FIVE ESTUARIES OFFSHORE WIND FARM

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PRELIMINARY ENVIRONMENTAL INFORMATION REPORT

VOLUME 4, ANNEX 4.10: DIGITAL VIDEO AERIAL SURVEYS OF SEABIRDS AND MARINE MAMMALS AT FIVE ESTUARIES: ANNUAL REPORT FOR MARCH 2019 TO FEBRUARY 2020

Document Reference	004685530-01
Revision	A
Date	October 2020

Project	Five Estuaries Offshore Wind Farm
Sub-Project or Package	Preliminary Environmental Information Report
Document Title	Volume 4, Annex 4.10: Digital Video Aerial Surveys of Seabirds and Marine Mammals at Five Estuaries: Annual Report for March 2019 to February 2020
Document Reference	004685530-01
Revision	A

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Revision	Date	Status/Reason for Issue	Originator	Checked	Approved
A	Oct-20	Final for PEIR	HiDef	GoBe	VE OWFL

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Executive Summary

In February 2019, Five Estuaries Offshore Wind Farm Limited commissioned HiDef Aerial Surveying Limited ('HiDef') to undertake a programme of high-resolution digital video aerial surveys of marine megafauna, ornithological and human activity to characterise the baseline environment for a proposed extension to the Galloper wind farm (the 'Five Estuaries Offshore Wind Farm').

The Five Estuaries (VE) wind farm is located approximately 35 km east of the Suffolk coast in the North Sea.

Monthly surveys were flown from March 2019 to February 2020.This equated to 12 surveys in total, comprising the first full year of surveying. An additional 12 monthly surveys will be undertaken between March 2020 and February 2021. HiDef designed a survey that placed transects at 2.5km apart across the survey area, including a 4km buffer around the proposed extension site ('the survey area').

The HiDef surveys were undertaken using an aircraft equipped with four (4) HiDef Gen II cameras with sensors set to a resolution of 2 centimetres ('cm') Ground Sample Distance ('GSD'). Each camera sampled a strip of 125m width, separated from the next camera by ~25m, which provides a combined sampled width of 500m within a 575m overall strip. To ensure that sufficient footage is available to allow either a design-based or model-based analysis, footage from two (2) to three (3) cameras was analysed. The remaining footage has been archived.

Data analysis followed a two-stage process in which video footage is reviewed (with a 20% random sample used for audit) then the detected objects are identified to species or species group level (again with 20% selected at random for audit). The audit of both stages requires 90% agreement to be achieved.

Density and abundance estimates were calculated using strip transect analysis and a statistical technique called kernel density estimation ('KDE') was used to create density surface maps. In addition, known diving rates of certain seabirds were used to estimate the proportion of diving seabird species that would be underwater at the time of survey.

Surveys were successful in characterising the bird and mammal species present across the VE survey area, recording a total 6027 birds of 19 species and 266 marine mammals of two species over twelve months. An average identification rate to species level of 91.35% was achieved across the survey programme.

The primary observation from the surveys are that:

- Fulmar *Fulmarus glacialis* observations peaked in August and September;
- Gannet *Morus bassanus* were present within the survey area, with the highest counts observed in late autumn, suggesting migrant birds;
- Kittiwakes *Rissa tridactyla* were one of the most abundant species recorded during the surveys with the highest density occurring in March;
- Lesser black-backed gull were most abundant in the survey area during summer;
- The most abundant species recorded throughout the survey period was guillemot *Uria aalge* with high density estimates in winter, but low numbers recorded during summer and autumn months;
- Moderate density estimates of razorbill *Alca torda* were recorded with peak densities in winter; and

- Harbour porpoise *Phocoena phocoena* were the most abundant marine mammal recorded at the survey site

The distribution maps for all species show no clear regular patterns between surveys to give any clear suggestion that one part of the study area might be more important than any other; however, activity tended to be most concentrated in the southern array area for several species.

The work undertaken by HiDef has collected twelve months' continuous data towards satisfying the survey requirements for the consent application. This is the first annual report, with an additional 12 months of surveying still to be conducted (24 months in total).

1 Introduction

1 Galloper Wind Farm (GWF), run by RWE Renewables, is an operational offshore wind farm with 56 wind turbines, located adjacent to the operational Greater Gabbard Offshore Wind Farm (GGOW) in the Outer Thames Estuary, approximately 27km from the Suffolk Coast.

2 In February 2019, Five Estuaries Offshore Wind Farm Limited commissioned HiDef Aerial Surveying Limited ('HiDef') to undertake a programme of high-resolution digital video aerial surveys of marine megafauna, ornithological and human activity to characterise the baseline environment for a proposed eastward extension to the Galloper wind farm (the 'Five Estuaries Offshore Wind Farm').

3 HiDef designed the survey methodology to provide information suitable to make an accurate assessment of abundance and distribution of seabirds and marine mammals in order to enable an environmental impact assessment of the Five Estuaries (VE) project. Surveys were conducted across both the VE array and a surrounding 4km buffer (hereafter 'the survey area').

4 A number of important bird sites which have been classified as Special Protection Areas ('SPA') under the European Council ('EC') Directive 2009/147/EC on the Conservation of Wild Birds ('the Birds Directive') are in the vicinity of the survey area. Alde-Ore Estuary SPA lies to the north west of the development site and is important for avocet *Recurvirostra avosetta*, redshank *Tringa totanus*, ruff *Calidris pugnax* and Sandwich tern *Sterna sandvicensis*. It is important both as a feeding and breeding area. The saltmarsh within the SPA is also important for nesting lesser black-backed gulls *Larus fuscus*. The latter has been flagged by nature conservation bodies as the main concern in relation to Galloper.

5 The Outer Thames SPA to the west of the survey area is designated for non-breeding red-throated diver *Gavia stellata* and is also in close proximity to the Galloper offshore wind farm. The site is also important for breeding common tern *Sterna hirundo* and little tern *Sternula albifrons* in summer.

6 Other migratory and transient bird species are also known to occur in the area, requiring year-round surveys to be carried out in order to characterise their abundance.

7 The project area is also likely to be visited by marine mammals, with harbour porpoise *Phocoena phocoena* the most numerous. The survey area itself is located within the winter area of the Southern North Sea Special Area of Conservation ('SAC'), which is designated under the European Commission Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna ('the Habitats Directive') to protect this Annex II species.

8 This report ('the annual report') provides the results from the twelve (12) surveys undertaken between March 2019 and February 2020. Analysis is presented in the form of raw results, density surface distribution maps and abundance estimates with confidence estimates, summarised data on behaviour, age and flight direction. A discussion has also been provided as to the representativeness of the results. Data collection is ongoing, with a further 12 months of additional surveys projected for between March 2020 and February 2021.

2 Methods

2.1 Survey flights

9 A series of strip transects was flown on a monthly basis between March 2019 and February 2020, following the protocol agreed between Five Estuaries Offshore Wind Farm Limited and HiDef in February 2019 (document reference: HP00100-001).

10 For this reason, HiDef designed a survey that placed transects at 2.5km apart across the survey area, which includes a 4km buffer around the VE array site.

11 The strip transects were placed approximately perpendicular to the depth contours along the coast. Such a design helps to ensure that each transect samples a similar range of habitats (primarily relating to water depth) and will reduce the difference in bird and mammal abundance estimates for each transect.

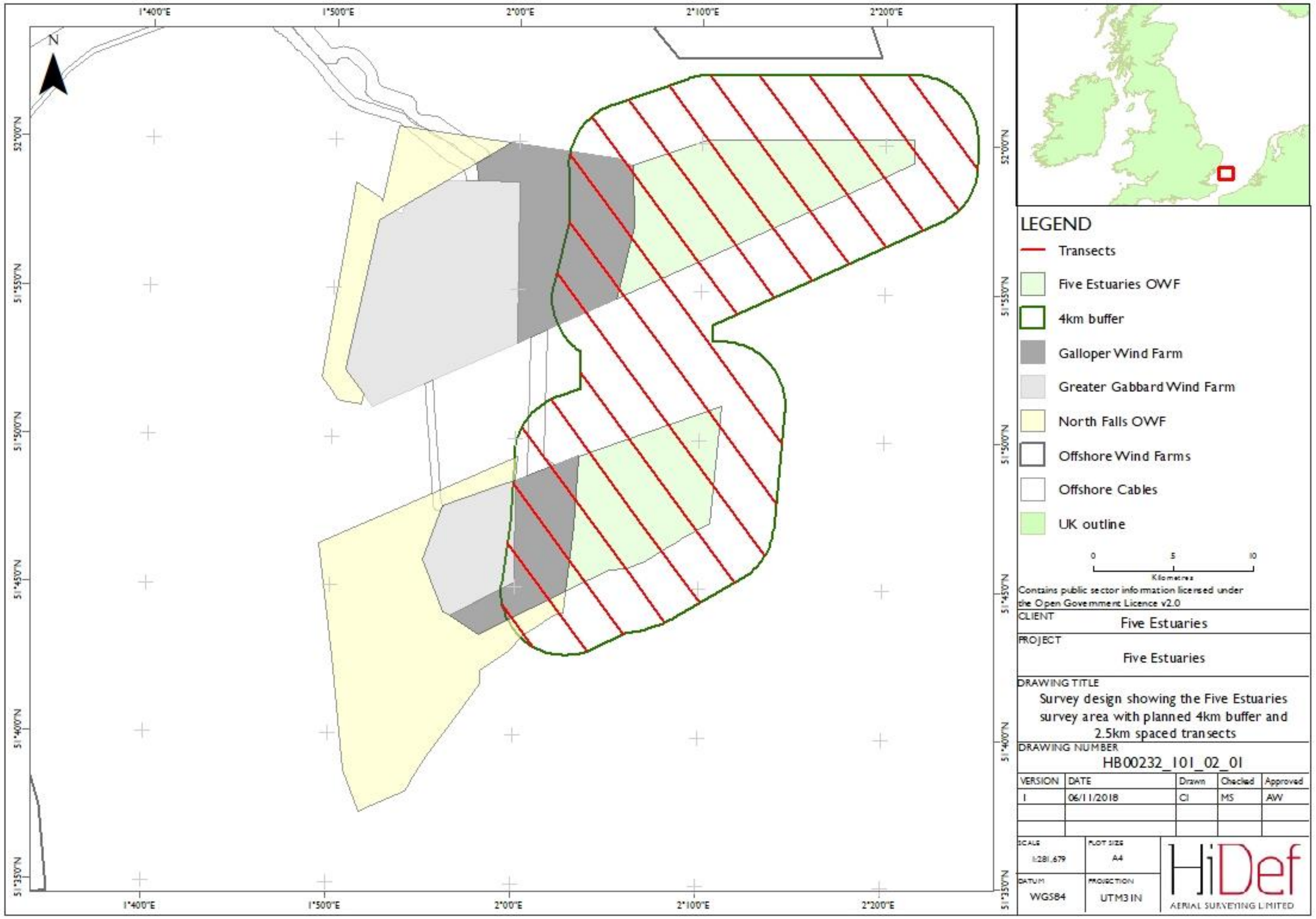
12 Surveys were undertaken using an aircraft equipped with four (4) HiDef Gen II cameras with sensors set to a resolution of 2 centimetres ('cm') Ground Sample Distance ('GSD'). Each camera sampled a strip of 125m width, separated from the next camera by ~25m, thus providing a combined sampled width of 500m within a 575m overall strip.

13 A minimum target of 10% site coverage was set, with the following survey effort agreed between HiDef and VE. Across three (3) winter months (October, November and January) 10% site coverage was achieved over the site, with data from two (2) cameras processed. Due to concurrent surveys across Galloper PCM, a supernumerary 15% site coverage was achieved for all other months (March to September, December and February), with data from three (3) cameras processed for these nine (9) surveys. This ensured a survey with sufficient coverage and number of transects, with the remaining unprocessed data archived.

14 The surveys were flown along the transect pattern shown in Figure 1 at a height of approximately 550m above sea level ('ASL') (~1800'). Flying at this height ensures that there is no risk of flushing those species which have been proven to be easily disturbed by aircraft noise (Thaxter *et al*. 2016) recommends a minimum flight altitude of 500m ASL).

15 Position data for the aircraft was captured from a Garmin GPSMap 296 receiver with differential GPS enabled to give 1m accuracy for the positions and recording updates in location at one second intervals for later matching to bird and marine mammal observations.

Figure 1 Survey design showing the VE survey area with planned 4km buffer and 2.5km spaced transects



2.2 Data Review and Object Detection

16 Data were viewed by trained reviewers who marked any objects in the footage as requiring further analysis, as well as determining which are birds, marine megafauna (defined within this report as cetaceans, pinnipeds or other large, non-avian marine fauna) or anthropogenic objects such as ships or buoys.

17 As part of HiDef's quality assurance ('QA') process, an additional 'blind' review of 20% of the raw data was carried out and the results compared with those of the original review. If 90% agreement is not attained during the QA process, then corrective action is initiated: the remaining data set is reviewed and where appropriate, the failed reviewer's data discarded and all the data re-reviewed. In addition, additional training is then given to the reviewer to improve performance. No re-reviews were required for the data set.

18 An object is only recorded where it reaches a reference line (known as 'the red line') which defines the true transect width of 125m for each camera. By excluding objects that do not cross the red line, biases to abundance estimates caused by flux (movement of objects in the video footage relative to the aircraft, such as 'wing wobble') are eliminated.

2.3 Object Identification

19 Images marked as requiring further analysis were reviewed by specialist ornithologists[1] and marine mammal specialists[2] for identification to the lowest taxonomic level possible and for assessment of the approximate age and the sex of each animal, as well as any behaviour traits visible from the imagery.

20 At least 20% of all objects were selected at random and subjected to a separate 'blind' QA process. If less than 90% agreement was attained for any individual camera then corrective action is initiated: if appropriate, the failed identifier's data were discarded and the data re-identified. Any disputed identifications were passed to a third-party expert ornithologist for a final decision[1]. The level of agreement within the QA process is calculated as the final number of agreements as a percentage of all identifications subjected for QA for the entire survey.

21 All objects were assigned to a species group and where possible, each of these then further identified to species level. The species identifications were given a confidence rating of 'possible', 'probable' or 'definite'[3].

22 It is important to note that these confidence ratings are not a standardised assessment and thus an estimate of probability cannot be applied to identification reliability. The likelihood of achieving a definite or probable identification is not consistent for all component members of a species group. For example, someone undertaking identification of a large auk species may find it easier to be confident of a guillemot identification than a razorbill. Confidence scores should not be used to filter or weight the probability

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1 HiDef currently employs three (3) of the ten (10) current members of the British Birds Rarities Committee ('BBRC') as expert ornithologists

2 HiDef staff have long-standing experience in marine mammal identification, regularly undertaking boat surveys as part of ESAS (European Seabirds At Sea Partnership). They process thousands of cetacean images, hold regular internal training sessions and have access to marine specialists within our wider company BioConsult SH.

3 Definite: as certain as reasonably possible. Probable: very likely to be this species or species group. Possible: more likely to be this species or species group than anything else.

of 'large auk' being one species or another in any analysis, as this will lead to biased results, particularly if the identification rate is low.

23 Any animals that could not be identified to species level were assigned to a category 'No ID'. If, on occasion, the unidentified bird is suspected of belonging to two different possible genera, then a broader group category may be used. For example, a bird would usually be assigned to the group category 'Shearwater species' if identified as a Manx shearwater *Puffinus puffinus*, or to 'Auk species' if identified as a guillemot. However, if the bird has the potential to be either, then it would be assigned to the group category 'Shearwater / Auk species' and the species level recorded as 'No_ID'.

24 In the case of birds, additional information was recorded on basic behaviour (whether the bird was sitting, loafing on land or other objects or flying). More detail was recorded where possible on foraging behaviour, approximate age and sex and any other details of interest. Aging of birds was based on moults and is thus mostly conducted on flying individuals and species which show seasonal variation in plumage.

25 Marine mammals and other marine megafauna were recorded using the same process. Animals were first assigned to a species group (e.g. 'cetacean species') and then given a species level identification (e.g. 'harbour porpoise', 'minke whale' or 'No ID'). If a precise species group could not be ascertained, then the record was assigned to a broader group category (e.g. 'seal or small cetacean') and the species level recorded as 'No ID'. In the case of marine mammals, surfacing behaviour was also recorded as either 'surfacing', 'surfacing at red line', 'submerged' or 'unknown'. Surfacing behaviour was defined as any part of the non-avian animal's body breaking the surface of the water in any frame. However, for the purposes of calculating availability bias, harbour porpoise surfacing behaviour was also classified if the animal's dorsal fin was above the water in the frame nearest to the 'red line' on the operator's screen ('surfacing at red line'). Sexing and aging of marine mammals was carried out where possible.

26 Anthropogenic activity was recorded as either 'man-made object', 'fishing boat' or 'other boat'. Further details were noted in the comments, including further specifying the type of object (e.g. 'fishing buoy', 'marker buoy', 'wind turbine') or noting any names and numbers that can be seen.

2.4 Data quality check

27 HiDef's method is designed to ensure low rejection of data on grounds of quality, such as low cloud, sun glare or other issues. Care is taken to avoid survey in low cloud or poor visibility by careful selection of survey days with the correct survey conditions. In the unlikely event that low cloud occurs during a survey, the pilot is instructed to either avoid areas affected and return to those at the end of the survey, return to a nearby base and wait for cloud to clear or abandon the survey. Sun glare is avoided by design of the survey rig which uses angled cameras on a rotating plinth. This means that the cameras are angled away from any sun glare at all times, with the camera rig rotated in between transects to ensure that this angle is maintained.

28 All data undergoes a full check on return to the office consisting of a review of every camera and every transect. Any issues that may affect usability of the data are flagged at this stage may result in a re-fly of the survey.

29 Glare is recorded on all cameras throughout the survey. For each individual survey, on one of the cameras (known as the 'weather camera' the following weather conditions are also recorded – sea state and turbidity. Operators carrying out bird and mammal identification carry out environmental checks of the data and score sun glare and turbidity on a scale from 1 - 4 in which score 4 is a high degree of sun glare or turbidity in which the data should not be used because it would affect detection rates. Sea

state is scored based on the WMO Sea State code, in which score 6 or more is a high degree of sea state in which the data should not be used as it would affect detection rates.

30 Tables are provided below to show how glare, sea state and turbidity are scored.

Table 1 Scoring criteria for recording glare and turbidity

Score	Criteria
0	Can't tell / Not Recorded / Over land
1	None present
2	Slight
3	Moderate
4	Strong

Table 2 Scoring criteria for recording sea state as outlined by the WMO Sea State code

WMO Sea State Code	Wave height	Characteristics
0	0 metres (0ft)	Calm (glassy)
1	0 to 0.1 metres (0.00 to 0.33ft)	Calm (rippled)
2	0.1 to 0.5 metres (3.9in to 1ft 7.7in)	Smooth (wavelets)
3	0.5 to 1.25 metres (1ft 8in to 4ft 1in)	Slight (first whitecaps)
4	1.25 to 2.5 metres (4ft 1in to 8ft 2in)	Moderate (many whitecaps)
5	2.5 to 4 metres (8ft 2in to 13ft 1in)	Rough (some spray)
6	4 to 6 metres (13 to 20ft)	Very rough (large waves, many whitecaps, much spray)
7	6 to 9 metres (20 to 30ft)	High (streaks of wind-blown foam)
8	9 to 14 metres (30 to 46ft)	Very high
9	Over 14 metres (46ft)	Phenomenal

2.5 Final processing

31 All data were geo-referenced, taking into account the offset from the transect line of the cameras, and compiled into a single output; Geographical Information System ('GIS') files for the Observation and Track data are issued in ArcGIS shapefile format, using UTM31N projection, WGS84 datum.

2.6 Data analysis

2.6.1 Data treatment

32 All observations were compiled for analysis and presentation. Records identified to species level were separated out from records of partially identified individuals to group level only, and the following analyses undertaken on both datasets. No apportioning of 'partially identified' birds or mammals to species level was undertaken. All confidence levels of species identifications were used in the analysis.

In the analysis of species groups, rationalisation of the full list of species groups was carried out to simplify the interpretation.

33 Using the observation data, the total number of records found during the strip transect surveys was calculated and seasonal abundance graphs created. Where available, behaviour and age data was compiled and presented in tables.

2.6.2 Population and density estimates

34 After raw totals were calculated, the same data were then used to estimate population (the total number of individuals estimated to exist within the survey area) and density estimates as follows.

35 In a strip transect analysis, each transect is treated as an independent analysis unit, and the assumption is made that transects can be treated as statistically independent random samples from the site. The length of each transect and its breadth (i.e. the width of the field of view of the camera) multiplied together give the transect area; dividing the number of observations on that transect by the transect area gives a point estimate of the density of that species for the site. The density of animals at the site (and hence the population size), the standard deviation, 95% confidence intervals ('CI') and coefficient of variance ('CV') are then estimated using a non-parametric bootstrap method with replacement (Buckland *et al.*, 2001).

36 The upper and lower 95% confidence intervals were calculated by way of a blocked bootstrapping technique to ensure equal transect effort was sampled across each iteration. This was done by using transect ID as the sampling unit with replacement, and then randomly sampling until the total length of the sampled transects equalled approximately the same length as the total survey length. A total of 5,000 bootstrap iterations were performed from which we calculated the mean and standard deviation of the sampled means, as well as the relative standard error as defined by the standard deviation divided by the mean. Data were processed in the R programming language (version 3.4.3) and code can be provided on request. For most species these abundance estimates relate to absolute abundance, but for diving species (auks and marine mammals) the abundance relates to relative abundance. In Section 2.6.4 we describe our method for taking account of availability, which provides a reasonable measure of absolute abundance.

37 The density estimate is expressed as the average number of animals per square km surveyed over the whole study area or the project area, and the population estimate is then calculated as the density multiplied up to the area of the whole survey area (project area with 4 km buffer). The upper and lower CI define the range that the population estimate falls within with 95% certainty. The CV, also referred to as the relative standard error, is a measure of the precision of the population and density estimates.

2.6.3 Availability bias

38 In wildlife surveys, a proportion of seabirds or marine mammals that spend any time underwater, especially while feeding, will not be detectable at the surface. This may lead to an under-estimate of their abundance during surveys, which is known as 'availability bias'. For species that make long dives underwater, this bias might be significant (for example, shag).

39 There are two main approaches to accounting for availability bias: by using double platform surveys (for example Borchers et al. 2002) which is logistically difficult to achieve and relatively expensive; and by using known data on time spent underwater to apply correction factors to abundance estimates (for example Barlow et al., 1988).

40 Barlow used an equation to determine the proportion of time that an animal is not available in equation 1:

$$\Pr(being\ visible) = \frac{(s+t)}{(s+d)}$$

Where *s* is the average time spent below the surface, *t* is the window of time that the animal is within view and *d* is the average time spent at the surface. In the case of digital video surveys, the value of *t* is negligibly small and is treated as 0.

41 Due to a lack of diving rate data for many species, availability bias corrections were only conducted on four species: guillemots, razorbills, puffins and harbour porpoises.

2.6.3.1 Seabirds

42 All available data for seabirds relate to diving behaviour obtained by direct observation, or in the case of guillemots and razorbills, to data obtained during the breeding season using data loggers. Thaxter *et al.* (2010) give average times for these species engaged in flying, feeding and spent underwater during the chick-rearing period. We have used the mean time spent underwater (1.9 and 0.8 hours for guillemots and razorbills respectively) as a percentage of the mean time spent at sea not flying (8.0 and 4.6 hours respectively). Thus, the percentage time spent underwater for guillemots is 23.75% and for razorbills of 17.4%. For puffins, data from data loggers were used from Spencer (2012), which estimated that puffins spend 14.16% of daylight time underwater.

