Jun-18	13:18	Brooding chick	2019	Yes
24	Razorbill	3	M78981	BN058	13-Jun-18	05:53	17-Jun-18	13:13	Brooding chick	NA	NA
25	Razorbill	3	M78984	BN101	13-Jun-18	07:44	19-Jun-18	13:17	Brooding chick	2019	Yes
26	Razorbill	3	M78988	BN84	13-Jun-18	06:55	17-Jun-18	14:18	Unknown	NA	NA
27	Razorbill	3	M78989	BN91	13-Jun-18	07:00	18-Jun-18	12:54	Brooding chick	NA	NA
28	Razorbill	Boat	M72417	BN53	13-Jun-18	06:49	02-Jul-18	09:45	Unknown	NA	NA
29	Razorbill	Boat	M72418	BN86	13-Jun-18	06:57	02-Jul-18	10:21	Unknown	NA	NA
30	Razorbill	Boat	M72420	BN93	13-Jun-18	07:01	02-Jul-18	11:02	Unknown	NA	NA
31	Razorbill	Boat	M72423	BN88	13-Jun-18	06:58	02-Jul-18	10:41	Unknown	NA	NA
32	Razorbill	Boat	M72424	BN59	13-Jun-18	06:53	02-Jul-18	10:03	Unknown	2019	Yes
33	Guillemot	1b	X83633	B3821	12-Jun-18	19:10	19-Jun-18	10:48	Incubating egg	2019	Yes
34	Guillemot	1b	X83637	B3820	12-Jun-18	19:10	19-Jun-18	10:53	Incubating egg	2019	Yes
35	Guillemot	1b	X83639	B3852	12-Jun-18	19:22	19-Jun-18	11:26	Incubating egg	2019	Yes
36	Guillemot	1b	X83664	B3831	12-Jun-18	19:14	19-Jun-18	11:44	Incubating egg	2019	Yes
37	Guillemot	1b	X83675	B3846	12-Jun-18	19:20	19-Jun-18	10:43	Unknown	NA	NA
38	Guillemot	1b	X83676	B3819	12-Jun-18	19:09	19-Jun-18	10:59	Unknown	2019	Yes
39	Guillemot	1b	X83677	B3814	12-Jun-18	19:07	19-Jun-18	11:04	Brooding chick	2019	Yes
40	Guillemot	1b	X83678	B3844	12-Jun-18	19:19	19-Jun-18	11:08	Brooding chick	2019	Yes
41	Guillemot	1b	X83679	B3838	12-Jun-18	19:17	19-Jun-18	11:13	Brooding chick	NA	NA
42	Guillemot	1b	X83680	B3841	12-Jun-18	19:18	19-Jun-18	11:17	Incubating egg	NA	NA
43	Guillemot	1b	X83681	B3815	12-Jun-18	19:08	19-Jun-18	11:21	Brooding chick	2019	Yes
44	Guillemot	1b	X83682	B3833	12-Jun-18	19:15	19-Jun-18	11:31	Brooding chick	2019	Yes
45	Guillemot	1b	X83683	B3845	12-Jun-18	19:20	19-Jun-18	11:35	Brooding chick	2019	Yes
46	Guillemot	1b	X83684	B3822	12-Jun-18	19:11	19-Jun-18	11:40	Brooding chick	NA	NA
47	Guillemot	1b	X83685	B3816	12-Jun-18	19:08	19-Jun-18	11:49	Incubating egg	NA	NA
48	Guillemot	2	X83687	B3836	12-Jun-18	19:16	19-Jun-18	12:41	Incubating egg	2019	Yes
49	Guillemot	2	X83688	B3812	12-Jun-18	19:06	19-Jun-18	12:45	Incubating egg	NA	NA
50	Guillemot	2	X83689	B3828	12-Jun-18	19:13	19-Jun-18	12:48	Brooding chick	NA	NA