43 These correction values can only be applied to estimates of relative abundance of birds sitting on the sea, which should then be added to the abundance of flying birds to give an estimate of absolute abundance for the species overall. For this reason, it was necessary to calculate the percentage of sitting birds as a total of all observations and apply these to the estimates of abundance for each of the three species. Because of low sample sizes of guillemots and razorbills in many months, we used the percentage of sitting birds to calculate the correction factors for abundance estimates within the proposed development area. For some species, too few observations were available to assess the ratio of sitting to flying birds with confidence and consequently, a ratio was used that pooled data for certain species. We have used these percentage figures to scale up the relative abundance estimate of guillemots, razorbills and puffins sitting on the sea by factors of 1.2375, 1.174 and 1.1416 respectively, and then added these corrected abundance estimates for sitting birds to the abundance estimate of flying birds. A scaling factor was also applied for large auks and auk species in proportion to the ratio of the estimated abundance of sitting guillemots, razorbills and puffins to each other and to other species within each of the mapped grid cells.

2.6.3.2 Marine mammals

44 Harbour porpoise abundance is also affected by availability bias, and further complicated because detections of animals are also possible while they are submerged. There are two approaches to using known diving rates to correct for availability bias for this species: to apply a correction factor to the density of animals that were recorded surfacing only using data on the surfacing rates from tagged animals; or to apply a correction factor to the density of all animals using the proportion of time spent at known depths by tagged animals.

45 The depth above which animals are available for detection is not known and is likely to vary according to the turbidity of the water, and perhaps other factors, but has been estimated to be 2m by Teilmann *et al.* (2013) when correcting for availability bias during visual aerial surveys of harbour porpoise.

46 Teilmann *et al.* (2013) provides detailed information which accommodates variation in time of year, geographical location and time of day in the proportion of time spent in the surface 2m of the water column and breaking the surface. All of these metrics relate to model outputs in Teilmann and are used to refine the predicted amount of time that harbour porpoise spend surfacing in the outputs. The tagging study of Teilmann did not extend to the area of the North Sea surrounding the VE site, and no other data are available on surfacing behaviour for this species in the relative area. For our analysis, we assumed that diving behaviour in the VE region was similar to that in North Sea areas of similar depths in Teilmann's study, and used the model outputs from the North Sea in our calculations. In order to estimate the density of surfacing harbour porpoise, it was necessary for us to use the density of all detectable animals and calculate the proportion where the dorsal fin was snapshot surfacing. Snapshot surfacing indicates where the head of a seal or dorsal fin of a cetacean are clear of the water surface in the middle frame of the sequence in which the animal is present. This was done using data from all months combined because sample sizes were too small to be accurate when calculating the surfacing proportions in individual months. We multiplied the calculated density of harbour porpoise by the proportion of snapshot surfacing encounters in our surveys and divided this by the proportion of surfacing behaviour from Teilmann *et al.* (2013) in Table 3, to derive the estimates of absolute density and abundance used Table 58.

Table 3 Correction factors used to account for availability bias for harbour porpoise at different times of the year and at different times of the day (after Teilmann *et al.* 2013)

Month	Behaviour			
	Surface		0 – 2 m	
	09:00 – 15:00	15:00 – 21:00	09:00 – 15:00	15:00 – 21:00
January	0.0490	0.0476	0.4381	0.418614
February	0.0398	0.0384	0.3748	0.355348
March	0.0543	0.0529	0.4637	0.444271
April	0.0646	0.0632	0.5708	0.551331
May	0.0563	0.0549	0.5262	0.506735
June	0.0518	0.0503	0.5093	0.489809
July	0.0493	0.0479	0.5116	0.492099
August	0.0530	0.0516	0.4508	0.431293
September	0.0420	0.0406	0.4468	0.427348
October	0.0413	0.0399	0.4422	0.42276
November	0.0406	0.0392	0.4439	0.424431
December	0.0429	0.0415	0.4790	0.459555

47 Availability bias was not corrected for in other marine mammal species due to the low number of individuals present, and a lack of information about diving patterns.

2.6.4 Density Mapping

48 Density maps were created to display the distribution of key species only. Key species were selected based on their high abundance or their significance at nearby SPAs. For diving species (guillemot and razorbill), density mapping was undertaken using 'relative' density estimates, *prior* to adjustment for availability bias.

49 The density maps have been derived using a Watson-Nadaraya type kernel density estimation ('KDE') technique (Simonoff, 1996). In KDE, a small 'window' function (the kernel) is used to calculate a local density at each point in the study area. To evaluate the density at a given point, the kernel is centred on that point and all the observations within the window are summed to obtain a local count. The total area of the transect(s) intersecting the window is then summed to obtain a local measure of effort. By dividing the local count by the local effort, a local density estimate is obtained. To build a density map, the study area is covered with a fine mesh of study points and the density is calculated at each point in the mesh in turn.

50 Kernel techniques are robust and not as complex as other density estimation techniques because they have few parameters; as a result, they are arguably the easiest density surface technique to reproduce independently. The only variables are the size and shape of the kernel or window function. For these analyses, we have used a Gaussian window function, which has the advantages of being smooth, rotationally symmetric, and easy to compute. The shape of the Gaussian window is determined by a single width parameter; the selection of this parameter is the only variable in the computation of the density maps.

51 Rather than set the width parameter arbitrarily, we have used a leave-one-out cross validation method. Cross validation estimates the predictive power of a model by removing some of the data from the data set and using the remainder of the data and the model to predict the values for the data that was removed. The closer the predicted values represent the removed data, the better the model performance and the width parameter used in the model.

52 To apply cross validation to the survey area, each transect is subdivided into 1km long segments. To evaluate a particular choice of kernel width, each segment is removed in turn, use the kernel and the remaining data to predict the density of the missing segment and subtract the known value from the prediction to obtain an error score. This process is repeated for every segment and the error scores for all segments are squared and summed to give a total performance score for that particular choice of kernel width. The kernel width is then varied and the process repeated; if the new score is lower than the old, the new kernel width is a better choice than the previous value. An exhaustive search over all kernel widths is then used to identify the best global choice. The result is a smooth density estimate which has been derived without any manual parameter selection. The whole process is repeated from scratch for each map, as different kernel sizes are appropriate for different species.

53 It should be noted that several of the KDE maps are effectively flat (i.e. they appear the same colour throughout the study area). These correspond to distributions where the density surface as obtained from a small local kernel was not effective at predicting missing data; this can happen with evenly distributed birds, but mainly happens for very sparse distributions. In the case of sparse distributions, the 'flat' map does not necessarily mean that the true underlying distribution is 'flat'; it could mean that

the data doesn't contain enough evidence to determine what the underlying distribution is. It is therefore useful to refer back to the population estimates for the corresponding map when looking at these 'flat' densities; we have also overlaid the relevant observations as dots to help with interpretation of the maps. In extreme cases, the kernel density maps were not included in the results section, and the data were only presented as dot maps. This occurred where there were fewer than five observations of the species in question.

54 For less abundant bird and non-avian species, as well as those partially identified to group level, density mapping was not undertaken. Instead, distribution is illustrated by dot maps.

3 Results

3.1 Survey effort

55 The date, number of transects and survey effort (as expressed by length of transects) undertaken between March 2019 and February 2020 are shown in Table 4. The number of transects and the total length of transects are those used in subsequent analysis (see Figure 1 for the aircraft flight pattern).

56 The flight variations (including times on task, minimum, maximum and average flight height of the plane) and environmental conditions of glare, sea state and turbidity have been included in Table 5. On this basis, 100% of all data collected could be used in the subsequent analysis. Tracks for each flight as shown in Figure 2.

Table 4 Survey effort across the VE survey area between March 2019 and February 2020 inclusive

Survey date	Survey Number	Number of transects analysed	Total length of transects analysed (km)	Area covered (km²)	% covered
26 March 2019	1	17	240.20	90.07	14.87
5 April 2019	2	17	245.75	92.16	15.22
11 May 2019	3	17	243.91	91.47	15.10
6 June 2019	4	17	240.12	90.04	14.87
1 July 2019	5	17	240.90	90.34	14.92
28 August 2019	6	17	240.14	90.05	14.87
10 September 2019	7	17	240.42	90.16	14.89
5 October 2019	8	17	240.43	60.11	9.92
6 November 2019	9	17	280.18	70.05	11.57
23 December 2019	10	17	239.48	89.80	14.83
18 January 2020	11	17	261.27	65.32	10.78

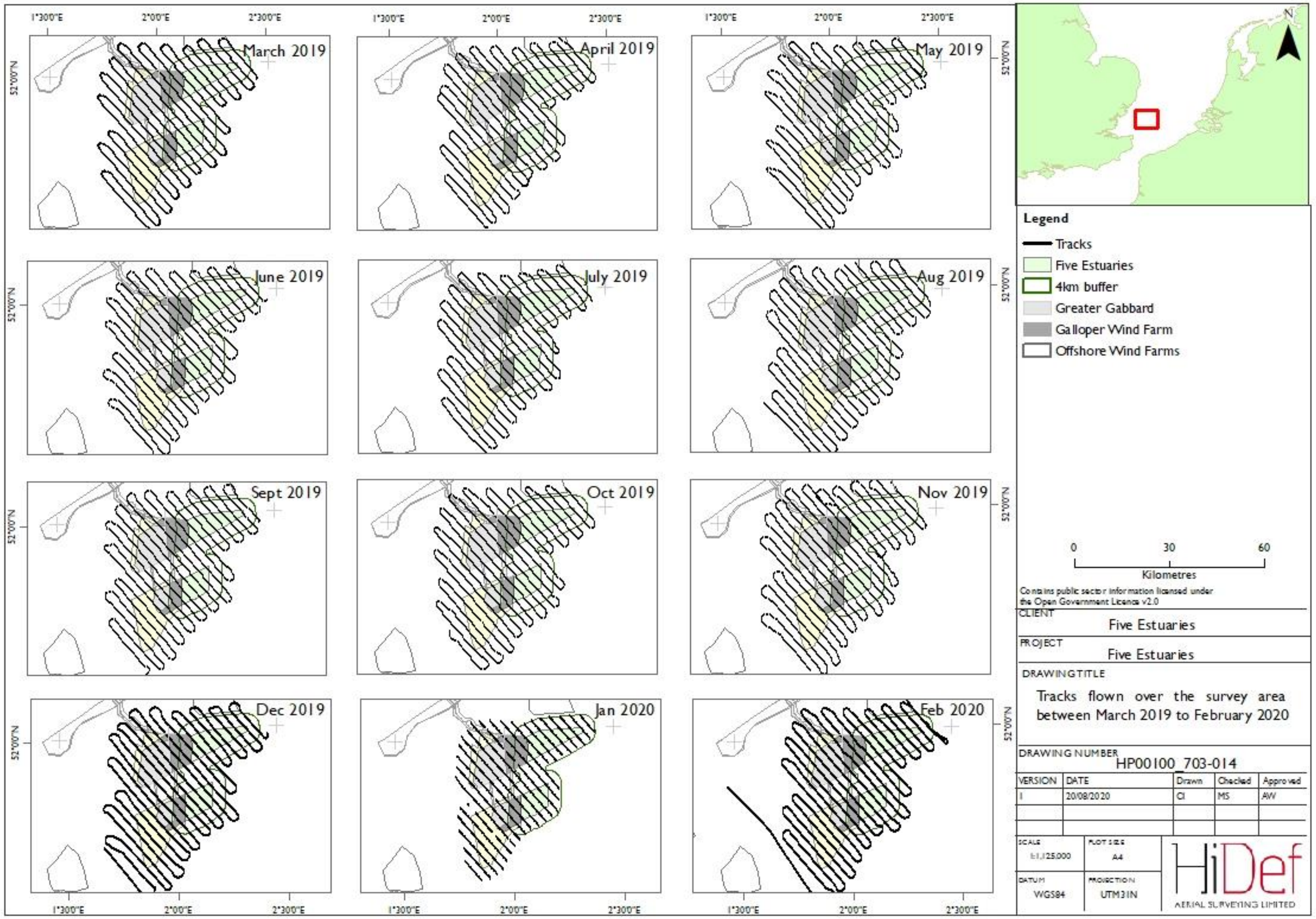
Survey date	Survey Number	Number of transects analysed	Total length of transects analysed (km)	Area covered (km^2)	% covered
14 February 2020	12	17	241.35	90.50	14.94

Table 5 Survey summary outlining times and plane flight height over the survey area, and environmental conditions across the survey

Survey date	Survey Number	Start of survey	End of survey	Hours on task (hrs)	Camera resolution	Glare (average)	Sea state (average)	Turbidity (average)	Average flight height (ft)	Minimum flight height (ft)	Maximum flight height (ft)
26 March 2019	1	09:15	13:00	03:45	2cm	1.00	3.00	0.00	1772	1722	1820
5 April 2019	2	10:45	14:55	04:10	2cm	1.07	3.02	0.00	1752	1668	1771
11 May 2019	3	10:20	14:15	03:55	2cm	1.38	3.03	0.00	1737	1505	1916
6 June 2019	4	09:20	13:10	03:50	2cm	1.21	3.83	1.32	1763	1676	1856
1 July 2019	5	09:20	13:05	03:45	2cm	1.00	2.98	1.03	1756	1689	1840
28 August 2019	6	09:00/14:45	13:30/15:15	04:00	2cm	1.00	1.05	1.00	1761	1715	1784
10 September 2019	7	09:00	12:40	03:40	2cm	1.01	2.00	1.01	1758	1702	1814
5 October 2019	8	11:10	15:05	03:55	2cm	1.01	2.12	0.99	1766	1584	1863
6 November 2019	9	10:35	14:50	04:15	2cm	1.00	1.99	0.00	1764	1719	1820
23 December 2019	10	10:35	13:10	02:35	2cm	1.14	4.99	0.00	1776	1571	1991
18 January 2020	11	09:30	13:30	04:00	2cm	1.02	3.97	0.01	1758	1630	3021

Survey date	Survey Number	Start of survey	End of survey	Hours on task (hrs)	Camera resolution	Glare (average)	Sea state (average)	Turbidity (average)	Average flight height (ft)	Minimum flight height (ft)	Maximum flight height (ft)
14 February 2020	12	09:55	13:40	03:45	2cm	1.05	3.00	0.04	1741	1588	1922

Figure 2 Flight pattern for each monthly survey over the VE survey array area



3.2 Survey results

57 The total number of objects detected in each survey flight, as well as uncorrected numbers of species and species group are presented in Table 9 to Table 10.

58 Each animal was assigned to at least a species group (e.g. large auk), and where possible these were also assigned a further species level identification (e.g. guillemot or razorbill) with confidence levels of 'Possible', 'Probable' or 'Definite'. Any animals that could not be identified to species level were assigned to a category 'No ID' in the species column. The analysis of data to species level uses all levels of identification confidence. The overall identification rate of birds and non-avian animals to a species level (not including 'No ID's) for the 12 surveys are given in Table 3. Confidence limit rates are provided in Table 7.

Table 6 Survey identification rates at the VE survey area between March 2019 and February 2020 inclusive

Survey date	ID rate (%)
26 March 2019	95.89
5 April 2019	95.15
11 May 2019	89.46
6 June 2019	94.59
1 July 2019	98.45
28 August 2019	88.74
10 September 2019	77.29
5 October 2019	90.58
6 November 2019	94.39
23 December 2019	92.21
18 January 2020	90.80
14 February 2020	88.66
Average	**91.35%**

Table 7 Survey confidence limit rates at the VE survey area between March 2019 and February 2020 inclusive

Survey date	Definite (%)	Probable (%)	Possible (%)
26 March 2019	49.57	40.61	6.33
5 April 2019	46.01	43.84	6.52
11 May 2019	60.00	26.67	2.86
6 June 2019	73.53	17.91	5.35
1 July 2019	82.21	13.94	2.40
28 August 2019	48.25	29.21	9.21
10 September 2019	28.22	48.02	2.48
5 October 2019	24.36	30.13	32.69
6 November 2019	42.97	37.34	12.79
23 December 2019	9.03	67.49	14.45
18 January 2020	8.76	60.22	20.80
14 February 2020	10.56	56.75	23.95
Average	**40.29**	**39.34**	**11.65**

Table 8 Level of agreement within the identification QA processes at the VE survey area between March 2019 and February 2020 inclusive

Survey date	Identifier QA Agreement (%)
26 March 2019	89.52
5 April 2019	92.33
11 May 2019	93.62
6 June 2019	96.65
1 July 2019	95.61
28 August 2019	95.04
10 September 2019	100.00
5 October 2019	91.75
6 November 2019	96.02
23 December 2019	93.32
18 January 2020	94.92
14 February 2020	95.45
Average	**94.52**

Table 9 Number of objects detected during each survey assigned to species level March 2019 to February 2020. Survey number dates can be observed in Table 4. Species highlighted in light grey are considered to be in low or relatively low abundances.

Species	Scientific Name	Month												Total
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Red-throated diver	*Gavia stellata*	2	0	0	0	0	0	1	0	0	1	0	5	9
Fulmar	*Fulmarus glacialis*	26	5	16	17	7	39	37	2	2	0	3	1	155
Gannet	*Morus bassanus*	75	27	3	53	13	100	20	32	137	2	0	50	512
Cormorant	*Phalacrocorax carbo*	0	0	0	0	0	0	6	0	0	0	0	0	6
Great crested grebe	*Podiceps cristatus*	0	0	0	0	0	0	0	0	0	0	1	0	1
Arctic skua	*Stercorarius parasiticus*	0	0	0	0	0	0	1	0	0	0	0	0	1
Great skua	*Stercorarius skua*	0	0	0	0	0	4	2	0	0	0	0	0	6
Kittiwake	*Rissa tridactyla*	366	109	52	37	9	14	33	7	58	83	29	84	881
Little gull	*Hydrocoloeus minutus*	0	2	0	0	0	0	0	4	4	0	0	0	10
Black-headed gull	*Chroicocephalus ridibundus*	5	0	0	0	0	0	1	2	2	0	0	0	10
Common gull	*Larus canus*	0	1	0	1	0	0	0	0	0	1	1	5	9
Lesser black-backed gull	*Larus fuscus*	1	30	4	239	152	92	21	1	3	4	0	1	548
Herring gull	*Larus argentatus*	0	0	0	13	12	6	0	1	2	1	2	0	37
Great black-backed gull	*Larus marinus*	3	6	0	2	0	4	32	9	6	4	4	1	71
Sandwich tern	*Thallaseus sandvicensis*	0	1	0	0	0	0	0	1	0	0	0	0	2

Species	Scientific Name	Month												Total
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Common tern	*Sterna hirundo*	0	0	0	0	0	0	1	0	0	0	0	0	1
Guillemot	*Uria aalge*	545	305	11	0	11	12	4	27	109	168	157	1368	2717
Razorbill	*Alca torda*	333	46	8	0	1	2	0	50	41	290	49	230	1050
Puffin	*Fratercula arctica*	1	0	0	0	0	0	0	0	0	0	0	0	1
Grey seal	*Halichoerus grypus*	1	0	0	0	0	2	0	0	0	0	0	1	4
Harbour porpoise	*Phocoena phocoena*	23	6	3	13	10	46	43	10	77	12	4	15	262
Total		**451**	**1381**	**538**	**97**	**375**	**215**	**321**	**202**	**146**	**441**	**566**	**1761**	**6293**

Table 10 Number of objects with no species ID detected during each survey assigned to species groups March 2019 to February 2020. Survey number dates can be observed in Table 4.

Species group (No ID)	Month												Total
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Fulmar / gull species	2	0	7	6	1	15	26	2	2	1	2	1	65
Grebe species	1	0	0	0	0	0	0	0	0	0	0	0	1
Skua species excluding great	0	0	0	0	0	0	0	2	0	0	0	0	2
Small gull species	10	2	0	1	0	2	2	0	4	1	0	5	27
Black-backed gull species	0	0	0	1	0	0	0	0	0	0	0	0	1
Large gull species	0	0	0	3	0	7	8	1	0	1	0	0	20
Gull species	1	0	0	1	0	8	3	1	1	0	1	0	16
Arctic / common tern	0	0	3	0	1	6	1	0	0	0	0	0	11
Tern species	0	0	0	0	1	0	0	0	0	0	0	0	1
Tern / small gull species	0	0	0	0	0	2	0	2	0	0	0	0	4
Large auk	25	13	1	0	0	0	2	8	16	44	16	127	252
Auk species	9	4	0	0	0	2	1	3	4	4	2	15	44
Auk / small gull	1	1	0	0	0	0	0	1	0	2	4	11	20
Large auk / diver species	0	0	0	0	0	0	0	0	0	1	3	7	11
Small bird species	0	0	0	0	0	0	0	0	0	1	0	1	2
Seal species	2	0	0	0	0	0	1	2	1	5	1	1	13
Cetacean species	1	0	0	0	0	0	0	0	0	0	0	0	1
Seal / small cetacean species	1	0	0	0	0	1	2	0	0	0	0	1	5
Total	**53**	**20**	**11**	**12**	**3**	**43**	**46**	**22**	**28**	**60**	**29**	**169**	**496**

3.3 Distribution patterns and seasonal abundance

59 Density estimates calculated for the whole survey area, as well as 95% confidence limits, are presented for key species only. For density and abundance estimates for all species and species groups, as well as measures of standard deviation and CV, please see Appendix 1. An explanation of these elements is presented in Table 11.

60 Some of these estimates, for certain diving bird species, were multiplied by a scaling factor as outlined in section 2.5.3 in order to take account of availability bias and give estimates of absolute abundance. The *adjusted* (absolute) density and abundances provide the best estimate of abundance at the time of survey. These have only been calculated for three bird species: guillemots, razorbills and puffins, and one marine mammal: harbour porpoise. They have not been calculated for any other seabird species which either do not dive or would be submerged for too short a time to warrant calculation of availability bias. No calculation of availability bias was carried out for any other marine mammals due to the low numbers present, and a lack of any information about their diving patterns. Absolute density and abundance estimates can be found in Appendix II and are presented in this section instead of relative density for the relevant key species.

61 Distribution patterns of the most abundant species are presented as density maps, in which a density surface depicts the estimated density of individuals per km^2. Distributions of less abundant and unidentified species are presented as dot maps only.

62 Anthropogenic activity is presented as dot maps for reference only (Figure 33).

Table 11 Terms used in density and abundance analysis

Term	Definition
Density estimate *(birds/km²)*	The mean number of birds (or animals) per square km surveyed over the whole area (VE site plus 4km buffer)
Population estimate *(number)*	The mean number of birds (or animals) estimated to exist across the whole survey area (VE site plus 4km buffer)
95% confidence intervals or 'limits' of population *(CI)*	A measure of uncertainty in the mean value. If the analysis was repeated, 95% of the time the mean population estimate would fall within this upper and lower boundary. The smaller the relative CI range, the more confident we can be that the mean estimate is an accurate reflection of the true population size.
Standard deviation *(SD)* of population estimate	The amount of variation or dispersion of a set of values. A low SD indicates that the bootstrap values tend to be close to the mean of the set.
CV (%)	The coefficient of variation is a standard measure that describes the dispersion of data points around the mean. The lower the CV the more precise the estimate. It is calculated as the SD / mean.
Relative abundance	In the case of diving birds and mammals, this is the estimated population size based on animals recorded on or above the sea surface and does not account for any that may be diving and thus submerged at the time of survey.
Absolute abundance	The most accurate estimate of population size. In the case of diving birds and mammals, this includes an estimate for the number that are believed to be submerged at the time of survey.

3.3.1 Distribution and seasonal abundance for all bird species

63 Bird distribution across all months is shown in Figure 4. Overall, large numbers of birds were recorded across the wintering period in the VE site, with fewer birds recorded from May to October. There were differences in abundance for all birds across the year with the highest number of birds recorded in March and February.

64 The monthly density maps for all bird species combined show observations across the whole survey area (Figure 4) with the highest number of detections being made during the February survey, especially in the southern section of the survey area (Figure 4). Overall winter months showed high densities of birds widespread across the site.

Table 12 Number of birds recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
All birds	1406	552	105	374	208	315	202	156	391	609	274	1912	6504

Figure 3 Number of birds observed between March 2019 to February 2020

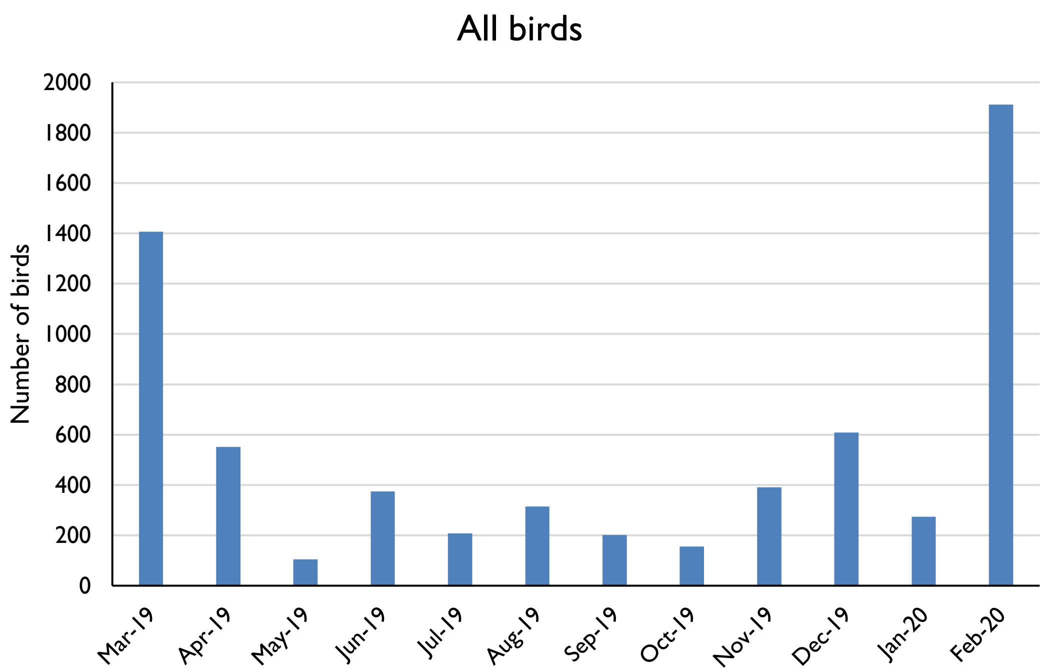
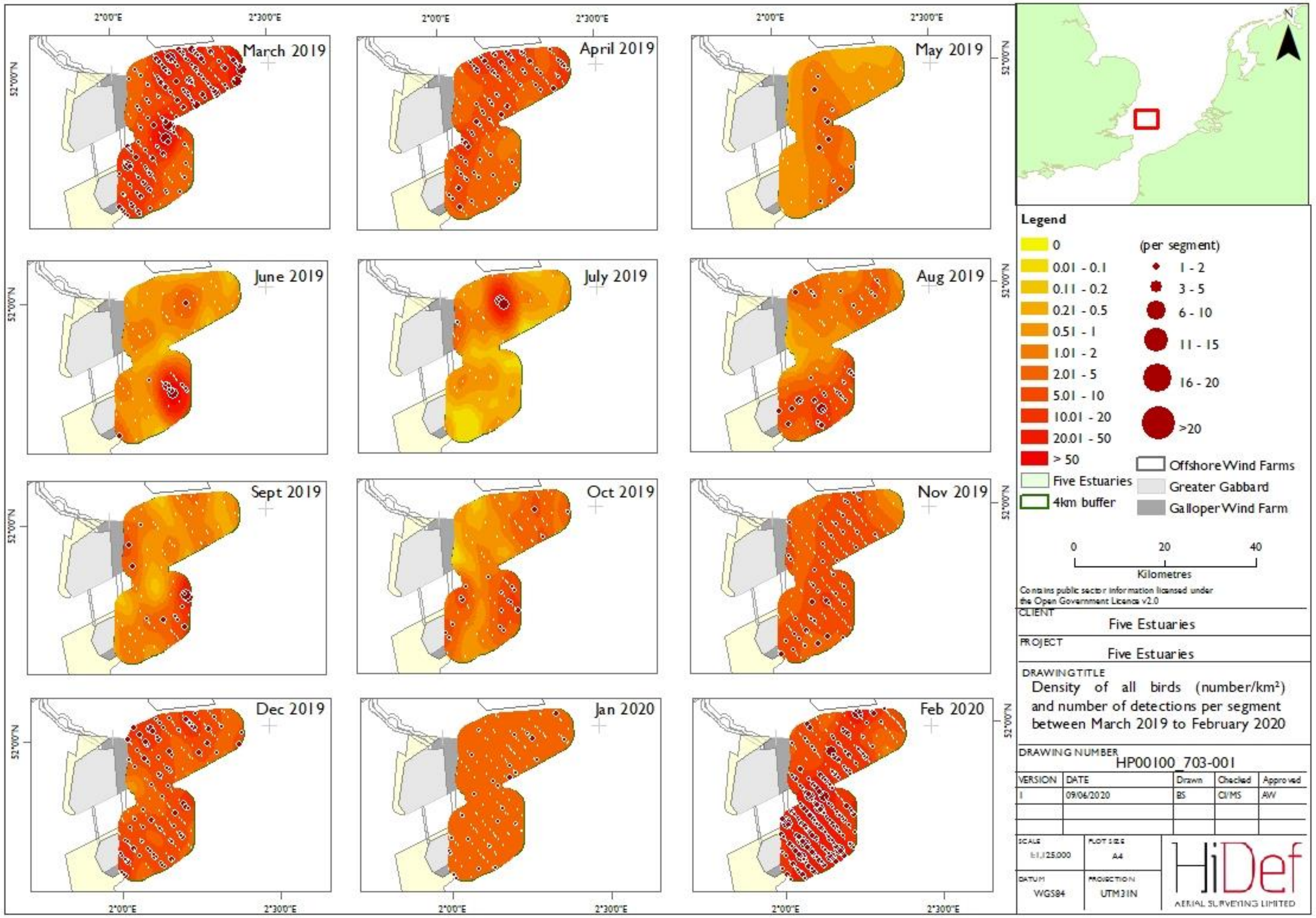


Figure 4 Density of all birds (number/km²) and number of detections per segment between March 2019 to February 2020



3.3.2 Distribution and seasonal abundance of fulmars

65 Fulmar observations varied from March to September with low numbers recorded from October to February. There were no observations recorded in December (Table 13**Figure 5**).

66 Moderate to low densities were estimated between March and July, ranging between 0.05 and 0.29 birds/km^2 (Figure 5). Density estimates were highest in August and September, peaking at 0.44 birds/km², which equated to 265 birds (±95% CI 81 – 484). From October to February, very low density estimates were recorded, with estimates no higher than 0.05 birds/km².

67 Low numbers of fulmars were recorded across the survey area in April, July, and from October to February. During March, fulmars were distributed in the east of the survey area, there was no obvious distribution pattern during the May survey. During June, August and September the species was concentrated in the south east of the survey area. (Figure 7).

Table 13 Number of fulmars recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Fulmar	26	5	16	17	7	39	37	2	2	0	3	1	155

Figure 5 Fulmar density estimates with lower and upper 95% confidence intervals between March 2019 to February 2020

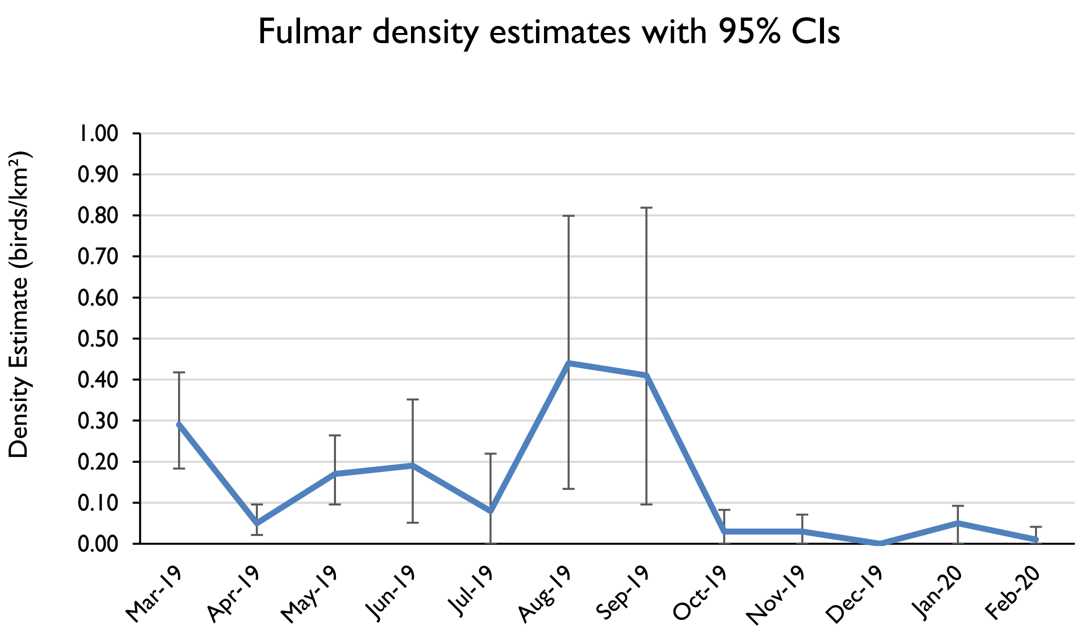


Table 14 Summary of fulmar behaviours between March 2019 to February 2020

Survey date	Number recorded diving	Number recorded flying	Number recorded landing	Number recorded sitting	Number recorded taking off	% Flying	Total
26 March 2019	0	12	0	14	0	46%	26
5 April 2019	0	5	0	0	0	100%	5
11 May 2019	0	5	0	11	0	31%	16
6 June 2019	0	4	0	13	0	24%	17
1 July 2019	0	5	0	2	0	71%	7
28 August 2019	0	4	0	35	0	10%	39
10 September 2019	0	2	0	35	0	5%	37
5 October 2019	0	0	0	2	0	0%	2
6 November 2019	0	1	0	1	0	50%	2
23 December 2019	0	0	0	0	0	0%	0
18 January 2020	0	2	0	1	0	67%	3
14 February 2020	0	0	0	1	0	0%	1
Total	**0**	**40**	**0**	**115**	**0**	**26%**	**155**

Figure 6 Flying direction of fulmars observed between March 2019 to February 2020

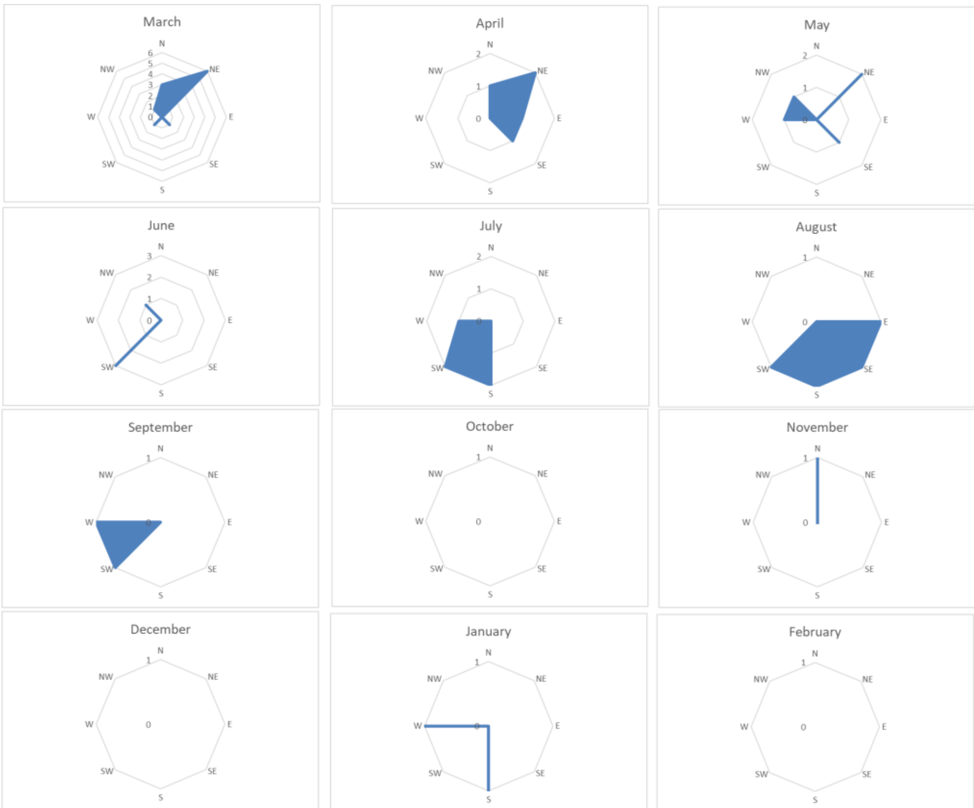
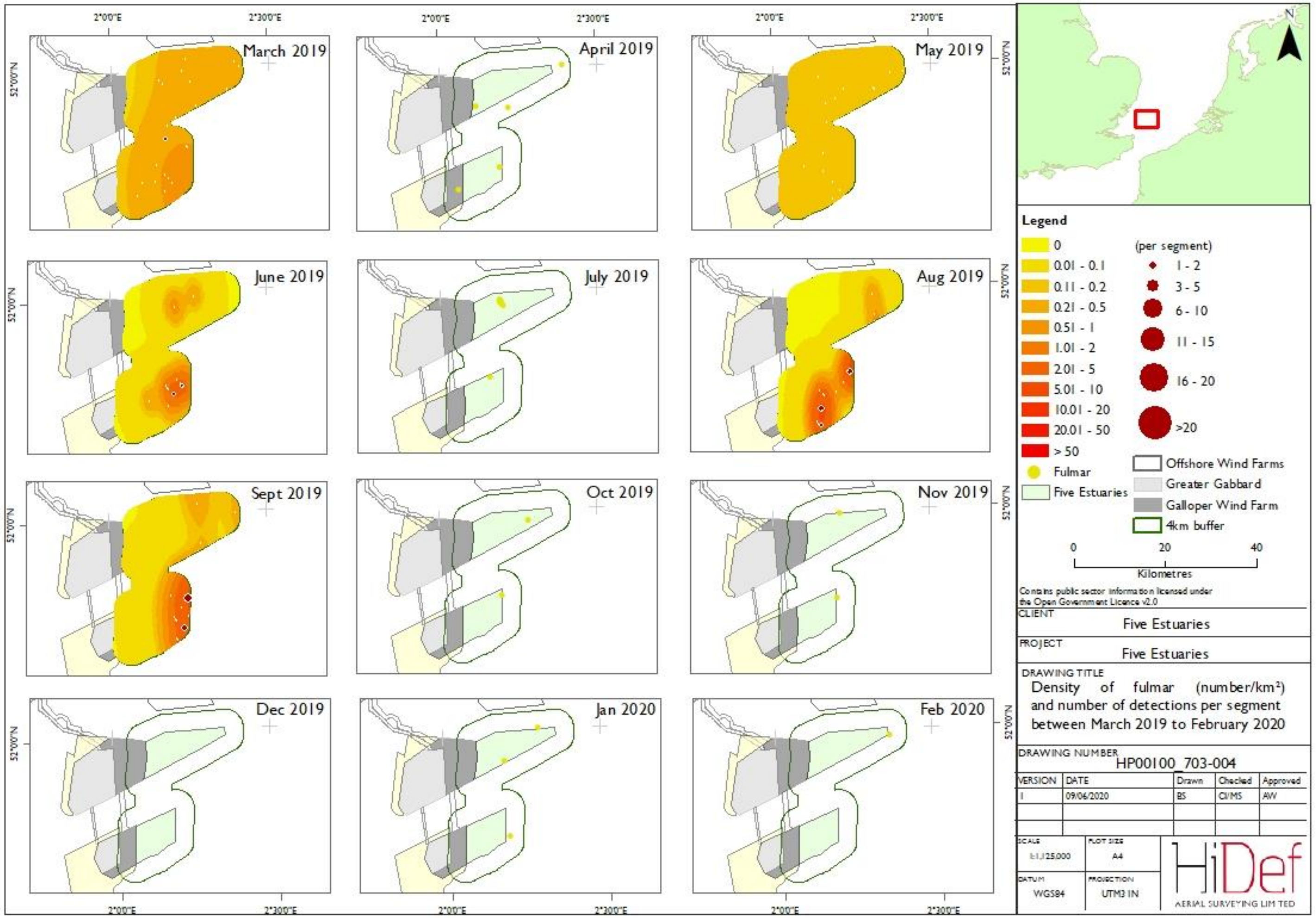


Figure 7 **Density of fulmars (number/km²) and number of detections per segment between March 2019 to February 2020**



3.3.3 Distribution and seasonal abundance of gannets

68 Gannet observations varied over the survey period, with peak observations recorded in November and August. Due to the time of year, this would relate to movements south from breeding colonies. Low numbers of the species were recorded in May and December with no gannets recorded in January (Table 15).

69 As such, relative density and abundance estimates also varied greatly (Figure 8). Peak relative density reached 1.96 birds/km² in November, equating to 1188 birds (±95% CI 750 – 1623). Gannets were concentrated in the north east and east of the survey area during March and October. In April, May and July, there was no clear distribution pattern. During the June survey, the species was concentrated in the south east of the survey area. Gannets were distributed across the survey area in August, September and November. During February, gannets were concentrated in the south, west and east of the survey area.

Table 15 Number of gannets recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Gannet	75	27	3	53	13	100	20	32	137	2	0	50	512

Figure 8 Gannet density with lower and upper 95% confidence intervals between March 2019 to February 2020

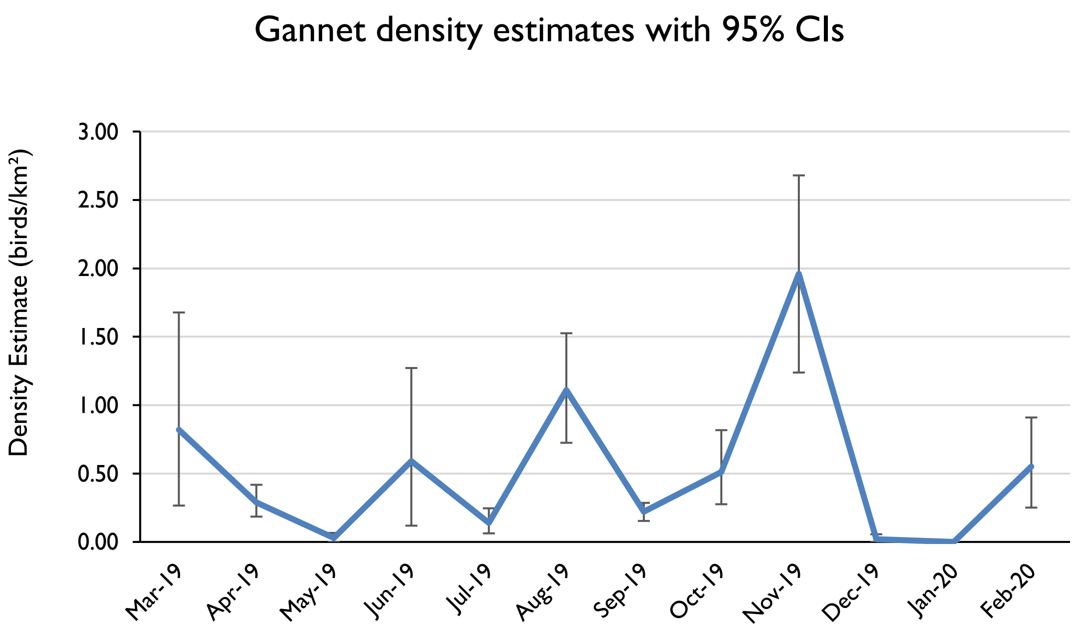


Table 16 Summary of gannet behaviours between March 2019 to February 2020

Survey date	Number recorded diving	Number recorded flying	Number recorded landing	Number recorded sitting	Number recorded taking off	% Flying	Total
26 March 2019	0	18	0	55	2	24%	75
5 April 2019	0	15	0	12	0	56%	27
11 May 2019	0	2	0	1	0	67%	3
6 June 2019	0	10	0	43	0	19%	53
1 July 2019	0	1	0	12	0	8%	13
28 August 2019	0	49	0	49	2	49%	100
10 September 2019	0	10	0	10	0	50%	20
5 October 2019	0	20	0	12	0	63%	32
6 November 2019	0	44	0	93	0	32%	137
23 December 2019	0	1	0	1	0	50%	2
18 January 2020	0	0	0	0	0	0%	0
14 February 2020	0	15	0	34	1	30%	50
Total	**0**	**167**	**0**	**267**	**3**	**38%**	**437**

Figure 9 Flying direction of gannets observed between March 2019 to February 2020