51	Guillemot	2	X83700	B3825	12-Jun-18	19:12	19-Jun-18	16:06	Brooding chick	2019	Yes
52	Razorbill	3	M89255	BN57	13-Jun-18	06:52	18-Jun-18	11:45	Brooding chick	NA	NA
53	Razorbill	3	M89256	BN99	13-Jun-18	07:05	18-Jun-18	11:55	Incubating egg	NA	NA
54	Razorbill	3	M89257	BN92	13-Jun-18	07:01	18-Jun-18	12:05	Brooding chick	NA	NA
55	Razorbill	3	M89259	BN98	13-Jun-18	07:04	18-Jun-18	12:19	Brooding chick	NA	NA
56	Razorbill	3	M89260	BN85	13-Jun-18	06:56	18-Jun-18	12:25	Incubating egg	NA	NA
57	Razorbill	3	M89261	BN90	13-Jun-18	06:59	18-Jun-18	12:35	Brooding chick	NA	NA
58	Razorbill	3	M89263	BN52	13-Jun-18	06:49	18-Jun-18	13:08	Brooding chick	NA	NA
59	Razorbill	3	M89264	BN51	13-Jun-18	06:48	18-Jun-18	14:14	Brooding chick	NA	NA
60	Razorbill	3	M89265	BN96	13-Jun-18	07:03	18-Jun-18	14:20	Brooding chick	2019	Yes
61	Razorbill	3	M89271	BN56	13-Jun-18	06:51	19-Jun-18	13:56	Unknown	NA	NA
62	Razorbill	3	M89273	BN95	13-Jun-18	07:02	19-Jun-18	14:04	Incubating egg	NA	NA
63	Razorbill	3	M89274	BN102	13-Jun-18	07:08	19-Jun-18	14:08	Brooding chick	NA	NA
64	Razorbill	3	M89277	BN87	13-Jun-18	06:57	19-Jun-18	14:26	Incubating egg	NA	NA
65	Razorbill	3	M89283	BN83	13-Jun-18	06:54	19-Jun-18	14:51	Unknown	NA	NA
66	Razorbill	3	M89284	BN89	13-Jun-18	06:59	19-Jun-18	14:57	Brooding chick	NA	NA
67	Razorbill	3	M89254	BN50	13-Jun-18	06:47	17-Jun-18	15:25	Brooding chick	NA	NA
68	Razorbill	3b	M89258	BN94	13-Jun-18	07:02	18-Jun-18	12:13	Brooding chick	NA	NA
69	Razorbill	3b	M89262	BN54	13-Jun-18	06:50	18-Jun-18	12:45	Brooding chick	NA	NA

Table A2b: geolocator deployment details for Buchan Ness to Collieston Coast in 2018. Start date and start time denote the start of data collection.

n	Species	Site	BTO ring	Logger ID	Start date	Start time	Deployment date	Deployment Time	Nest Status	Year retrieved	Deployment successful
1	Guillemot		T23762	B3854	12-Jun-18	19:23	19-Jun-18	19:53	Unknown	NA	NA
2	Guillemot	1	T23764	B3869	12-Jun-18	19:30	23-Jun-18	11:40	Brooding chick	NA	NA
3	Guillemot		T23769	B3879	12-Jun-18	20:34	24-Jun-18	18:22	Brooding chick	NA	NA
4	Guillemot		T23771	B3867	12-Jun-18	19:29	24-Jun-18	18:17	Brooding chick	2019	Yes
5	Guillemot		T23777	B3881	12-Jun-18	20:35	24-Jun-18	18:19	Brooding chick	2019	Yes
6	Guillemot	1	T23778	B3872	12-Jun-18	19:31	24-Jun-18	16:41	Brooding chick	NA	NA