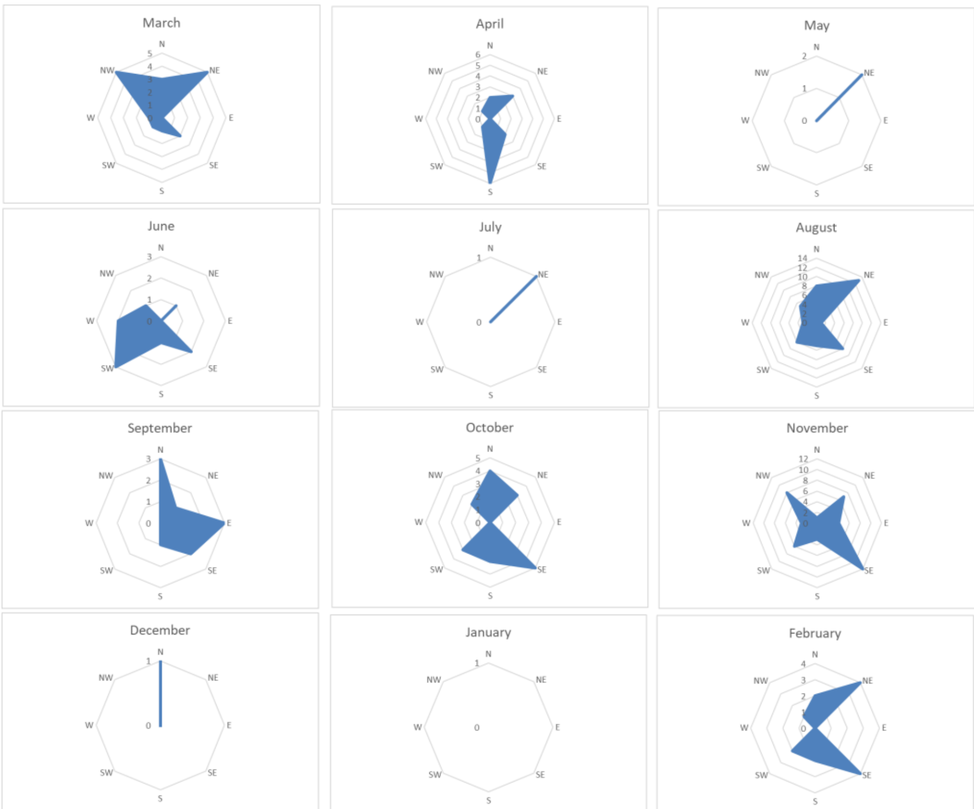
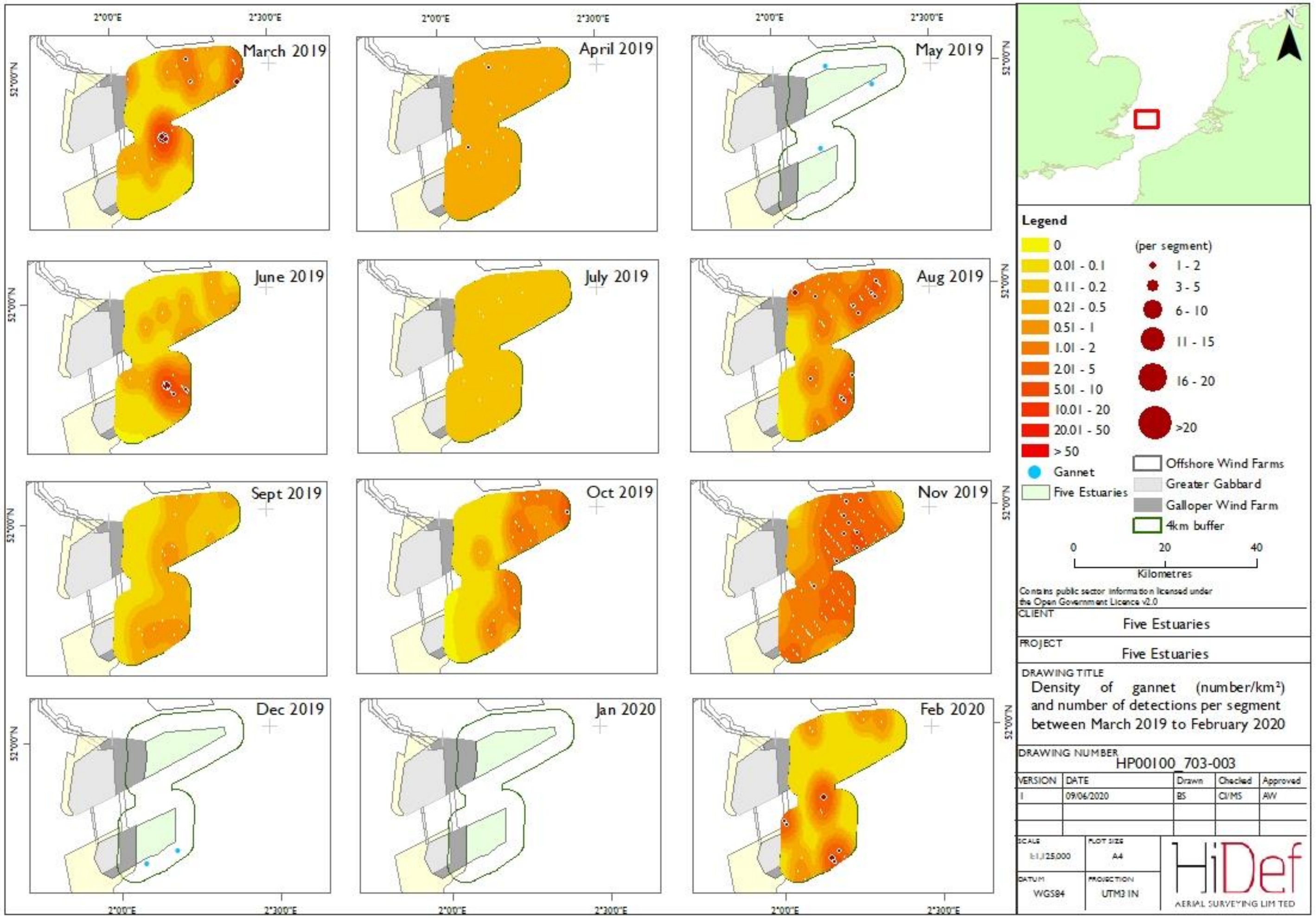


Figure 10 **Density of gannets (number/km²) and number of detections per segment between March 2019 to February 2020**



3.3.4 Distribution and seasonal abundance of kittiwakes

70 Observations of kittiwakes were very high in March compared to other months, and then records decreased in April. From May to February no more than 84 kittiwakes were recorded in the survey area (Table 17).

71 Density and abundance estimates reached a peak of 4.05 birds/km^2 in March, equating to 2457 birds (±95% CI 1797 – 3224) (Figure 11). From April to February, estimated density was much lower, ranging between 0.1 and 1.18 birds/km^2. This equated to an estimated abundance of between 61 birds (±95% CI 27 – 100) and 716 birds (±95% CI 466 – 1002). Kittiwakes distribution from March to June was spread across the survey area with no clear concentration pattern, especially in June. During July and September, the species were concentrated in the north west of the survey area. Kittiwakes were concentrated in the south of the survey area during November. Distribution varied across the survey area from December to February (Figure 13).

Table 17 Number of kittiwakes recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Kittiwake	366	109	52	37	9	14	33	7	58	83	29	84	881

Figure 11 Kittiwake density estimates with lower and upper 95% confidence intervals between March 2019 to February 2020

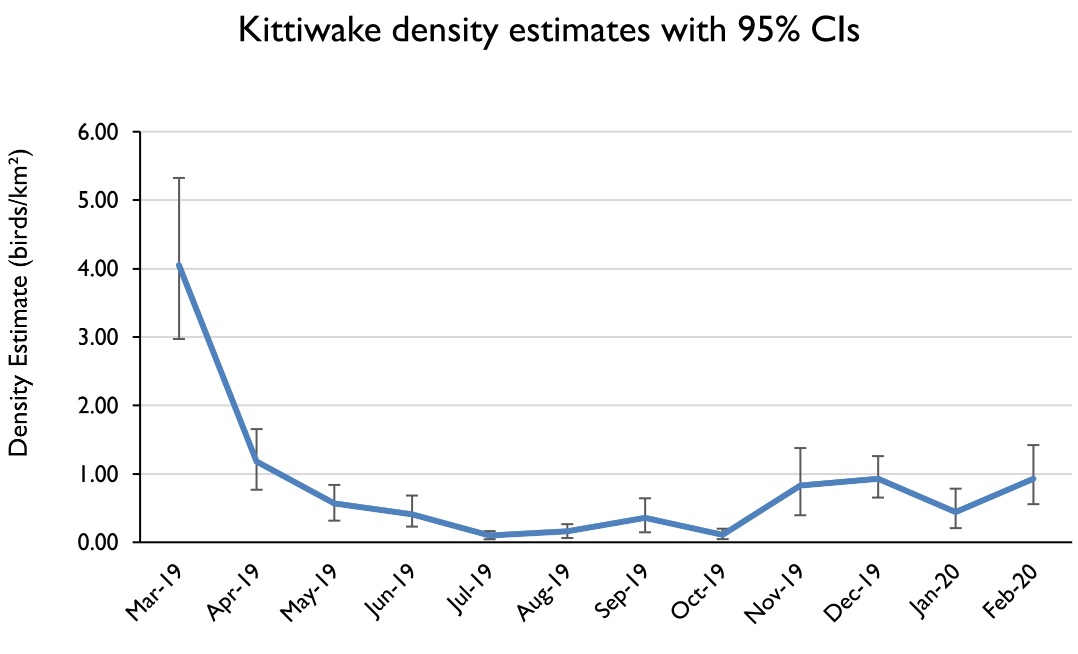


Table 18 Summary of kittiwake behaviours between March 2019 to February 2020

Survey date	Number recorded diving	Number recorded flying	Number recorded landing	Number recorded sitting	Number recorded taking off	% Flying	Total
26 March 2019	0	146	0	219	1	40%	366
5 April 2019	0	38	0	71	0	35%	109
11 May 2019	0	15	0	37	0	29%	52
6 June 2019	0	20	0	17	0	54%	37
1 July 2019	0	6	0	3	0	67%	9
28 August 2019	0	1	0	13	0	7%	14
10 September 2019	0	6	0	27	0	18%	33
5 October 2019	0	4	0	3	0	57%	7
6 November 2019	0	27	0	31	0	47%	58
23 December 2019	0	57	0	26	0	69%	83
18 January 2020	0	28	0	1	0	97%	29
14 February 2020	0	37	0	47	0	44%	84
Total	**0**	**239**	**0**	**276**	**0**	**46%**	**515**

Figure 12 Flying direction of kittiwakes observed between March 2019 to February 2020

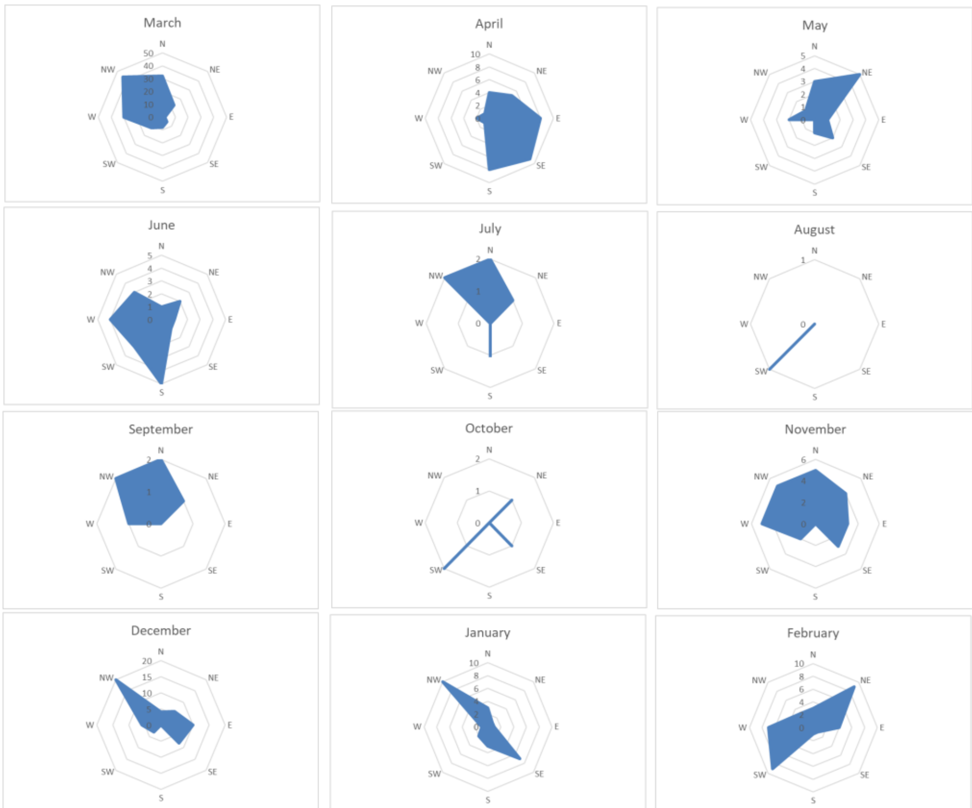
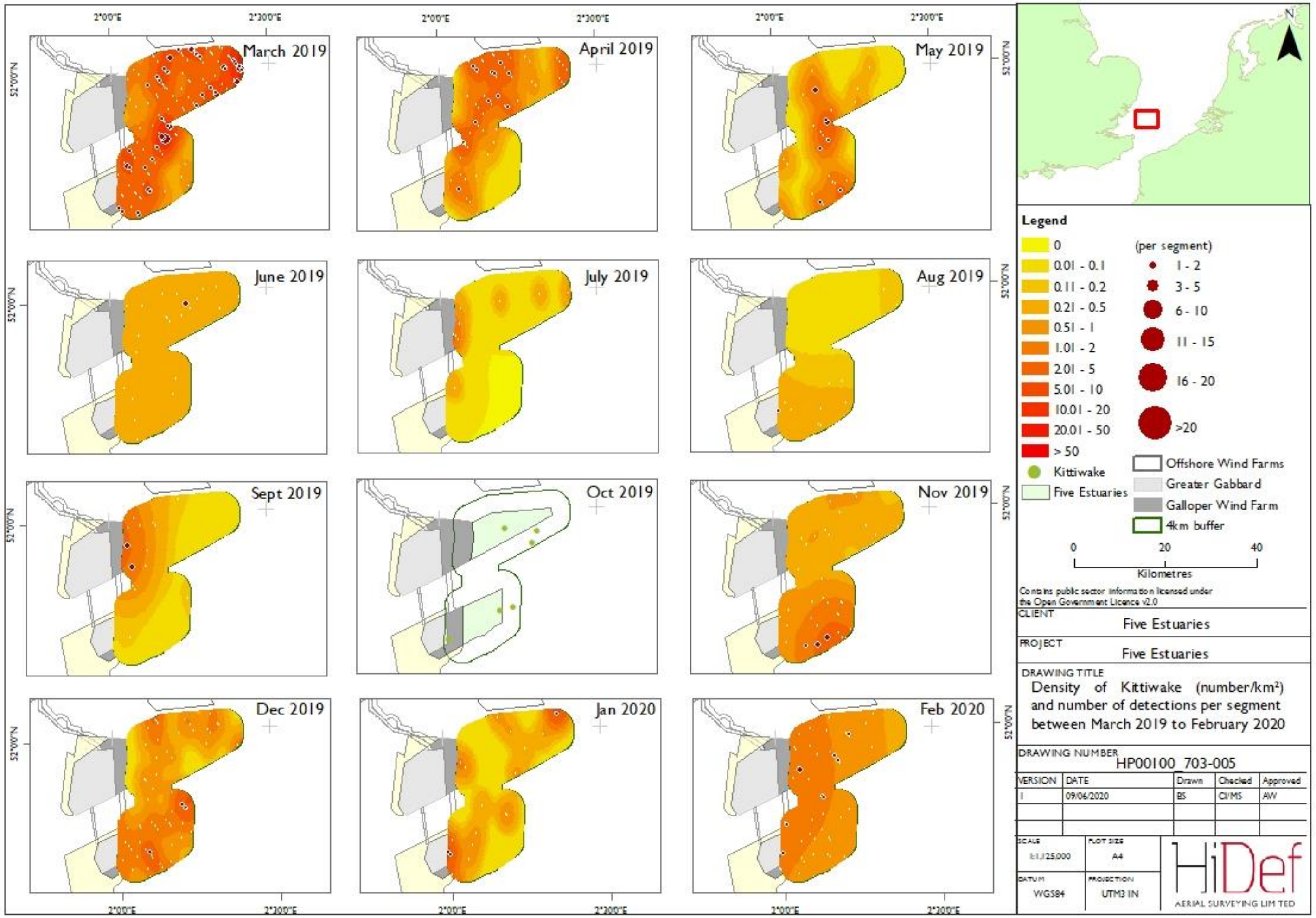


Figure 13 **Density of kittiwakes (number/km²) and number of detections per segment between March 2019 to February 2020**



3.3.5 Distribution and seasonal abundance of lesser black-backed gulls

72 Lesser black-backed gulls were recorded in all months apart from January. Most observations were in the breeding season from June to August, with very few observations recorded from October to February. (Table 19).

73 Lesser black-backed gull density estimates varied across the survey period (Figure 14). Markedly higher densities were estimated from June to August, ranging between 1.03 and 2.64 birds/km^2, and reaching a peak abundance of 1601 birds (±95% CI 79 – 4487). Outside of these months, density estimates were much lower, ranging between only 0.01 and 0.32 birds/km^2.

74 Low numbers of lesser black-backed gulls recorded in March, May, and October to February show no clear distribution pattern. During April, the species was concentrated in the south west of the survey area. In June, species distribution was concentrated in the south east of the survey area. Low numbers of gannet were recorded mainly in the east of the survey area during May and June. During July, lesser black-backed gulls were concentrated in the north of the survey area. There was a similar distribution in August and September with the species concentrated in the south west of the survey area in August and in the south west and south east in September (Figure 16).

75 In June, the most flying lesser black-backed gulls were recorded with 74% of all observations flying. Across the twelve-month survey period 46% of the species were recorded flying.

Table 19 Number of lesser black-backed gulls recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Lesser black-backed gull	1	30	4	239	152	92	21	1	3	4	0	1	548

Figure 14 Lesser black-backed gull density estimates with lower and upper 95% confidence intervals between March 2019 to February 2020

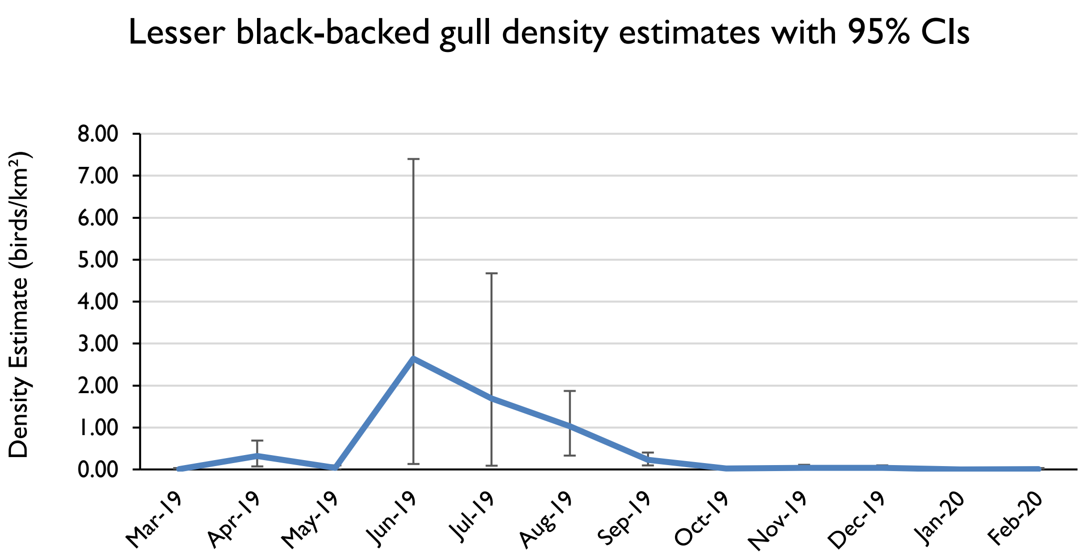


Table 20 **Summary of lesser black-backed gull behaviours between March 2019 to February 2020**

Survey date	Number recorded diving	Number recorded flying	Number recorded landing	Number recorded sitting	Number recorded taking off	% Flying	Total
26 March 2019	0	1	0	0	0	100%	1
5 April 2019	0	7	0	23	0	23%	30
11 May 2019	0	1	0	3	0	25%	4
6 June 2019	0	176	0	63	0	74%	239
1 July 2019	0	38	0	114	0	25%	152
28 August 2019	0	10	0	82	0	11%	92
10 September 2019	0	13	0	8	0	62%	21
5 October 2019	0	1	0	0	0	100%	1
6 November 2019	0	1	0	2	0	33%	3
23 December 2019	0	4	0	0	0	100%	4
18 January 2020	0	0	0	0	0	0%	0
14 February 2020	0	0	0	1	0	0%	1
Total	**0**	**251**	**0**	**296**	**0**	**46%**	**547**

Figure 15 **Flying direction of lesser black-backed gulls observed between March 2019 to February 2020**

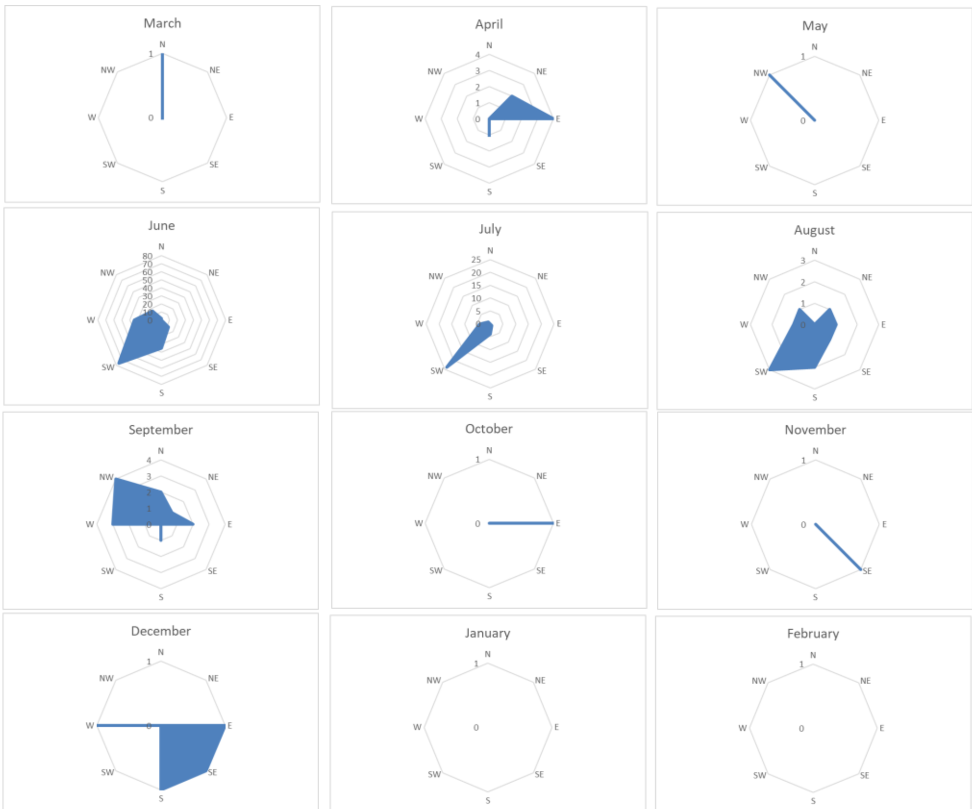
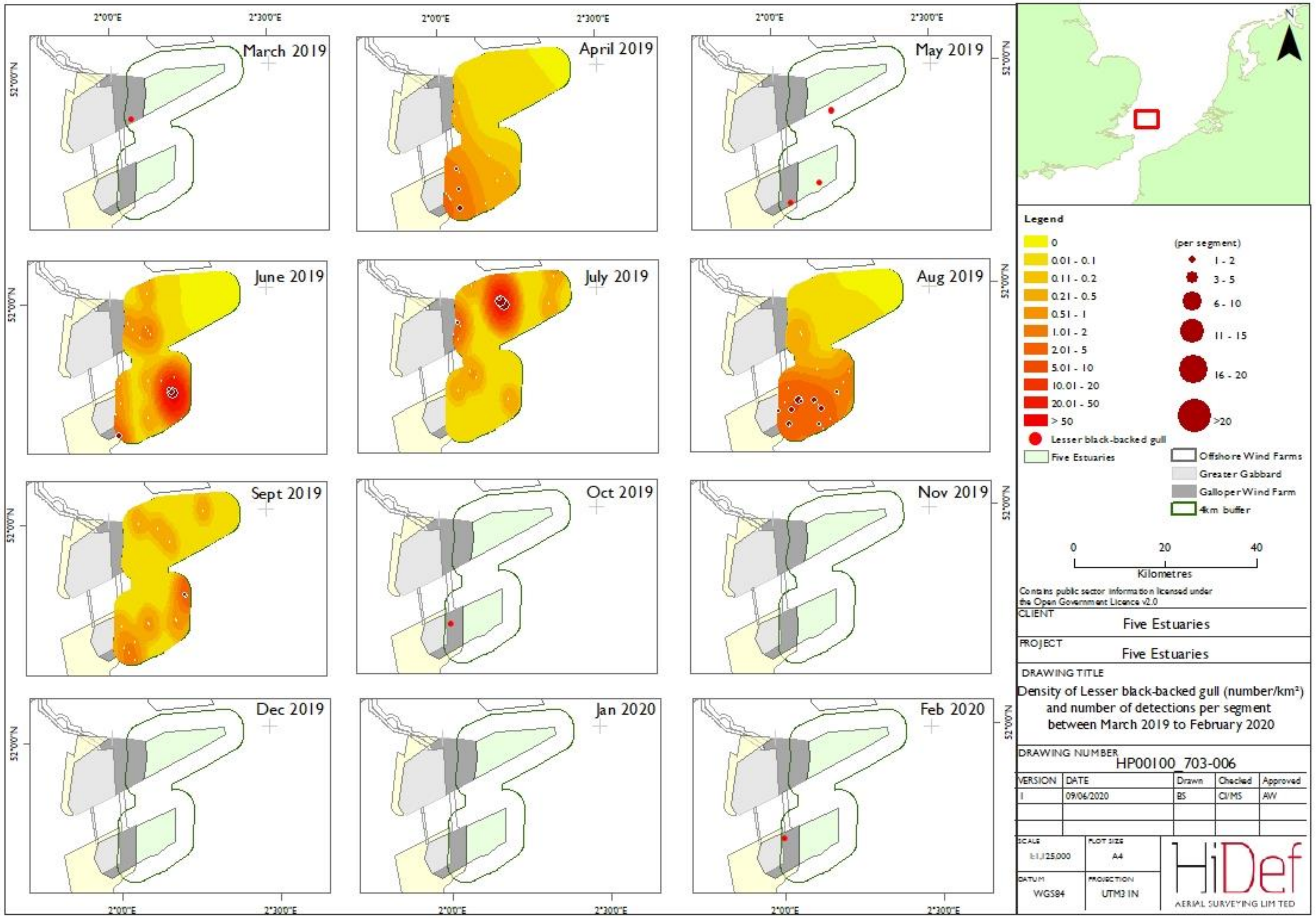


Figure 16 Density of lesser black-backed gulls (number/km²) and number of detections per segment between March 2019 to February 2020



3.3.6 Distribution and seasonal abundance of guillemots

76 Guillemots were the most abundant species recorded during the survey programme and had high relative density estimates in the winter months with peak observations recorded in February (Figure 17). Low numbers of the species were recorded from May to October. Lowest densities were recorded in the north west of the site near existing turbines.