7	Guillemot	1	T23785	B3883	12-Jun-18	20:36	23-Jun-18	14:10	Unknown	2019	Yes
8	Guillemot	1	T23786	B3874	12-Jun-18	20:32	23-Jun-18	11:28	Brooding chick	2019	Yes
9	Guillemot	1	T23787	B3890	12-Jun-18	20:39	23-Jun-18	14:16	Brooding chick	2019	Yes
10	Guillemot	1	T23789	B3858	12-Jun-18	19:25	24-Jun-18	17:11	Brooding chick	NA	NA
11	Guillemot	1	T23790	B3875	12-Jun-18	20:33	23-Jun-18	13:43	Brooding chick	NA	NA
12	Guillemot	1	T23793	B3855	12-Jun-18	19:24	23-Jun-18	10:49	Brooding chick	2019	Yes
13	Guillemot	1	T23794	B3861	12-Jun-18	19:26	19-Jun-18	19:51	Unknown	NA	NA
14	Guillemot	1	T23795	B3862	12-Jun-18	19:27	19-Jun-18	19:41	Brooding chick	2019	No
15	Guillemot	1	T23797	B3868	12-Jun-18	19:29	19-Jun-18	19:22	Brooding chick	2019	Yes
16	Guillemot	1	T23798	B3876	12-Jun-18	20:33	23-Jun-18	13:59	Brooding chick	NA	NA
17	Guillemot	1	T23800	B3856	12-Jun-18	19:24	19-Jun-18	20:00	Brooding chick	2019	Yes
18	Guillemot		T70757	B3887	12-Jun-18	20:38	23-Jun-18	12:56	Brooding chick	2019	Yes
19	Guillemot	1	T70810	B3864	12-Jun-18	19:27	19-Jun-18	19:20	Brooding chick	2019	Yes
20	Guillemot		T70818	B3889	12-Jun-18	20:39	24-Jun-18	18:13	Brooding chick	2019	Yes
21	Guillemot	1	T70901	B3857	12-Jun-18	19:24	19-Jun-18	20:03	Unknown	NA	NA
22	Guillemot	1	T70903	B3880	12-Jun-18	20:35	23-Jun-18	13:23	Brooding chick	2019	Yes
23	Guillemot	1	T70904	B3866	12-Jun-18	19:28	19-Jun-18	19:45	Brooding chick	2019	Yes
24	Guillemot	1	T70905	B3860	12-Jun-18	19:26	19-Jun-18	19:49	Unknown	2019	Yes
25	Guillemot	1	T70906	B3888	12-Jun-18	20:38	24-Jun-18	17:37	Brooding chick	2019	Yes
26	Guillemot	1	T70911	B3877	12-Jun-18	20:33	23-Jun-18	13:35	Brooding chick	NA	NA
27	Guillemot		T70915	B3878	12-Jun-18	20:34	23-Jun-18	11:42	Brooding chick	2019	Yes
28	Guillemot		T70916	B3882	12-Jun-18	19:36	24-Jun-18	16:53	Brooding chick	NA	NA
29	Guillemot		T70917	B3863	12-Jun-18	19:27	24-Jun-18	17:33	Brooding chick	2019	Yes
30	Guillemot		T70918	B3865	12-Jun-18	19:28	24-Jun-18	18:06	Brooding chick	2019	Yes
31	Guillemot		T70919	B3870	12-Jun-18	19:30	24-Jun-18	18:10	Brooding chick	NA	NA
32	Guillemot		T70920	B3893	12-Jun-18	20:40	24-Jun-18	18:20	Brooding chick	NA	NA
33	Guillemot		T70921	B3886	12-Jun-18	20:37	24-Jun-18	18:25	Brooding chick	2019	Yes
34	Guillemot		T70922	B3891	12-Jun-18	20:39	24-Jun-18	18:27	Brooding chick	NA	NA