77 Absolute density and abundance estimates varied markedly (Figure 17). Very low densities were estimated between May and October, ranging between 0 and 0.56 birds/km^2, equating to an absolute abundance of no more than 335 birds (±95% CI 178 - 491). Peak density occurred in February, at 13.32 birds/km^2, equating to an estimated absolute abundance of 11,283 birds (±95% CI 8066 – 14,637). Outside of these months, estimates ranged between 1.92 and 7.46 birds/km^2.

78 Guillemots distribution were widely dispersed across the study area at mostly high density in March, April, and November to February (Figure 19).

Table 21 Number of guillemots recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Guillemot	545	305	11	0	11	12	4	27	109	168	157	1368	2717

Figure 17 Guillemot absolute density estimates with lower and upper 95% confidence intervals between March 2019 to February 2020

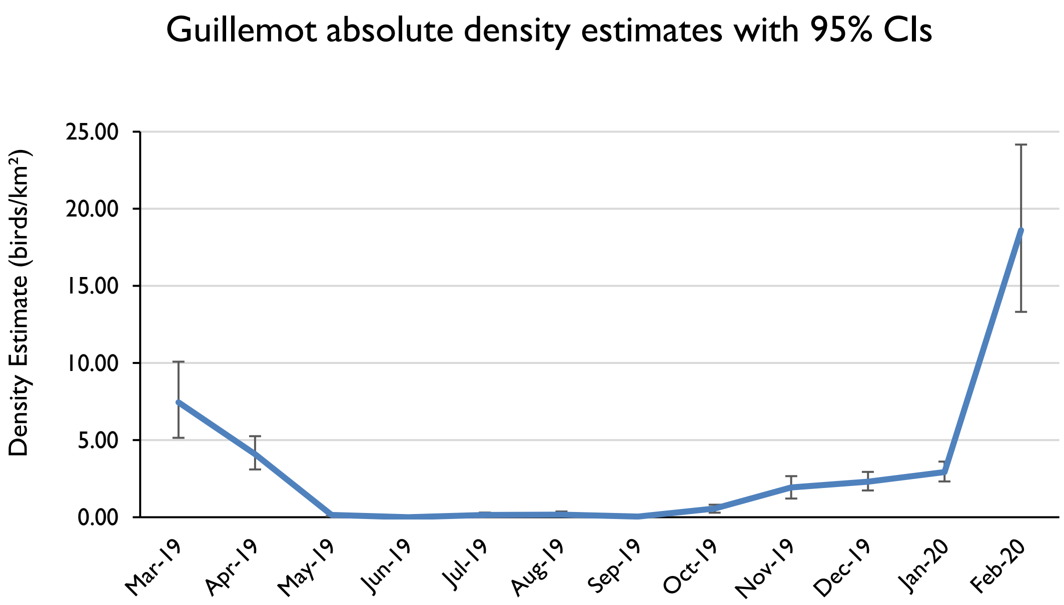


Table 22 Summary of lesser black-backed gull behaviours between March 2019 to February 2020

Survey date	Number recorded diving	Number recorded flying	Number recorded landing	Number recorded sitting	Number recorded taking off	% Flying	Total
26 March 2019	0	5	0	540	0	1%	545
5 April 2019	0	1	0	303	1	0%	305
11 May 2019	0	0	0	11	0	0%	11
6 June 2019	0	0	0	0	0	0%	0
1 July 2019	0	0	0	11	0	0%	11
28 August 2019	0	0	0	12	0	0%	12
10 September 2019	0	0	0	4	0	0%	4
5 October 2019	0	0	0	27	0	0%	27
6 November 2019	0	2	0	107	0	2%	109
23 December 2019	0	7	0	161	0	4%	168
18 January 2020	0	12	0	145	0	8%	157
14 February 2020	0	19	0	1349	0	1%	1368
Total	**0**	**41**	**0**	**2130**	**1**	**2%**	**2172**

Figure 18 Flying direction of guillemots observed between March 2019 to February 2020

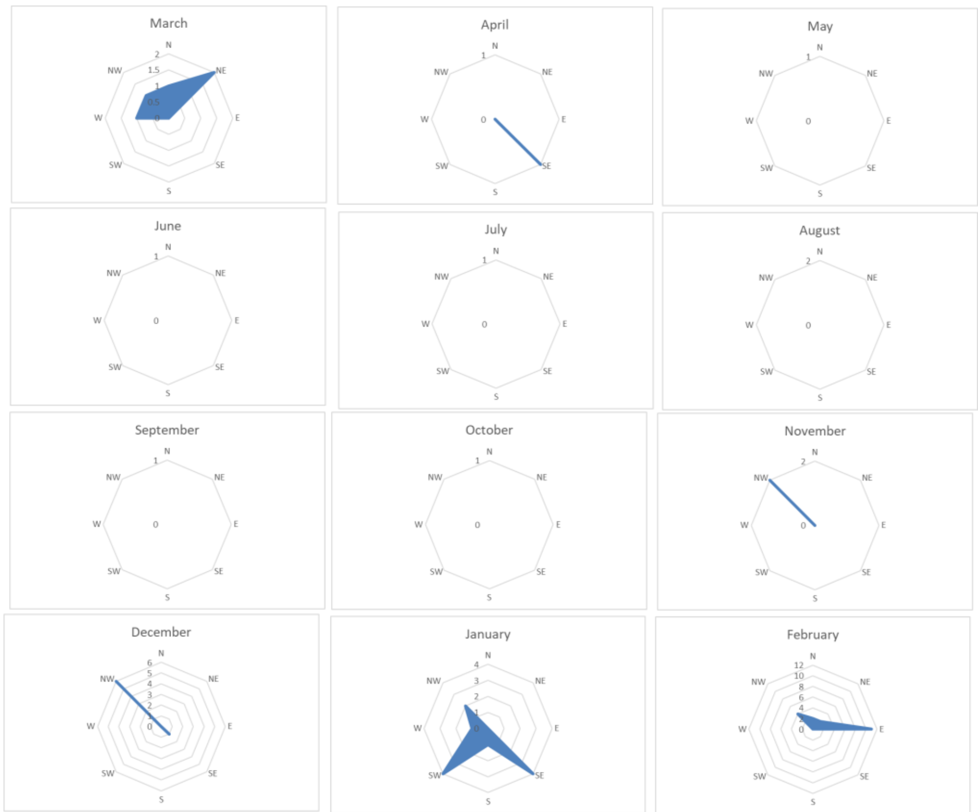
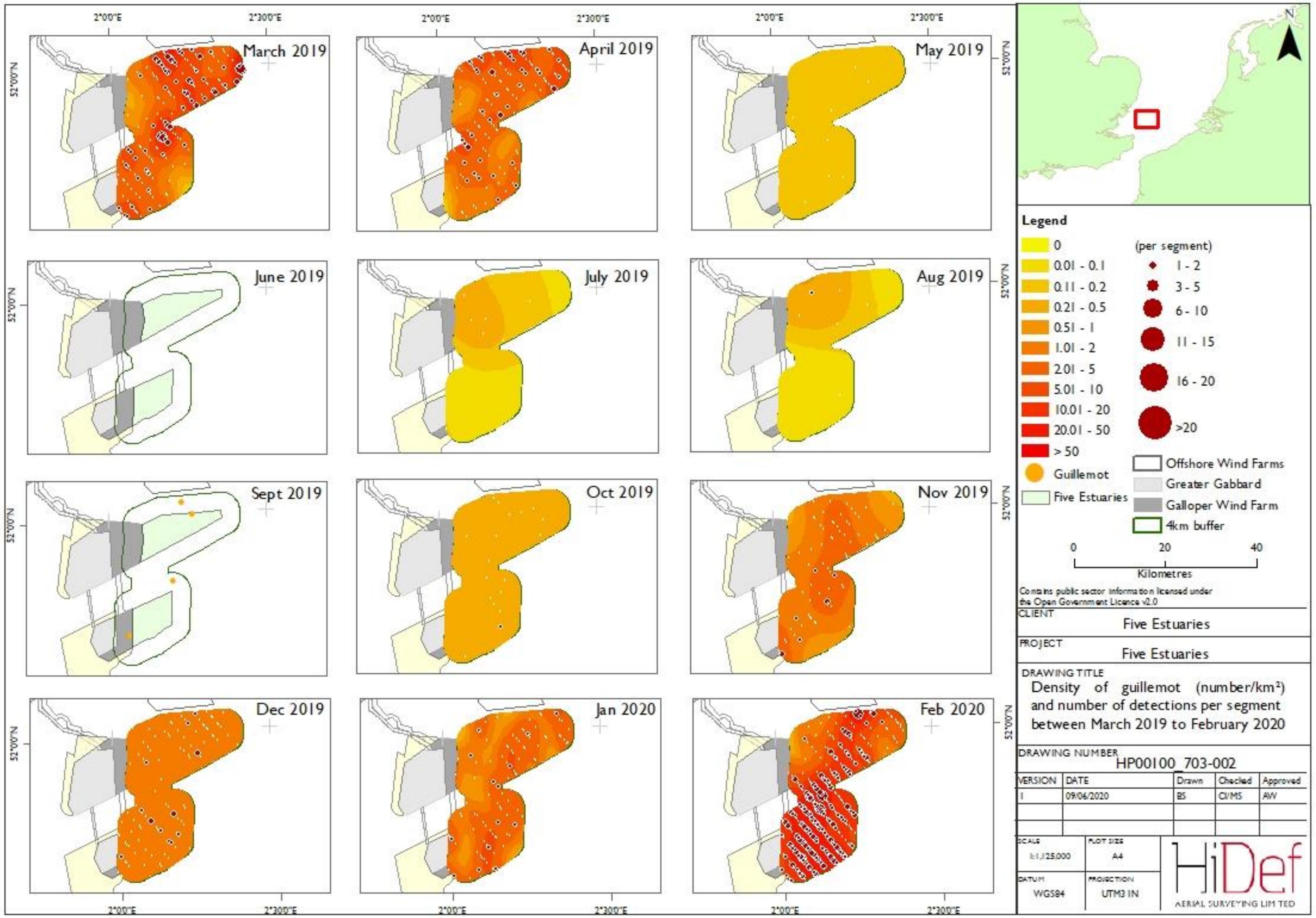


Figure 19 Density of guillemot (number/km²) and number of detections per segment between March 2019 to February 2020



3.3.7 Distribution and seasonal abundance of razorbills

79 Razorbills were recorded across all months expect June and September, with peak observations recorded in March (Table 23Figure 20).

80 Absolute density estimates varied through the survey period (Figure 20). In March, peak density reached 4.34 birds/km², equating to 2633 birds (±95% CI 1781 – 3593) in the survey area. Between April and September, densities were markedly low, ranging between 0 and 0.11 birds/km² and equating to no more than 62 birds (±95% CI 15 – 119). Between September and February, moderate to high densities were recorded, ranging between 0.69 and 3.79 birds/km².

81 The distribution pattern for razorbills varied across the surveys (Figure 21), with few to no observations recorded between May to September. Razorbill distribution varied across the survey area in March and in April, the species were concentrated in the north of the survey area. During October razorbills were concentrated in the south east and west of the survey area. This was similar to November when the species was concentrated in the west of the survey area. From December to February, razorbill distribution was spread across the survey area (Figure 21).

Table 23 Number of razorbills recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Razorbill	333	46	8	0	1	2	0	50	41	290	49	230	1050

Figure 20 Razorbill absolute density estimates with lower and upper 95% confidence intervals between March 2019 to February 2020

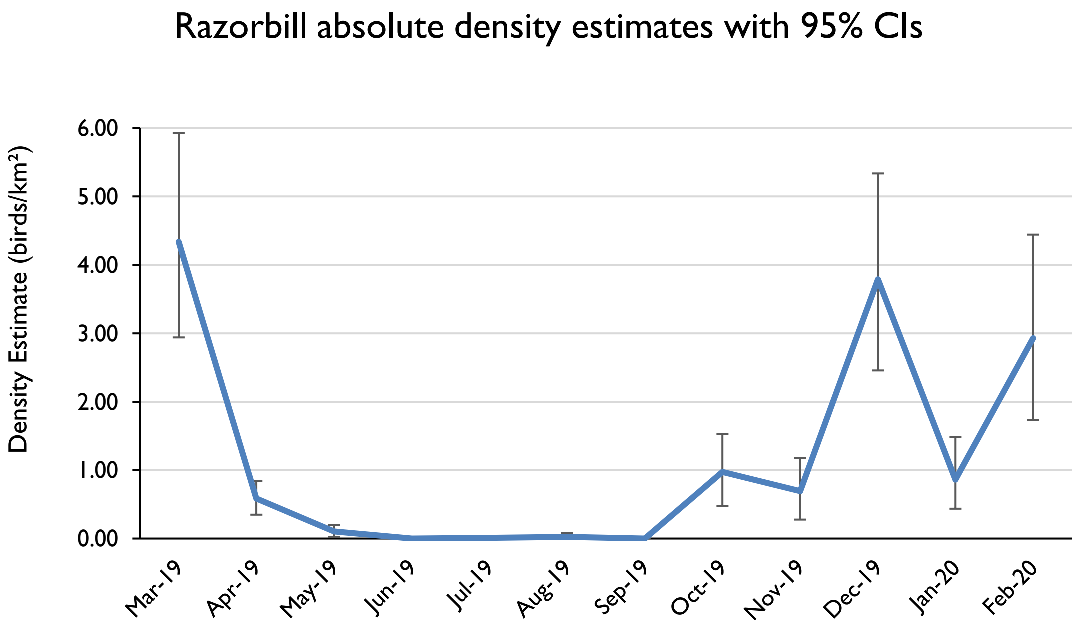
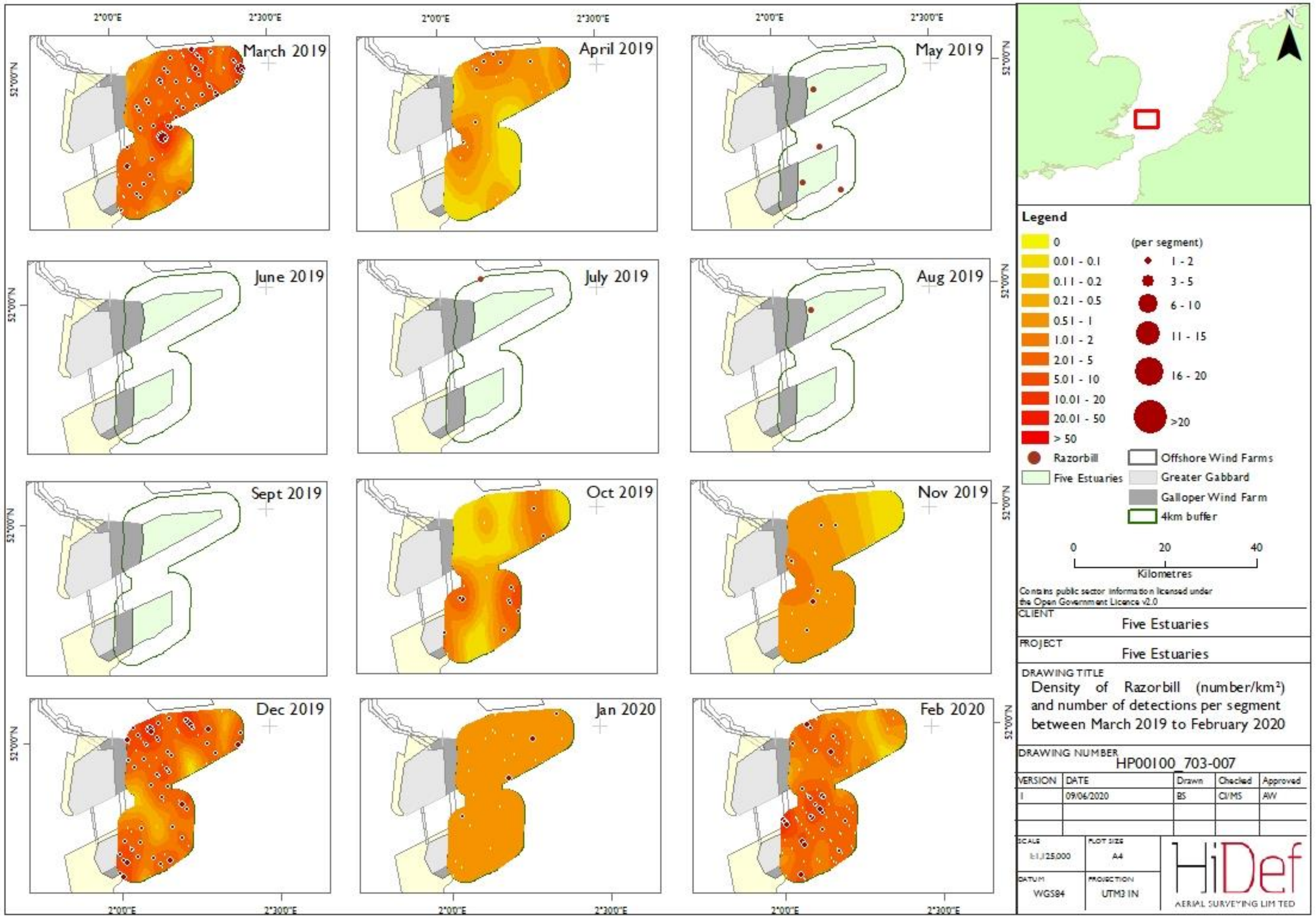


Table 24 Summary of razorbill behaviours between March 2019 to February 2020

Survey date	Number recorded diving	Number recorded flying	Number recorded landing	Number recorded sitting	Number recorded taking off	% Flying	Total
26 March 2019	0	3	0	330	0	1%	333
5 April 2019	0	0	0	46	0	0%	46
11 May 2019	0	0	0	8	0	0%	8
6 June 2019	0	0	0	0	0	0%	0
1 July 2019	0	0	0	1	0	0%	1
28 August 2019	0	0	0	2	0	0%	2
10 September 2019	0	0	0	0	0	0%	0
5 October 2019	0	0	0	50	0	0%	50
6 November 2019	0	0	0	41	0	0%	41
23 December 2019	0	1	0	289	0	0%	290
18 January 2020	0	8	0	41	0	16%	49
14 February 2020	0	26	0	204	0	11%	230
Total	**0**	**35**	**0**	**682**	**0**	**5%**	**717**

Figure 21 **Density of razorbill (number/km²) and number of detections per segment between March 2019 to February 2020**



3.3.8 Distribution analysis for less abundant bird species

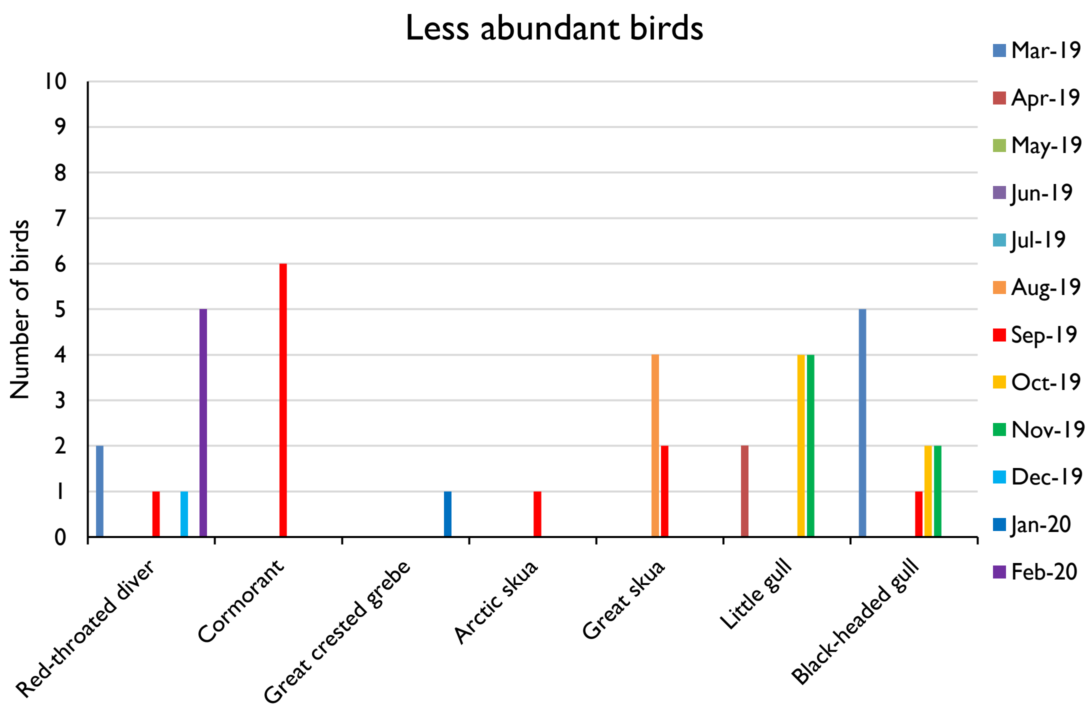
82 Less abundant bird species were recorded sporadically throughout the year (Table 25; Figure 22). Density and abundance estimates can be found in Appendix I. Detections are shown in Figure 23.

Table 25 Number of less abundant bird species recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Less abundant bird species	11	10	0	16	12	14	44	17	14	7	8	11	164

Figure 22 Number of less abundant bird species observed between March 2019 to February 2020 (A to B)

A:



B:

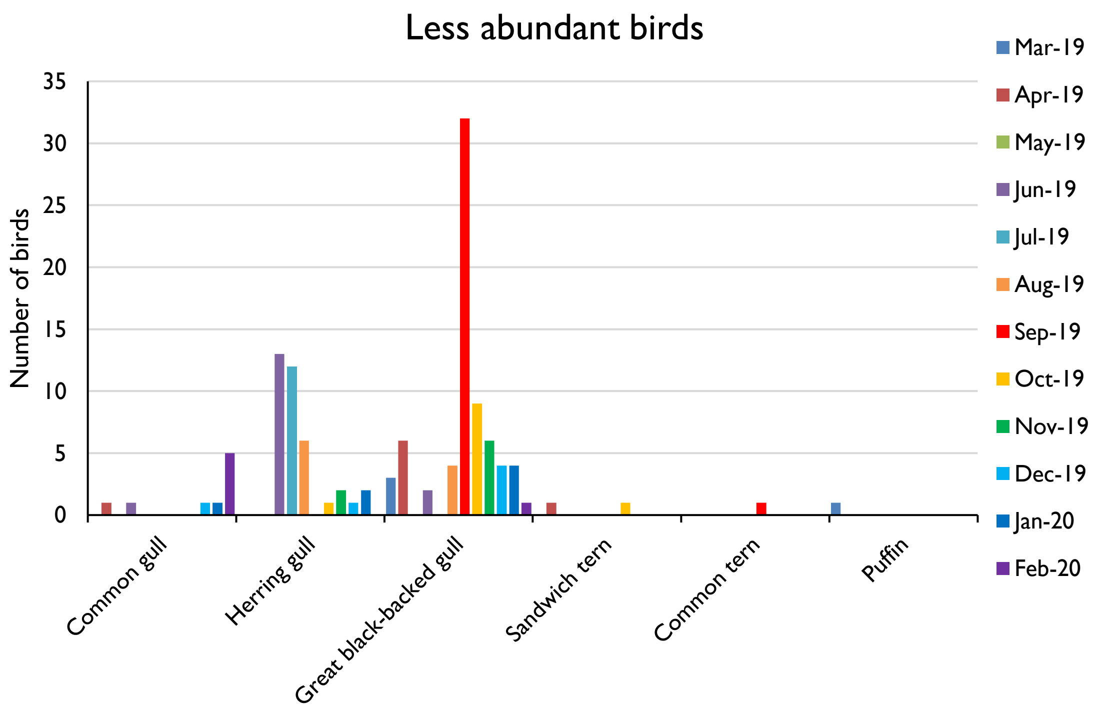
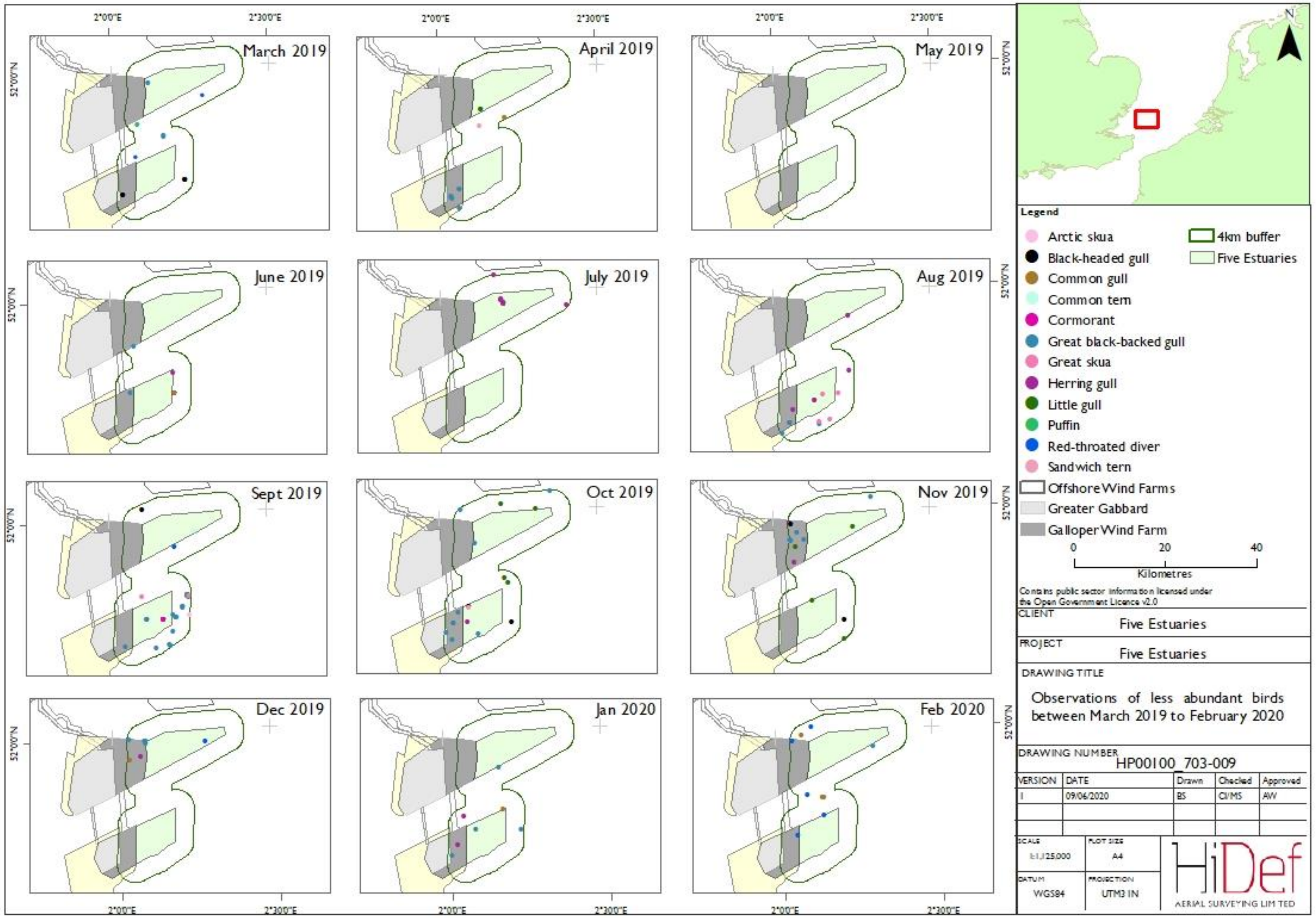

Less abundant birds
Number of birds
0
5
10
15
20
25
30
35
Common gull
Herring gull
Great black-backed gull
Sandwich tern
Common tern
Puffin
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20

Figure 23 Detections of less abundant bird species (number/km²) between March 2019 to February 2020



3.3.9 Distribution analysis for partially identified birds

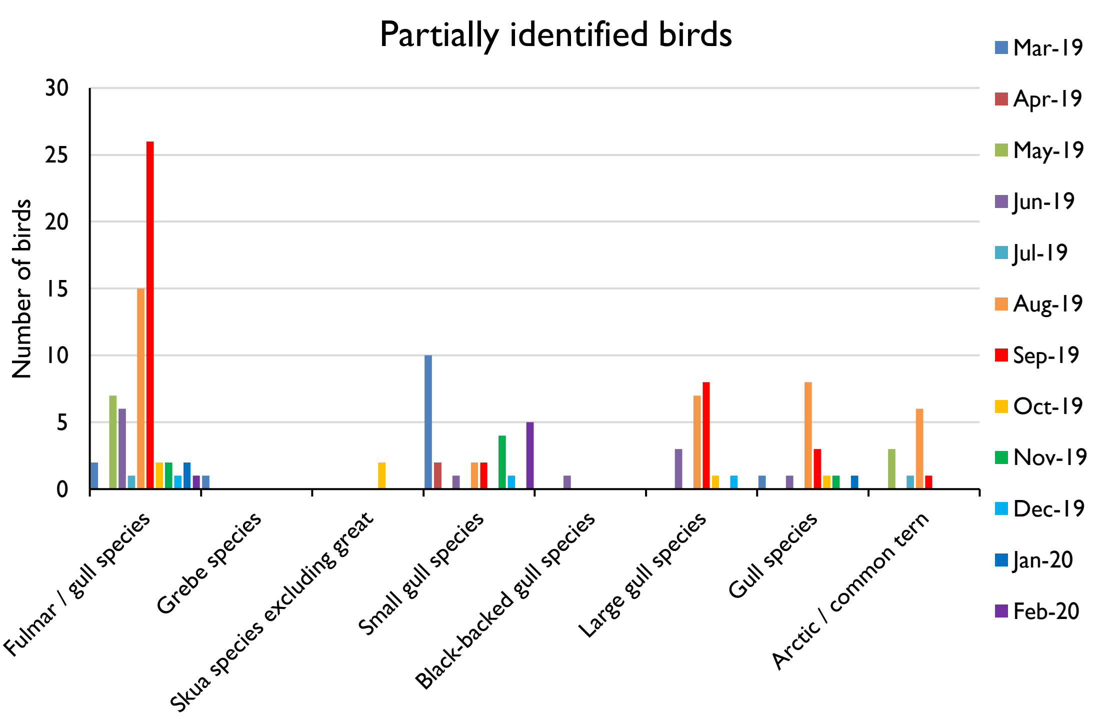
83 The numbers of partially identified birds (those assigned to species group but not species) observed across the survey season are presented in Table 26. The autumn peaks of partial-identification relate primarily to problematic identification issues with razorbill and guillemot (Figure 24). These are especially problematic to identify in autumn when juvenile birds are more abundant. Additionally, the partial-identification peaks for fulmar/gull species in August and September coincide with increased influxes of fulmars in these months. These observations relate exclusively to sitting birds. Fulmars can be harder to distinguish between gulls of a similar size at certain angles when sat on the water. Detections are shown in Figure 25.

Table 26 Number of partially identified birds recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Partially identified birds	49	20	11	12	3	42	43	20	27	55	28	167	477

Figure 24 Number of partially identified birds observed between March 2019 to February 2020 (A to B)

A:



B:

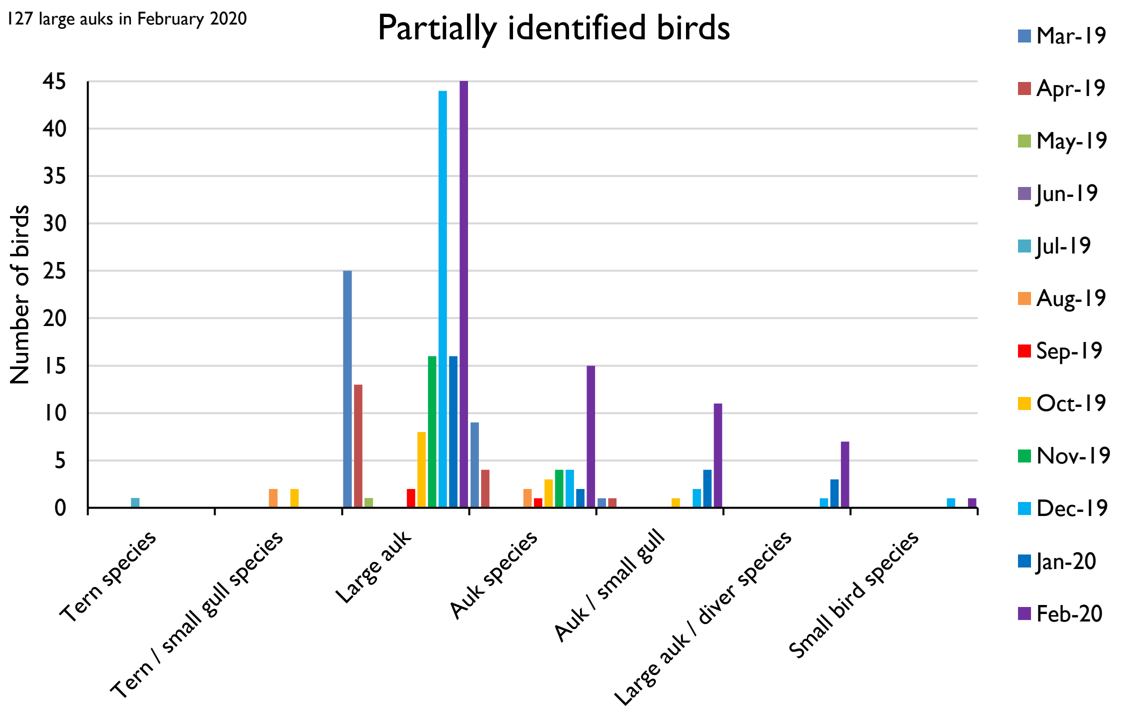
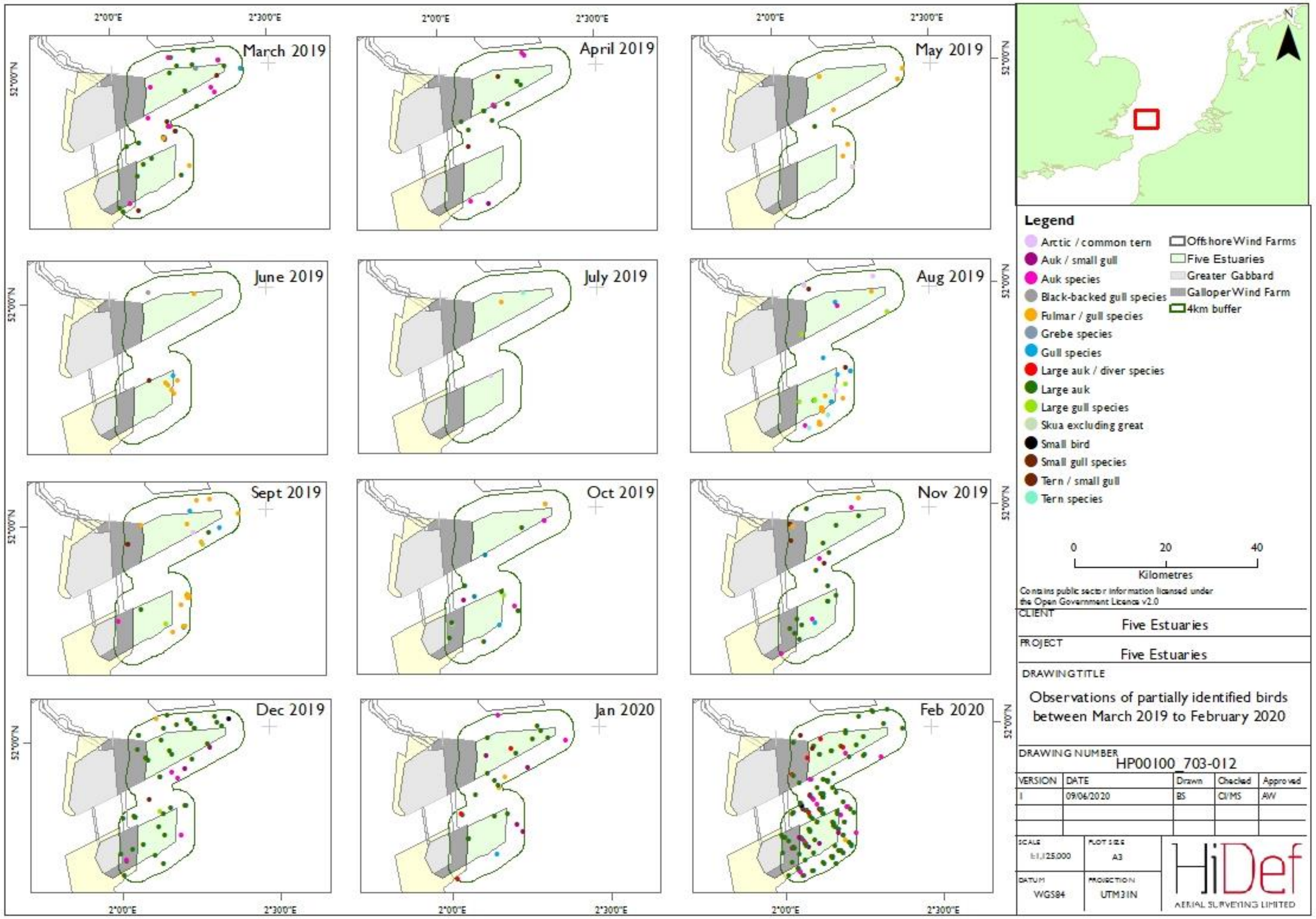

127 large auks in February 2020
Partially identified birds
Number of birds
45
40
35
30
25
20
15
10
5
0
Tern species
Tern / small gull species
Large auk
Auk species
Auk / small gull
Large auk / diver species
Small bird species
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20

Figure 25 Detections of partially identified birds(number/km²) between March 2019 to February 2020



3.3.10 Distribution and seasonal abundance of harbour porpoises

84 Harbour porpoises were the most abundant non-avian animal species and were observed throughout the survey period, with peak observations recorded in November (Table 27).

85 Absolute density and abundance was estimated at moderate to high levels, with notably high estimates in late summer and autumn (Figure 26). Harbour porpoises reached a peak density of 8.59 animals/km^2 in November, equating to 5200 animals (±95% CI 2959 – 7581). In the subsidiery peak in August and September, density was estimated at 3.05 and 3.62 animal/km^2. Outside of these three months, absolute density ranged between 0.17 and 1.52 animals/km^2, with abundance ranging between 113 animals (±95% CI 0 – 287) and 905 animals (±95% CI 350 – 1629).

86 Distribution patterns for harbour porpoises (Figure 27) varied with a high density in the north and north east of the survey area in March. Low numbers of harbour porpoises were recorded in April and May. there was no clear distribution of the species in June and July. During August, the species were concentrated in the north and south east of the survey area. From September to December, harbour porpoises were spread across the survey area. During February, harbour porpoises were concentrated in the north east and west of the survey area.

Table 27 Number of harbour porpoises recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Harbour porpoise	23	6	3	13	10	46	43	10	77	12	4	15	262

Figure 26 Harbour porpoise absolute density estimates with lower and upper 95% confidence intervals between March 2019 to February 2020

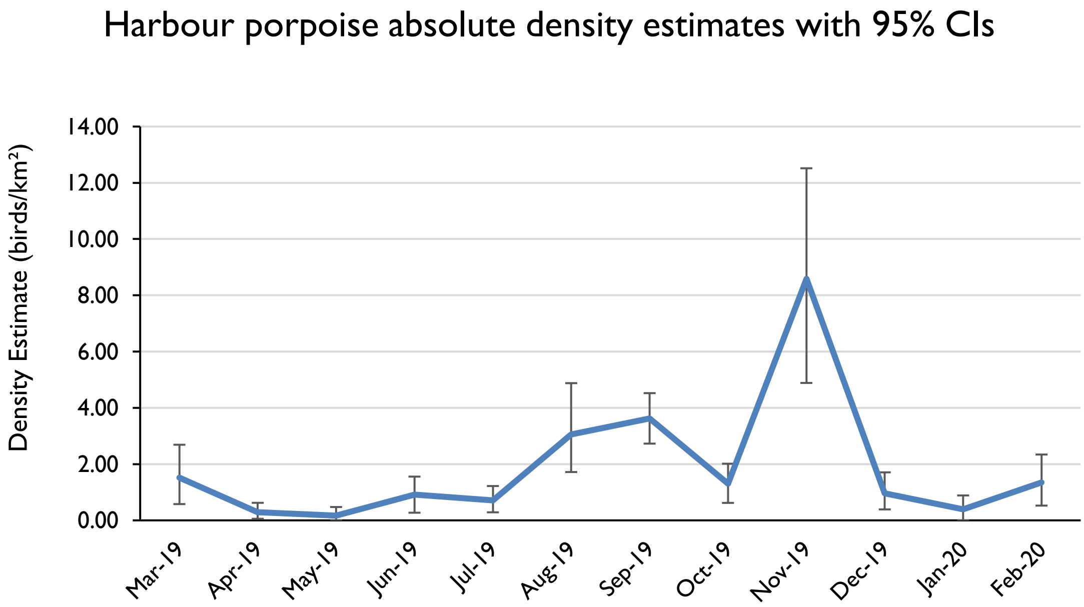
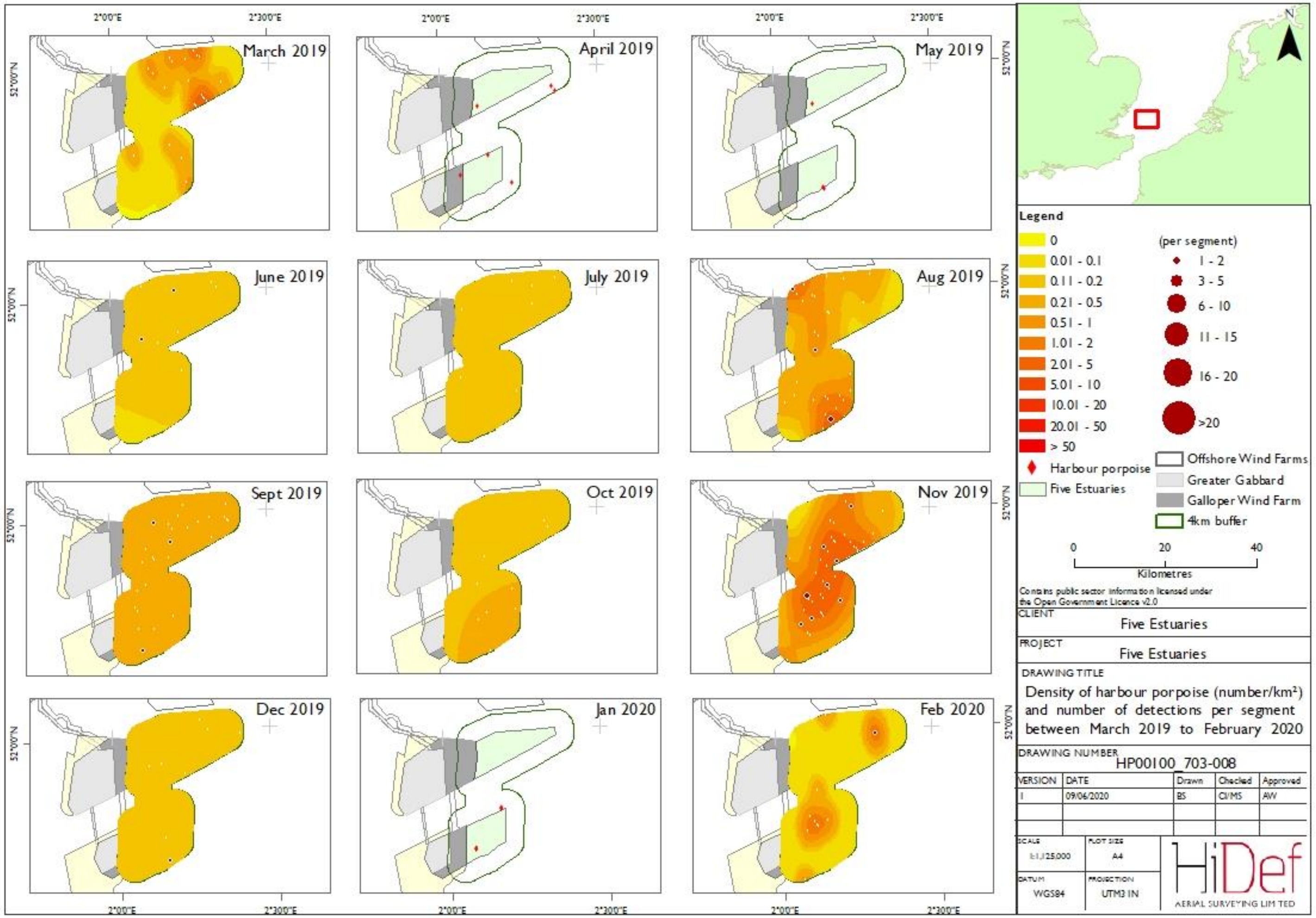


Figure 27 **Density of harbour porpoises (number/km²) and number of detections per segment between March 2019 and February 2020**



3.3.11 Distribution analysis of less abundant non-avian animal species

87 The only other non-avian animal species observed during the survey period was grey seal *Halichoerus grypus*. One or two individuals were observed intermittently through the survey period, in March, August and February (Figure 28). Detections are shown in Figure 29.