35	Guillemot		T70923	B3884	12-Jun-18	20:36	24-Jun-18	18:29	Brooding chick	NA	NA
36	Guillemot	1	T70956	B3873	12-Jun-18	19:32	23-Jun-18	11:59	Brooding chick	2019	Yes
37	Guillemot		T70958	B3885	12-Jun-18	20:37	24-Jun-18	18:31	Brooding chick	2019	Yes
38	Guillemot		T70960	B3892	12-Jun-18	20:40	24-Jun-18	18:08	Brooding chick	NA	NA
39	Guillemot	1	T70961	B3871	12-Jun-18	19:31	19-Jun-18	20:16	Brooding chick	2019	Yes
40	Guillemot	1	T70962	B3859	12-Jun-18	19:25	23-Jun-18	11:06	Brooding chick	NA	NA
41	Razorbill	3	M88609	BN41	13-Jun-18	05:59	24-Jun-18	20:38	Brooding chick	NA	NA
42	Razorbill	4	M88621	BN48	13-Jun-18	06:04	24-Jun-18	19:07	Brooding chick	NA	NA
43	Razorbill	4	M88622	BN39	13-Jun-18	05:57	24-Jun-18	19:27	Brooding chick	NA	NA
44	Razorbill	4	M88623	BN36	13-Jun-18	05:55	24-Jun-18	19:30	Brooding chick	2019	Yes
45	Razorbill	3	M88624	BN49	13-Jun-18	06:04	24-Jun-18	20:38	Brooding chick	NA	NA
46	Razorbill	4	M88625	BN30	13-Jun-18	05:50	01-Jul-18	17:58	Brooding chick	NA	NA
47	Razorbill	3	M88626	BN31	13-Jun-18	05:51	01-Jul-18	19:05	Brooding chick	NA	NA
48	Razorbill	3	M88627	BN32	13-Jun-18	05:52	01-Jul-18	19:30	Brooding chick	NA	NA
49	Razorbill	3	M88628	BN33	13-Jun-18	05:53	01-Jul-18	20:03	Brooding chick	NA	NA
50	Razorbill	4	M88629	BN34	13-Jun-18	05:54	08-Jul-18	14:10	Brooding chick	NA	NA
51	Razorbill	4	M88630	BN45	13-Jun-18	06:01	17-Jul-18	12:00	Brooding chick	NA	NA
52	Razorbill	4	M88631	BN37	13-Jun-18	05:56	17-Jul-18	12:49	Brooding chick	2019	Yes
53	Razorbill	4	M88632	BN47	13-Jun-18	06:03	17-Jul-18	13:04	Brooding chick	2019	Yes
54	Razorbill	4	M88633	BN44	13-Jun-18	06:01	17-Jul-18	13:22	Brooding chick	NA	NA
55	Razorbill	4	M88634	BN42	13-Jun-18	06:00	17-Jul-18	14:56	Brooding chick	NA	NA
56	Razorbill	4	M88635	BN35	13-Jun-18	05:54	19-Jul-18	13:50	Brooding chick	NA	NA
57	Razorbill	4	M88636	BN40	13-Jun-18	05:58	19-Jul-18	15:05	Brooding chick	NA	NA
58	Razorbill	4	M88637	BN46	13-Jun-18	06:02	19-Jul-18	15:42	Brooding chick	2019	Yes
59	Razorbill	3	M88638	BN38	13-Jun-18	05:57	19-Jul-18	17:55	Unknown	2019	Yes

Table A2c: geolocator deployment details for Isle of May in 2018. Start date and start time denote the start of data collection. Deployments on guillemots were carried out as part of the SEATRACK project.