Table 28 Number of less abundant non-avian animals recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Grey seal	1	0	0	0	0	2	0	0	0	0	0	1	4

Figure 28 Number of less abundant non-avian animal species observed between March 2019 to February 2020

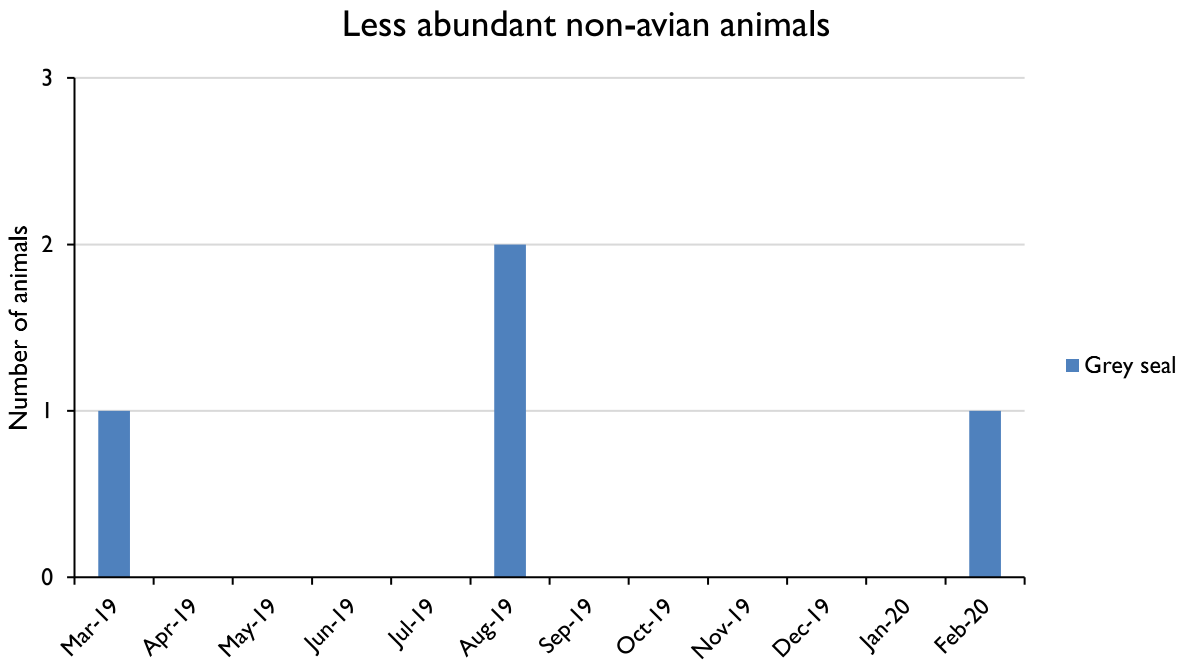
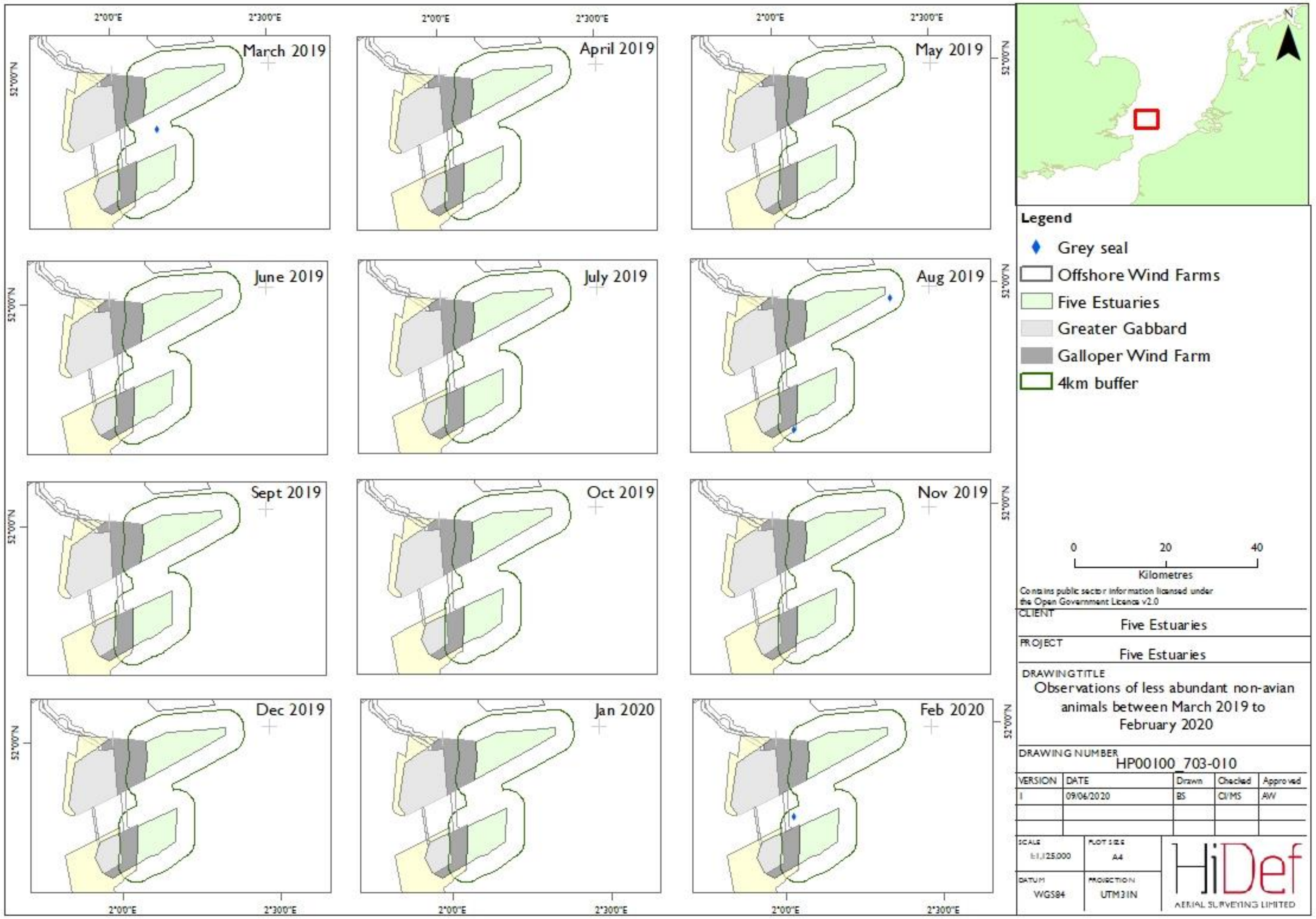


Figure 29 **Detections of less abundant non-avian species (number/km²) between March 2019 to February 2020**



3.3.12 Distribution analysis of partially identified non-avian animals

88 Partially identified non-avian animals were observed in low numbers for most months through the survey period (Figure 30). The spatial distribution of observations is shown in Figure 31. The majority of partial identifications were due to difficulty discerning between grey seal and harbour seal *Phoca vitulina*. Whilst this can be very apparent for bull grey seals due to their large size and pronounced muzzles, identification can be harder for females where body length overlaps and discerning characteristics, such as pelt and muzzle, may be concealed if the animal is submerged.

Table 29 Number of partially identified non-avian animals recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Partially identified non-avian animals	4	0	0	0	0	1	3	2	1	5	1	2	19

Figure 30 Number of partially identified non-avian animals observed between March 2019 to February 2020

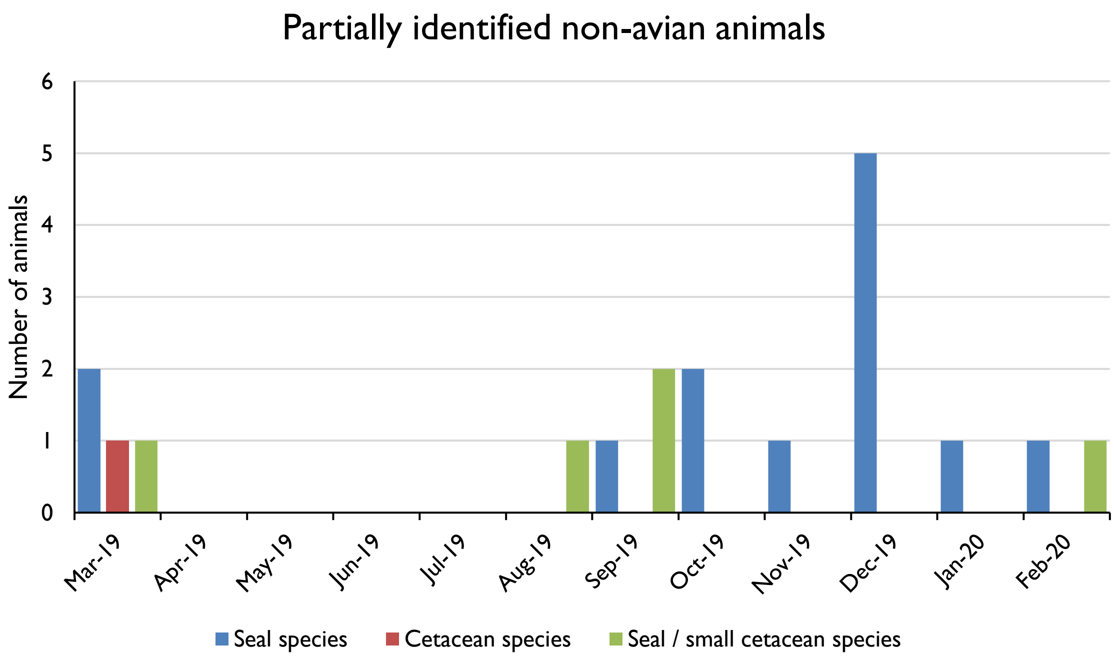
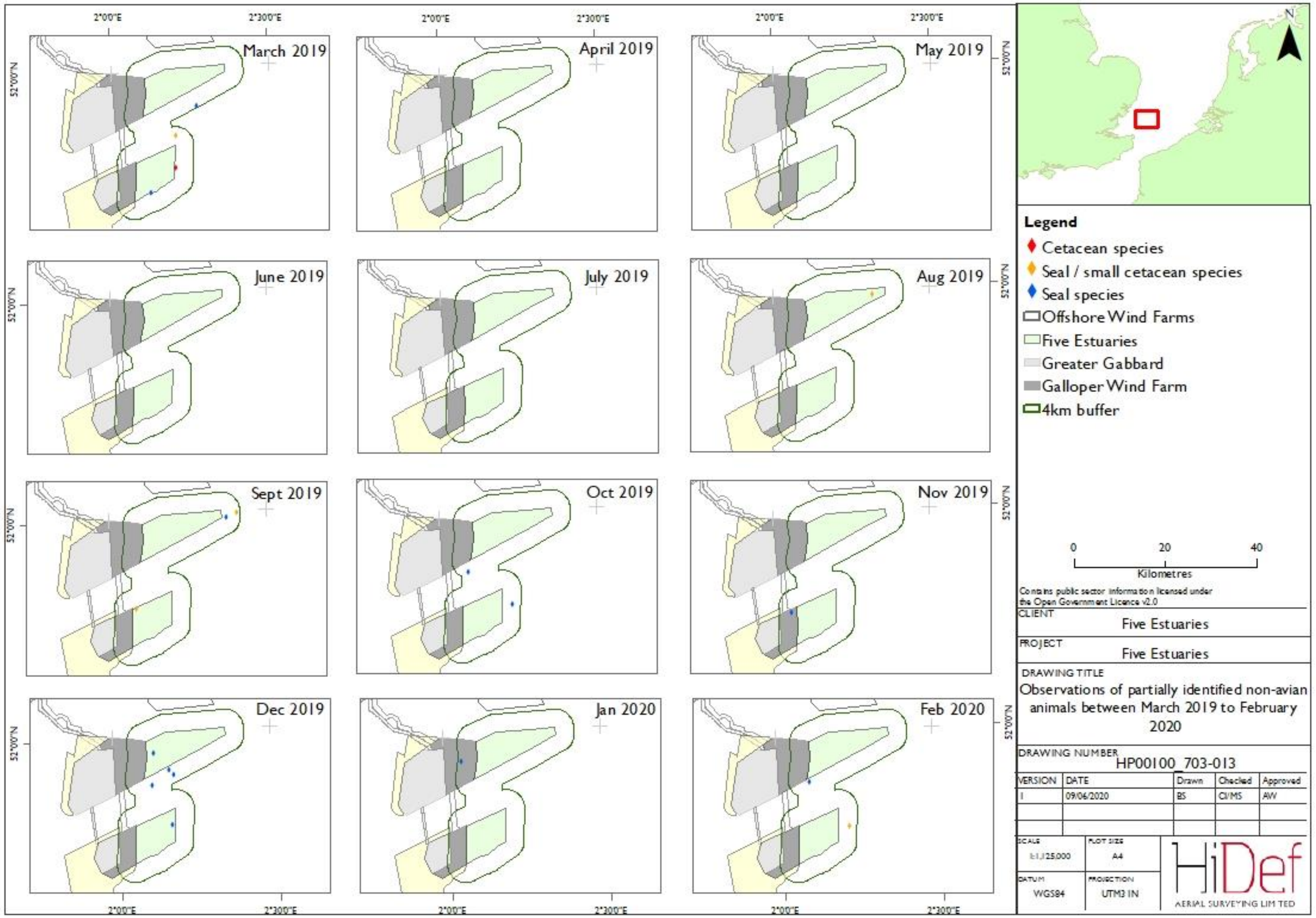


Figure 31 **Detections of partially identified non-avian animals (number/km²) between March 2019 to Feb 2020**



3.3.13 Distribution and seasonal abundance of anthropogenic activity

89 Anthropogenic activity, such as man-made objects and vessel traffic, was observed throughout the survey period (Figure 32). Detections are shown in Figure 33. Few boats were observed through the survey period. Man-made objects were recorded in all surveys, with at least 61 out of 205 observations listed as fishing buoys or equipment.

Table 30 Number of anthropogenic objects recorded between March 2019 to February 2020

Survey	1	2	3	4	5	6	7	8	9	10	11	12	Total
Fishing Boat	0	0	0	4	0	0	0	0	0	0	0	0	4
Man-made object	24	24	18	13	19	13	15	13	24	19	12	11	205
Other boat	1	1	1	0	0	1	0	0	0	0	0	3	7

Figure 32 Number of anthropogenic objects observed between March 2019 to February 2020

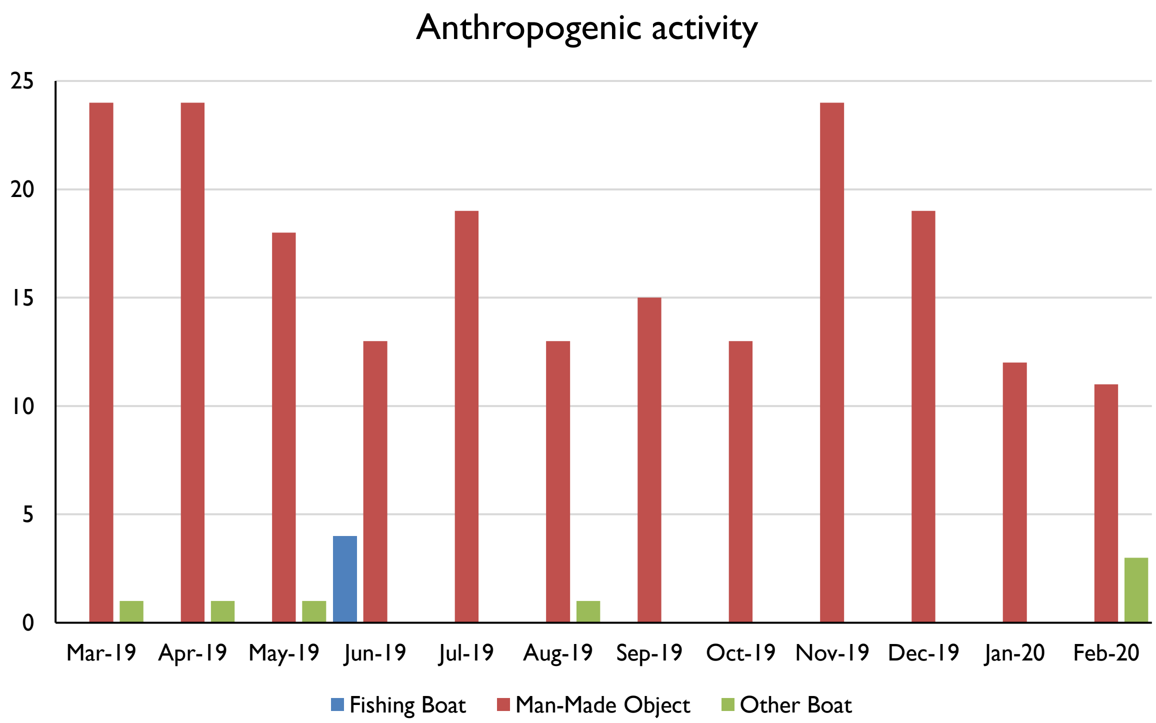
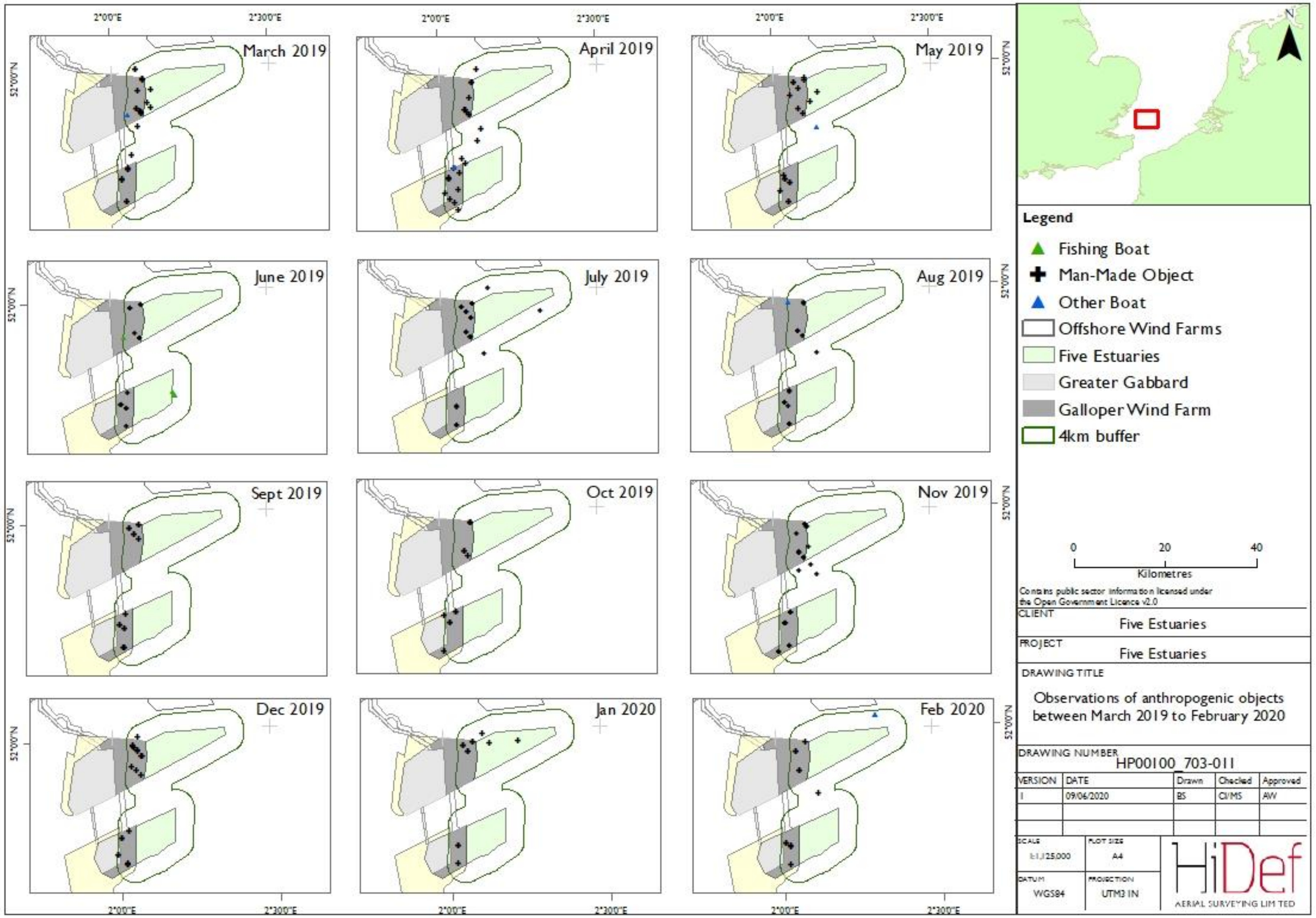


Figure 33 **Detections of vessels and anthropogenic objects between March 2019 to February 2020**



4 Discussion and conclusions

90 The surveys were successful in characterising the bird and mammal species present across the VE survey area, recording a total 6027 birds of 19 species and 266 marine mammals of two species over 12 surveys undertaken between March 2019 and February 2020. Additionally, 477 birds were partially identified to 15 separate species groups and 19 non-avian animals were partially identified to three (3) species groups. The identification rate achieved to species level was 91.35% across the survey programme.

91 The survey area can be classed as having relatively low numbers of seabirds and marine mammals in general, with occasional high densities of gannet, kittiwake, lesser black-backed gull, guillemot, razorbill and harbour porpoise being recorded.

92 Red-throated diver forms part of the classifications of the Outer Thames Estuary and Greater Wash SPAs and lesser black-backed gull form part of the Alde-Ore Estuary SPA respectively. Both species were recorded in their expected seasons and will form species of interest in further reporting.

93 Linkage of red-throated divers from the Outer Thames Estuary SPA with the survey area appears to be low, with birds rarely observed in the winter months.

94 Lesser black backed gulls were present in the survey area throughout the year, with peak densities occurring in the summer months suggesting a linkage with a breeding colony. The nearest breeding site is the Alde-Ore Estuary SPA to the north-west of the survey site

95 Kittiwakes were one of the most abundant species, and this small gull is likely to be an important receptor. Density and abundance estimates varied across the survey period with highest counts in spring. Density estimates were considerably lower through summer to negligible numbers in October. Larger numbers of birds are usually seen offshore in the winter in the southern North Sea, which corresponds to patterns observed at VE. The large influx in March and April is likely to be of passage birds travelling to their breeding grounds in spring.

96 Guillemots were the most abundant species and were recorded on every survey, except June, over the 12 months. Peak densities in early spring suggest that the area hosts concentrations of birds pre-breeding before they move north to breeding colonies. Relative and absolute density decreased significantly through the breeding season. Many of these birds will be linked to different North Sea SPA populations, such as the Forth Islands SPA, Farne Islands SPA and the Flamborough and Filey Coast SPA.

97 Razorbills showed a broadly similar pattern of records to guillemot. Peak densities in late winter and spring are likely to relate to birds gathering before moving north in the breeding season. The paucity of summer records suggests birds from UK colonies do not venture to feed in the survey area at this time. The area is used post-breeding, as with guillemot, for moulting. Relative and absolute density estimates varied between January and March but were notable enough to suggest that a winter population does exist in the survey area.

98 Harbour porpoise was the most abundant non-avian animal species with animals present in all seasons. and is also likely to be flagged as a species of interest for the site due to its significance within the Southern North Sea SAC. The relative and absolute density increased from late summer (August) through to November, decreasing in spring.

5 References

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Appendix I: Non-adjusted abundance estimates

99 The density, total estimated population, upper and lower 95% CI, standard deviation and CV for each species and species group have been calculated using strip transect analysis and are presented here for each of the 12 surveys undertaken. A description of the values presented can be found in Table 11.