n	Species	Site	BTO ring	Logger ID	Start date	Start time	Deployment date	Deployment Time	Nest Status	Year retrieved	Deployment successful
1	Guillemot	3	R76644	B3472	16-Apr-18	14:50	27-Jun-18	12:00	Brooding chick	NA	NA
2	Guillemot	3	R03499	B3473	16-Apr-18	14:51	27-Jun-18	12:00	Brooding chick	2019	Yes
3	Guillemot	3	Y09073	B3474	16-Apr-18	14:51	27-Jun-18	12:00	Brooding chick	2019	Yes
4	Guillemot	9	R76260	B3475	16-Apr-18	14:52	27-Jun-18	12:00	Brooding chick	2019	Yes
5	Guillemot	9	R76638	B3476	16-Apr-18	14:52	27-Jun-18	12:00	Brooding chick	2019	Yes
6	Guillemot	3	X80054	B3477	16-Apr-18	14:53	01-Jul-18	11:00	Brooding chick	2019	Yes
7	Guillemot	3	Y09105	B3478	16-Apr-18	14:53	01-Jul-18	11:00	Brooding chick	NA	NA
8	Guillemot	3	R02615	B3479	16-Apr-18	14:54	01-Jul-18	11:00	Brooding chick	2019	Yes
9	Guillemot	9	R76090	B3480	16-Apr-18	14:54	04-Jul-18	11:00	Brooding chick	NA	NA
10	Guillemot	9	Y09072	B3481	16-Apr-18	14:55	04-Jul-18	11:00	Brooding chick	NA	NA
11	Guillemot	9	X80140	B3482	16-Apr-18	14:55	04-Jul-18	15:00	Brooding chick	2019	Yes
12	Guillemot	9	X53431	B3483	16-Apr-18	14:56	05-Jul-18	09:00	Brooding chick	NA	NA
13	Guillemot	9	Y09008	B3484	16-Apr-18	14:56	05-Jul-18	10:30	Brooding chick	2019	Yes
14	Guillemot	4	Y09124	B3485	16-Apr-18	14:57	05-Jul-18	10:30	Brooding chick	NA	NA
15	Guillemot	4	R01694	B3486	16-Apr-18	14:57	05-Jul-18	10:30	Brooding chick	2019	Yes
16	Guillemot	4	R76319	B3487	16-Apr-18	14:58	06-Jul-18	10:30	Brooding chick	NA	NA
17	Guillemot	4	Y09127	B3488	16-Apr-18	14:58	05-Jul-18	15:00	Brooding chick	NA	NA
18	Guillemot	3	R76263	B3489	16-Apr-18	14:58	01-Jul-18	11:00	Brooding chick	NA	NA
19	Guillemot	3	Y09126	B3490	16-Apr-18	14:59	06-Jul-18	09:00	Brooding chick	NA	NA
20	Guillemot	9	R02610	B3996	25-Jun-18	18:42	05-Jul-18	09:00	Brooding chick	2019	Yes
21	Guillemot	9	Y09106	B3997	25-Jun-18	18:42	04-Jul-18	15:00	Brooding chick	NA	NA
22	Guillemot	9	Y09010	B3998	25-Jun-18	18:43	04-Jul-18	15:00	Brooding chick	2019	Yes
23	Guillemot	3	R03179	B3999	25-Jun-18	18:43	04-Jul-18	15:00	Brooding chick	2019	Yes
24	Guillemot	9	Y09104	B4000	25-Jun-18	18:44	04-Jul-18	15:00	Brooding chick	NA	NA
25	Guillemot	9	Y09107	B4001	25-Jun-18	18:44	04-Jul-18	15:00	Brooding chick	2019	Yes
26	Guillemot	9	Y09118	B4002	25-Jun-18	18:45	05-Jul-18	10:30	Brooding chick	2019	Yes
27	Guillemot	9	Y09109	B4003	25-Jun-18	18:45	05-Jul-18	09:00	Brooding chick	NA	NA
28	Guillemot	9	R76657	B4004	25-Jun-18	18:48	05-Jul-18	09:00	Brooding chick	2019	Yes
29	Guillemot	9	Y09121	B4005	25-Jun-18	18:48	05-Jul-18	10:30	Brooding chick	NA	NA
30	Guillemot	9	R23421	B4006	25-Jun-18	18:49	05-Jul-18	09:00	Brooding chick	2019	Yes
31	Guillemot	9	Y09108	B4007	25-Jun-18	18:49	05-Jul-18	09:00	Brooding chick	NA	NA
32	Guillemot	9	Y09119	B4010	26-Jun-18	13:28	05-Jul-18	10:30	Brooding chick	2019	Yes
33	Guillemot	4	Y09125	B4011	26-Jun-18	13:30	05-Jul-18	10:30	Brooding chick	2019	Yes
34	Guillemot	9	Y09120	B4013	26-Jun-18	13:31	05-Jul-18	10:30	Brooding chick	NA	NA
35	Razorbill	2	M82440	BN000	13-Jun-18	05:24	26-Jun-18	07:30	Brooding chick	NA	NA
36	Razorbill	2	M84641	BN001	13-Jun-18	05:25	26-Jun-18	07:50	Brooding chick	NA	NA
37	Razorbill	2	M82448	BN002	13-Jun-18	05:26	26-Jun-18	08:05	Brooding chick	2019	Yes
38	Razorbill	4	M84674	BN003	13-Jun-18	05:27	27-Jun-18	07:00	Brooding chick	2019	Yes
39	Razorbill	2	M84675	BN004	13-Jun-18	05:28	27-Jun-18	07:20	Brooding chick	NA	NA
40	Razorbill	3	M84676	BN005	13-Jun-18	05:28	27-Jun-18	07:50	Brooding chick	2019	Yes
41	Razorbill	8	M84677	BN006	13-Jun-18	05:29	27-Jun-18	08:10	Brooding chick	NA	NA
42	Razorbill	1	M84652	BN007	13-Jun-18	05:30	27-Jun-18	16:30	Brooding chick	NA	NA
43	Razorbill	1	M82449	BN008	13-Jun-18	05:31	27-Jun-18	17:00	Brooding chick	2019	Yes
44	Razorbill	3	M84643	BN009	13-Jun-18	05:31	27-Jun-18	17:20	Brooding chick	2019	Yes
45	Razorbill	10	M84678	BN010	13-Jun-18	05:32	28-Jun-18	07:40	Brooding chick	NA	NA
46	Razorbill	2	M84679	BN011	13-Jun-18	05:33	28-Jun-18	08:10	Brooding chick	NA	NA
47	Razorbill	3	M84680	BN012	13-Jun-18	05:33	28-Jun-18	08:30	Brooding chick	NA	NA
48	Razorbill	6	M84644	BN013	13-Jun-18	05:34	28-Jun-18	09:00	Brooding chick	NA	NA
49	Razorbill	5	M84636	BN014	13-Jun-18	05:35	28-Jun-18	09:20	Brooding chick	2019	Yes
50	Razorbill	6	M84681	BN015	13-Jun-18	05:36	28-Jun-18	12:00	Brooding chick	2019	Yes
51	Razorbill	4	M84682	BN016	13-Jun-18	05:37	28-Jun-18	17:00	Brooding chick	NA	NA
52	Razorbill	2	M84683	BN017	13-Jun-18	05:37	28-Jun-18	20:20	Brooding chick	NA	NA
53	Razorbill	10	M84684	BN018	13-Jun-18	05:38	28-Jun-18	20:55	Brooding chick	2019	Yes
54	Razorbill	8	M84685	BN019	13-Jun-18	05:39	29-Jun-18	09:00	Brooding chick	NA	NA
55	Razorbill	7	M84647	BN020	13-Jun-18	05:40	29-Jun-18	09:40	Brooding chick	2019	Yes
56	Razorbill	1	M84654	BN021	13-Jun-18	05:40	29-Jun-18	09:50	Incubating egg	NA	NA
57	Razorbill	4	M84686	BN022	13-Jun-18	05:41	29-Jun-18	10:01	Unknown	NA	NA
58	Razorbill	10	M51471	BN023	13-Jun-18	05:42	29-Jun-18	10:15	Brooding chick	NA	NA
59	Razorbill	6	M84687	BN024	13-Jun-18	05:45	30-Jun-18	08:40	Brooding chick	2019	Yes
60	Razorbill	11	M84688	BN025	13-Jun-18	05:46	30-Jun-18	09:00	Brooding chick	NA	NA
61	Razorbill	10	M84689	BN026	13-Jun-18	05:47	30-Jun-18	11:15	Brooding chick	2019	Yes
62	Razorbill	1	M84633	BN027	13-Jun-18	05:48	30-Jun-18	11:13	Incubating egg	NA	NA
63	Razorbill	3	M84690	BN028	13-Jun-18	05:49	30-Jun-18	12:14	Brooding chick	NA	NA
64	Razorbill	3	M84691	BN029	13-Jun-18	05:49	30-Jun-18	14:10	Brooding chick	NA	NA

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