Table 31 Abundance and density estimates of species groups in the survey area during Survey 1 on 26 March 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	15.55	9424	6818	12268	1409	14.94%
All non-avian animals	0.31	189	93	310	56	29.58%
Species group						
Diver species	0.02	14	0	33	9	65.41%
Fulmar / gull species	0.32	197	121	279	41	20.65%
Gannet species	0.84	507	167	1020	229	45.20%
Grebe species	0.01	7	0	21	7	97.57%
Small gull species	4.20	2546	1886	3340	374	14.67%
Black-backed gull species	0.01	7	0	20	7	93.71%
Large gull species	0.03	20	0	50	14	67.03%
Gull species	0.01	7	0	21	7	99.37%
Large auk	9.42	5711	4126	7502	865	15.14%
Auk species	0.69	418	219	659	114	27.10%
Auk / small gull	0.04	27	7	53	12	42.74%
Seal species	0.03	21	0	41	11	50.24%
Cetacean species	0.27	163	66	284	58	35.21%
Seal / small cetacean species	0.01	7	0	20	7	93.54%

Table 32 Abundance and density estimates of species in the survey area during Survey 1 on 26 March 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Red-throated diver	0.02	14	0	33	9	65.39%
Fulmar	0.29	175	111	253	37	20.77%
Gannet	0.82	498	161	1016	231	46.31%
Kittiwake	4.05	2457	1797	3224	367	14.92%
Black-headed gull	0.06	34	0	82	23	66.67%
Lesser black-backed gull	0.01	7	0	20	7	90.94%
Great black-backed gull	0.03	21	0	51	14	66.44%
Guillemot	6.02	3649	2509	4892	611	16.74%
Razorbill	3.70	2242	1550	3021	381	16.96%
Puffin	0.01	7	0	20	7	92.07%
Grey seal	0.01	7	0	20	7	91.85%
Harbour porpoise	0.26	155	60	279	57	36.59%

Table 33 Abundance and density estimates of species groups in the survey area during Survey 2 on 5 April 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	5.99	3633	2906	4390	378	10.38%
All non-avian animals	0.07	40	7	76	18	44.06%
Species group						
Fulmar / gull species	0.07	40	13	73	16	40.08%
Gannet species	0.29	178	111	254	37	20.51%
Small gull species	1.22	740	487	1016	136	18.29%
Black-backed gull species	0.27	164	25	368	91	55.63%
Large gull species	0.11	67	0	157	41	60.49%
Gull species	0.01	7	0	20	7	94.86%
Tern species	0.01	7	0	20	7	92.34%
Large auk	3.89	2356	1801	2973	302	12.78%
Auk species	0.09	53	13	103	23	42.99%
Auk / small gull	0.03	20	0	52	14	70.81%
Cetacean species	0.06	40	7	77	18	44.85%

Table 34 Abundance and density estimates of species in the survey area during Survey 2 on 5 April 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.05	33	13	58	12	35.61%
Gannet	0.29	177	112	253	37	20.46%
Kittiwake	1.18	716	466	1002	136	19.00%
Little gull	0.02	13	0	40	13	94.23%
Common gull	0.01	7	0	20	7	94.77%
Lesser black-backed gull	0.32	196	44	417	98	49.88%
Great black-backed gull	0.07	40	0	105	30	73.70%
Sandwich tern	0.01	7	0	20	7	92.46%
Guillemot	3.30	2002	1516	2554	266	13.25%
Razorbill	0.50	304	182	436	66	21.71%
Harbour porpoise	0.06	40	7	77	18	44.14%

Table 35 Abundance and density estimates of species groups in the survey area during Survey 3 on 11 May 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	1.15	696	482	913	111	15.86%
All non-avian animals	0.03	20	0	52	14	68.69%
Species group						
Fulmar / gull species	0.27	167	113	226	29	17.26%
Gannet species	0.03	21	0	40	10	49.91%
Small gull species	0.52	317	161	476	81	25.39%
Large gull species	0.04	27	0	59	15	55.53%
Gull species	0.01	7	0	20	7	101.94%
Arctic / common tern	0.03	20	0	59	19	93.53%
Large auk	0.21	126	59	197	35	27.70%
Auk species	0.01	7	0	20	7	91.23%
Auk / small gull	0.01	7	0	20	7	93.21%
Cetacean species	0.03	21	0	51	14	67.78%

Table 36 Abundance and density estimates of species in the survey area during Survey 3 on 11 May 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.17	106	58	160	27	24.99%
Gannet	0.03	20	0	40	10	49.70%
Kittiwake	0.57	344	192	509	82	23.82%
Lesser black-backed gull	0.04	27	0	59	15	55.74%
Guillemot	0.12	73	33	117	22	29.51%
Razorbill	0.09	53	13	100	22	40.53%
Harbour porpoise	0.03	20	0	51	14	68.23%

Table 37 Abundance and density estimates of species groups in the survey area during Survey 4 on 6 June 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	4.13	2505	475	6076	1658	66.19%
All non-avian animals	0.14	88	27	155	33	37.12%
Species group						
Fulmar / gull species	0.28	168	39	341	78	46.52%
Gannet species	0.59	356	71	758	187	52.28%
Small gull species	0.41	248	144	404	70	28.15%
Black-backed gull species	1.17	713	41	1916	569	79.87%
Large gull species	1.66	1006	40	2886	880	87.40%
Gull species	0.03	21	0	41	11	50.92%
Cetacean species	0.14	88	27	153	32	36.31%

Table 38 Abundance and density estimates of species in the survey area during Survey 4 on 6 June 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.19	115	31	213	47	40.77%
Gannet	0.59	358	72	770	189	52.71%
Kittiwake	0.41	249	139	414	73	29.32%
Common gull	0.01	7	0	20	7	91.70%
Lesser black-backed gull	2.64	1601	79	4481	1354	84.56%
Herring gull	0.14	88	0	244	74	84.06%
Great black-backed gull	0.02	14	0	33	9	62.52%
Harbour porpoise	0.15	89	27	154	32	35.49%

Table 39 Abundance and density estimates of species groups in the survey area during Survey 5 on 1 July 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	2.32	1404	287	3452	986	70.20%
All non-avian animals	0.11	68	27	114	23	33.46%
Species group						
Fulmar / gull species	0.09	53	0	148	45	84.19%
Gannet species	0.14	87	38	147	29	32.55%
Small gull species	0.10	61	27	101	20	31.63%
Black-backed gull species	0.01	7	0	21	7	97.65%
Large gull species	1.78	1077	64	3015	922	85.62%
Arctic / common tern	0.01	7	0	20	7	93.16%
Tern species	0.01	7	0	20	7	97.00%
Large auk	0.13	80	20	153	35	42.99%
Cetacean species	0.11	68	27	114	23	33.46%

Table 40 Abundance and density estimates of species in the survey area during Survey 5 on 1 July 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.08	48	0	133	39	82.30%
Gannet	0.14	88	38	149	30	33.29%
Kittiwake	0.10	61	27	100	19	31.45%
Lesser black-backed gull	1.69	1027	54	2831	872	84.88%
Herring gull	0.13	81	0	215	64	78.36%
Guillemot	0.12	73	13	148	36	48.17%
Razorbill	0.01	7	0	20	7	93.77%
Harbour porpoise	0.11	67	27	115	23	34.19%

Table 41 **Abundance and density estimates of species groups in the survey area during Survey 6 on 28 August 2019**

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	3.51	2127	1485	2900	360	16.91%
All non-avian animals	0.55	331	194	518	84	25.38%
Species group						
Fulmar / gull species	0.61	372	113	715	158	42.52%
Gannet species	1.11	674	436	925	129	19.07%
Skua species	0.04	28	7	48	11	40.02%
Small gull species	0.16	95	50	148	26	27.15%
Black-backed gull species	0.90	547	158	1034	225	41.14%
Large gull species	0.26	156	34	344	85	54.40%
Gull species	0.14	88	33	154	31	35.04%
Arctic / common tern	0.07	41	0	90	22	54.12%
Tern / small gull species	0.02	14	0	33	9	65.71%
Large auk	0.15	94	26	194	45	47.98%
Auk species	0.02	14	0	34	9	67.16%
Seal species	0.02	14	0	33	9	66.46%
Cetacean species	0.51	308	169	494	85	27.57%
Seal / small cetacean species	0.01	7	0	21	7	98.65%

Table 42 Abundance and density estimates of species in the survey area during Survey 6 on 28 August 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.44	265	81	484	103	38.89%
Gannet	1.11	670	439	924	126	18.76%
Great skua	0.04	27	7	51	12	41.18%
Kittiwake	0.16	95	39	161	32	32.86%
Lesser black-backed gull	1.03	624	200	1133	246	39.31%
Herring gull	0.07	41	13	74	16	39.18%
Great black-backed gull	0.05	28	0	66	17	60.03%
Guillemot	0.13	80	14	176	44	55.39%
Razorbill	0.02	14	0	41	14	97.06%
Grey seal	0.02	14	0	34	9	66.85%
Harbour porpoise	0.51	312	174	494	85	27.21%

Table 43 Abundance and density estimates of species groups in the survey area during Survey 7 on 10 September 2019

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	2.24	1357	763	2182	375	27.63%
All non-avian animals	0.51	310	232	390	41	13.14%
Species group						
Diver species	0.01	7	0	20	7	94.16%
Fulmar / gull species	0.72	439	131	824	184	41.86%
Gannet species	0.22	135	92	172	21	15.54%
Cormorant species	0.06	40	0	120	38	96.06%
Skua species	0.02	14	0	33	9	61.45%
Skua species excluding great	0.01	7	0	20	7	91.24%
Small gull species	0.39	235	87	430	89	37.84%
Black-backed gull species	0.28	168	47	349	82	48.70%
Large gull species	0.39	237	86	461	101	42.44%
Gull species	0.03	21	0	44	11	51.41%
Arctic / common tern	0.02	14	0	41	13	92.80%
Large auk	0.07	41	7	87	21	51.07%
Auk species	0.01	7	0	20	7	98.03%
Seal species	0.01	7	0	21	7	98.22%
Cetacean species	0.47	284	217	359	37	12.89%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Seal / small cetacean species	0.03	21	0	53	15	69.53%

Table 44 Abundance and density estimates of species in the survey area during Survey 7 on 10 September 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Red-throated diver	0.01	7	0	21	7	96.18%
Fulmar	0.41	251	58	496	116	45.91%
Gannet	0.22	135	93	173	21	15.26%
Cormorant	0.07	41	0	120	39	95.57%
Arctic skua	0.01	7	0	21	7	94.84%
Great skua	0.02	14	0	33	9	62.97%
Kittiwake	0.36	221	88	389	79	35.42%
Black-headed gull	0.01	7	0	21	7	94.04%
Lesser black-backed gull	0.23	143	58	244	48	33.61%
Great black-backed gull	0.36	216	54	454	108	49.63%
Common tern	0.01	7	0	21	7	93.98%
Guillemot	0.04	27	0	60	15	55.94%
Harbour porpoise	0.48	289	219	363	38	12.85%

Table 45 Abundance and density estimates of species groups in the survey area during Survey 8 on 5 October 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	2.58	1561	1130	1992	223	14.22%
All non-avian animals	0.20	121	60	182	31	25.46%
Species group						
Fulmar / gull species	0.07	41	0	90	24	56.95%
Gannet species	0.52	315	166	491	85	26.88%
Skua species excluding great	0.03	21	0	61	20	96.69%
Small gull species	0.22	131	71	192	31	23.05%
Black-backed gull species	0.12	72	20	132	30	41.29%
Large gull species	0.08	50	0	118	31	61.28%
Gull species	0.02	10	0	30	10	95.44%
Tern species	0.02	11	0	30	10	94.78%
Tern / small gull species	0.03	21	0	49	13	61.74%
Large auk	1.42	860	522	1238	183	21.21%
Auk species	0.05	31	0	78	22	68.85%
Auk / small gull	0.02	11	0	30	10	94.32%
Seal species	0.03	21	0	49	13	60.76%
Cetacean species	0.17	101	50	158	28	27.93%

Table 46 Abundance and density estimates of species in the survey area during Survey 8 on 5 October 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.03	21	0	50	13	64.39%
Gannet	0.51	309	167	495	85	27.27%
Kittiwake	0.11	70	29	121	25	34.93%
Little gull	0.07	41	0	87	22	52.31%
Black-headed gull	0.03	20	0	49	13	62.69%
Lesser black-backed gull	0.02	11	0	31	10	96.83%
Herring gull	0.02	11	0	31	10	94.17%
Great black-backed gull	0.15	91	30	160	34	36.88%
Sandwich tern	0.02	11	0	31	10	93.58%
Guillemot	0.45	274	152	398	63	22.89%
Razorbill	0.83	502	250	787	141	27.96%
Harbour porpoise	0.17	101	49	159	29	28.38%

Table 47 Abundance and density estimates of species groups in the survey area during Survey 9 on 6 November 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	5.58	3382	2225	4360	546	16.12%
All non-avian animals	1.12	678	390	973	148	21.84%
Species group						
Fulmar / gull species	0.09	53	9	110	27	49.84%
Gannet species	1.95	1185	732	1637	230	19.40%
Small gull species	0.89	539	281	829	139	25.79%
Large gull species	0.12	71	9	149	36	50.42%
Gull species	0.04	26	0	67	18	68.60%
Tern / small gull species	0.01	9	0	26	9	95.83%
Large auk	2.32	1404	898	1915	259	18.38%
Auk species	0.11	70	17	131	30	42.75%
Auk / small gull	0.06	35	0	94	27	76.18%
Seal species	0.01	9	0	26	9	97.27%
Cetacean species	1.10	668	372	965	153	22.83%

Table 48 Abundance and density estimates of species in the survey area during Survey 9 on 6 November 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.03	18	0	43	12	65.05%
Gannet	1.96	1188	750	1623	225	18.88%
Kittiwake	0.83	501	239	835	155	30.93%
Little gull	0.06	36	0	78	20	54.86%
Black-headed gull	0.03	18	0	42	11	62.15%
Lesser black-backed gull	0.04	26	0	67	18	69.30%
Herring gull	0.03	18	0	42	11	62.59%
Great black-backed gull	0.09	53	0	115	29	54.24%
Guillemot	1.56	944	604	1294	176	18.65%
Razorbill	0.59	356	142	606	120	33.69%
Harbour porpoise	1.10	666	379	971	151	22.65%

Table 49 **Abundance and density estimates of species groups in the survey area during Survey 10 on 23 December 2019**

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	6.79	4117	3345	4969	415	10.08%
All non-avian animals	0.19	116	54	186	34	28.72%
Species group						
Diver species	0.01	7	0	21	7	95.66%
Fulmar / gull species	0.01	7	0	21	7	94.53%
Gannet species	0.02	14	0	34	9	65.96%
Small gull species	0.92	561	397	749	91	16.14%
Large gull species	0.11	68	14	127	29	42.34%
Gull species	0.01	7	0	21	7	95.10%
Large auk	5.57	3380	2672	4165	385	11.38%
Auk species	0.04	27	0	60	15	54.53%
Auk / small gull	0.03	21	0	41	11	52.63%
Large auk / diver species	0.01	7	0	20	7	92.78%
Small bird species	0.01	7	0	21	7	98.57%
Seal species	0.06	34	0	77	20	58.35%
Cetacean species	0.13	82	33	141	29	34.98%

Table 50 Abundance and density estimates of species in the survey area during Survey 10 on 23 December 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Red-throated diver	0.01	7	0	21	7	96.64%
Gannet	0.02	14	0	34	9	66.42%
Kittiwake	0.93	562	396	763	95	16.79%
Common gull	0.01	7	0	21	7	94.01%
Lesser black-backed gull	0.04	28	0	59	15	51.91%
Herring gull	0.01	7	0	21	7	91.28%
Great black-backed gull	0.04	27	0	71	20	72.07%
Guillemot	1.87	1136	863	1443	150	13.12%
Razorbill	3.23	1960	1258	2784	390	19.86%
Harbour porpoise	0.13	81	32	140	29	34.83%

Table 51 **Abundance and density estimates of species groups in the survey area during Survey 11 on 18 January 2020**

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	4.20	2544	2182	2948	194	7.62%
All non-avian animals	0.08	47	0	100	26	55.64%
Species group						
Fulmar / gull species	0.08	47	18	75	15	31.54%
Grebe species	0.02	10	0	28	9	90.33%
Small gull species	0.46	279	138	477	89	31.64%
Black-backed gull species	0.05	28	0	62	16	54.88%
Large gull species	0.05	28	8	55	13	46.32%
Gull species	0.02	10	0	28	9	93.07%
Large auk	3.18	1931	1736	2138	105	5.39%
Auk species	0.21	130	26	289	70	53.44%
Auk / small gull	0.09	56	19	95	20	34.14%
Large auk / diver species	0.05	29	9	56	14	47.29%
Seal species	0.02	10	0	27	8	85.85%
Cetacean species	0.06	37	0	75	21	54.95%

Table 52 Abundance and density estimates of species in the survey area during Survey 11 on 18 January 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.05	28	0	56	14	48.46%
Great crested grebe	0.02	10	0	28	9	87.91%
Kittiwake	0.44	269	126	475	91	33.63%
Common gull	0.02	10	0	27	8	85.23%
Herring gull	0.03	19	0	46	13	66.32%
Great black-backed gull	0.06	38	9	72	16	41.63%
Guillemot	2.40	1457	1241	1698	117	8.01%
Razorbill	0.75	456	251	685	113	24.68%
Harbour porpoise	0.06	38	0	83	21	55.05%

Table 53 Abundance and density estimates of species groups in the survey area during Survey 12 on 14 February 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	21.03	12746	9175	16282	1823	14.30%
All non-avian animals	0.20	121	51	200	39	31.58%
Species group						
Diver species	0.03	21	7	40	10	47.36%
Fulmar / gull species	0.02	14	0	33	9	65.17%
Gannet species	0.55	334	144	548	104	30.95%
Small gull species	0.97	587	316	963	171	29.05%
Large gull species	0.02	14	0	33	9	66.63%
Gull species	0.06	34	0	73	18	52.48%
Large auk	17.92	10864	7866	13960	1572	14.47%
Auk species	1.03	625	351	930	150	23.98%
Auk / small gull	0.19	114	32	211	47	40.78%
Large auk / diver species	0.33	201	94	315	57	27.94%
Small bird species	0.01	7	0	20	7	93.75%
Seal species	0.02	14	0	33	9	63.79%
Cetacean species	0.17	101	39	176	36	35.31%
Seal / small cetacean species	0.01	7	0	20	7	92.07%

Table 54 Abundance and density estimates of species in the survey area during Survey 12 on 14 February 2020

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Red-throated diver	0.06	34	7	65	15	41.93%
Fulmar	0.01	7	0	25	7	98.35%
Gannet	0.55	335	152	551	103	30.59%
Kittiwake	0.93	564	338	861	136	24.08%
Common gull	0.06	34	0	90	26	75.39%
Lesser black-backed gull	0.01	7	0	20	7	96.34%
Great black-backed gull	0.01	7	0	20	7	94.74%
Guillemot	15.09	9150	6654	11798	1338	14.62%
Razorbill	2.53	1533	959	2228	325	21.15%
Grey seal	0.01	7	0	20	7	93.70%
Harbour porpoise	0.17	102	40	178	36	35.52%

Appendix II: Adjusted abundance estimates

100 Relative density and abundance estimates for three diving bird species (guillemot, razorbill and puffin) and one marine mammal species (harbour porpoise) were adjusted to account for the number of animals diving at the time of survey (availability bias) as outlined in section 2.6.3. The adjusted or 'absolute' density and population estimates and upper and lower 95% CIs for the four species are presented here for each of the 12 surveys undertaken, alongside the unadjusted 'relative' estimates.

Table 55 Adjusted density and population estimates for guillemot in the VE survey area between March 2019 and February 2020, taking into account the number of birds that are estimated as being unavailable for detection

Guillemot	Non-adjusted (relative) abundance estimates				Adjusted (absolute) abundance estimates			
	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)
26 March 2019	6.02	3649	2509	4892	7.46	4516	3119	6109
5 April 2019	3.30	2002	1516	2554	4.09	2481	1877	3183
11 May 2019	0.12	73	33	117	0.15	92	41	145
6 June 2019	0.00	0	0	0	0.00	0	0	0
1 July 2019	0.12	73	13	148	0.15	90	16	182
28 August 2019	0.13	80	14	176	0.16	100	17	225
10 September 2019	0.04	27	0	60	0.05	33	0	74
5 October 2019	0.45	274	152	398	0.56	335	178	491
6 November 2019	1.56	944	604	1294	1.92	1166	734	1615
23 December 2019	1.87	1136	863	1443	2.31	1396	1051	1781
18 January 2020	2.40	1457	1241	1698	2.93	1778	1406	2185
14 February 2020	15.09	9150	6654	11798	18.61	11283	8066	14637

Table 56 Adjusted density and population estimates for razorbill in the VE survey area between March 2019 and February 2020, taking into account the number of birds that are estimated as being unavailable for detection

Razorbill	Non-adjusted (relative) abundance estimates				Adjusted (absolute) abundance estimates			
	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)
26 March 2019	0.22	150	39	331	0.25	175	23	415
5 April 2019	0.45	311	182	453	0.49	341	132	589
11 May 2019	0.93	637	313	1025	1.05	724	282	1304
6 June 2019	0.12	80	0	240	0.14	94	0	282
1 July 2019	0.21	142	0	415	0.37	261	0	779
28 August 2019	9.82	6730	4763	8928	11.55	7919	5618	10444
10 September 2019	12.79	8766	6152	11839	14.93	10237	7024	14056
5 October 2019	2.12	1454	1068	1884	2.48	1698	1207	2215
6 November 2019	1.34	918	514	1369	1.58	1081	587	1641
23 December 2019	2.68	1838	326	3782	3.16	2166	365	4474
18 January 2020	1.07	735	120	1756	1.22	835	117	2075
14 February 2020	0.76	518	100	1109	0.89	606	94	1338

Table 57 Adjusted density and population estimates for puffin in the VE survey area between March 2019 and February 2020, taking into account the number of birds that are estimated as being unavailable for detection

Puffin	Non-adjusted (relative) abundance estimates				Adjusted (absolute) abundance estimates			
	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)
26 March 2019	0.01	7	0	20	0.01	8	0	23
5 April 2019	0.00	0	0	0	0.00	0	0	0
11 May 2019	0.00	0	0	0	0.00	0	0	0
6 June 2019	0.00	0	0	0	0.00	0	0	0
1 July 2019	0.00	0	0	0	0.00	0	0	0
28 August 2019	0.00	0	0	0	0.00	0	0	0
10 September 2019	0.00	0	0	0	0.00	0	0	0
5 October 2019	0.00	0	0	0	0.00	0	0	0
6 November 2019	0.00	0	0	0	0.00	0	0	0
23 December 2019	0.00	0	0	0	0.00	0	0	0
18 January 2020	0.00	0	0	0	0.00	0	0	0
14 February 2020	0.00	0	0	0	0.00	0	0	0

Table 58 Adjusted density and population estimates for harbour porpoise in the VE survey area between March 2019 and February 2020, taking into account the number of animals that are estimated as being unavailable for detection

Harbour porpoise	Non-adjusted (relative) abundance estimates				Adjusted (absolute) abundance estimates			
	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)
26 March 2019	0.26	155	60	279	1.52	905	350	1629
5 April 2019	0.06	40	7	77	0.29	196	34	378
11 May 2019	0.03	20	0	51	0.17	113	0	287
6 June 2019	0.15	89	27	154	0.92	545	165	942
1 July 2019	0.11	67	27	115	0.71	431	174	739
28 August 2019	0.51	312	174	494	3.05	1866	1041	2955
10 September 2019	0.48	289	219	363	3.62	2181	1653	2740
5 October 2019	0.17	101	49	159	1.30	775	376	1220
6 November 2019	1.1	666	379	971	8.59	5200	2959	7581
23 December 2019	0.13	81	32	140	0.96	599	236	1034
18 January 2020	0.06	38	0	83	0.39	246	0	537
14 February 2020	0.17	102	40	178	1.35	812	319	1418

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