Digital video aerial survey at sea of European shag (*Phalacrocorax aristotelis*) around the Isles of Scilly in 2015

First published May 2021

Natural England Research Report NECR356

www.gov.uk/natural-england

NATURAL ENGLAND

Natural England Research Report NECR356

Digital video aerial survey at sea of European shag (*Phalacrocorax aristotelis*) around the Isles of Scilly in 2015

Andy Webb & Catherine Irwin

Published May 2021

ISBN: 978-1-78354-750-0

Project details

This report should be cited as: Andy Webb & Catherine Irwin 2016. Digital video aerial survey at sea of European shag (*Phalacrocorax aristotelis) around* the Isles of Scilly in 2015. An IECS report to Natural England.

Natural England Project manager

Natural England Project Manager: Andrew Stanger

Contractor

Andy Webb & Catherine Irwin from HiDef Aerial Surveying Limited (“HiDef”)

Author

Andy Webb & Catherine Irwin from HiDef Aerial Surveying Limited (“HiDef”)

Keywords

European shag; Isles of Scilly

Further information

This report can be downloaded from the Natural England Access to Evidence Catalogue: **http://publications.naturalengland.org.uk/** . For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk**.

Acknowledgements

Contents

Figures

Tables

Executive Summary

1 HiDef Aerial Surveying Limited ("HiDef") was commissioned by Natural England to undertake a second year's monitoring of the distribution of European shag *Phalacrocorax aristotelis* (hereafter referred to as shag) at sea around the Isles of Scilly.

2 Three ultra-high resolution digital video aerial surveys were flown on 12 May 2015, 16 June 2015 and 29 July 2015 respectively across a high and a low intensity area of interest, as described in the survey protocol (HiDef document reference HP00049-001).

3 Transects were flown across the survey area on a monthly basis, with a transect spacing of 2.5 kilometres ("km") and 5km in the high and low interest areas respectively, with these limits being defined as the maximum likelihood for foraging ranges from the shag nests.

4 Data were reviewed with objects detected and identified before flight height analysis. Data were processed to estimate abundance and the distribution of shag and other key species and species groups. Behaviours, and flying directions were recorded during the process. Abundance estimates were adjusted to account for availability bias. All data were geo-referenced in the final process and analysed.

5 The results provide the raw counts of all seabirds and marine mammals detected during the surveys, with more detail being provided in the form of abundance estimates with bootstrapped 95% confidence intervals ("CI") and distribution patterns using kernel density estimation ("KDE") and dot maps for the less abundant species.

6 Separate abundance estimates and distribution maps were provided for flying and sitting shag and also to correct for availability bias. Flying direction maps were also presented for shag and lesser black-backed gulls *Larus fuscus*.

7 Two of the most abundant species recorded were shag and lesser black-backed gulls. One species which was not observed as being present within the survey area was European storm-petrel *Hydrobates pelagicus*. This mirrors the observations from the 2014 survey programme, when again, no European storm-petrel were recorded.

8 For shag, abundance estimates varied across the three months, with the peak abundance recorded in June 2015. This compares to the peak in 2014, which occurred in May. Abundance estimates in the study area were mostly lower in 2014 than the equivalent surveys in 2015; however, none of these differences were statistically significant.

9 All shag observed were recorded within the high intensity survey area and as was the case in the 2014 surveys, those sitting on the sea were found mostly in dense groups. Data collected across the survey programme demonstrated that the majority of individuals observed at sea were sitting on the water's surface.

10 The surveys were again highly successful in locating the main likely feeding areas used by shag. However, this study recommends that the precision of the abundance estimates for the species could be improved by increasing the number of transects in the high intensity area and that this may be adopted in the third year's monitoring programme.

11 Lesser black-backed and great black-backed gulls *L. marinus* were found to occur close to their nest sites on the islands, with lesser black-backed gulls being found far offshore during the

surveys. This was also the case for great black-backed gulls, once they had finished breeding in July.

1 Introduction

1 The Isles of Scilly form an archipelago consisting of over 300 islands, islets and rocks within the Celtic Sea. The archipelago is 45 kilometres ("km") south west from Land's End off the coast of Cornwall, England.

2 The islands and the surrounding waters have various national and international environmental designations including as a Special Protection Area ("SPA") under European Council Directive 2009/147/EC on the conservation of wild birds ("the Birds Directive"). The islands are a significant breeding area for migratory seabirds, supporting an assemblage of over 20,000 individual birds at the time of classification (but estimated at 9,161 breeding pairs in 2006) and 14 different species, including European shag *Phalacrocorax aristotelis* (hereafter referred to shag), lesser black-backed gull *Larus fuscus*, great black-backed gull *L. marinus* and European storm-petrel *Hydrobates pelagicus* (Heaney *et al.*, 2008).

3 The Isles of Scilly are designated a Special Area of Conservation ("SAC") under European Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora ("the Habitats directive"), an Area of Outstanding Natural Beauty ("AONB") under the Countryside and Rights of Way Act 2000 ("CRoW") (due to the unique mix of marine communities, including mammals and seabirds) and a Marine Conservation Zone ("MCZ") under the Marine and Coastal Access Act 2009 ("MCAA").

4 The Isles of Scilly possess half of south-west England's total of nesting shag and is also nationally important, as breeding shags on Scilly represent 5% of the British total. The main breeding season of this species is between mid-April and late-August, but varies considerably for individuals and between years. Generally, the peak incubation period is between mid-April and the end of June, and chicks fledge within about 2 months of hatching (Mitchell *et al.* 2004).

5 In 2014, Natural England commissioned HiDef Aerial Surveying Limited ("HiDef") to obtain data across the Isles of Scilly for the at-sea locations of shag during the breeding season. This was recommissioned in 2015 with the option in place for a third year's monitoring in 2016.

6 The methodology for the 2015 survey programme was the same as that followed in 2014, which included recording various behaviours of shag such as engaging in maintenance, or foraging behaviour, and distinguished between any non-transit and in flight birds.

7 The primary purpose of the programme was to support a possible marine extension to the Isles of Scilly SPA, with the secondary focus being on obtaining distribution data on other seabirds in the area.

8 Surveys were undertaken over a three month period between May and July 2015 to cover the breeding season for shag. The survey area consisted of both a detailed area with extra transects and a broader, more sparsely covered area both centring on the known breeding areas for shag on the islands. This coverage of the area in the surveys aimed to gain the maximum information. The surveys were flown as close to the original survey dates in 2014 as possible, where weather permitted.

9 This report includes information on the three surveys completed in 2015 and details the results of statistical analysis for seabirds and marine mammals observed, including estimates of abundance and density maps. Where appropriate, abundance estimates have been adjusted to account for availability bias. This provides an assessment of the true abundance rather than relative

abundance for diving species. Behaviour information and flight direction has also been detailed for certain species.

2 Methods

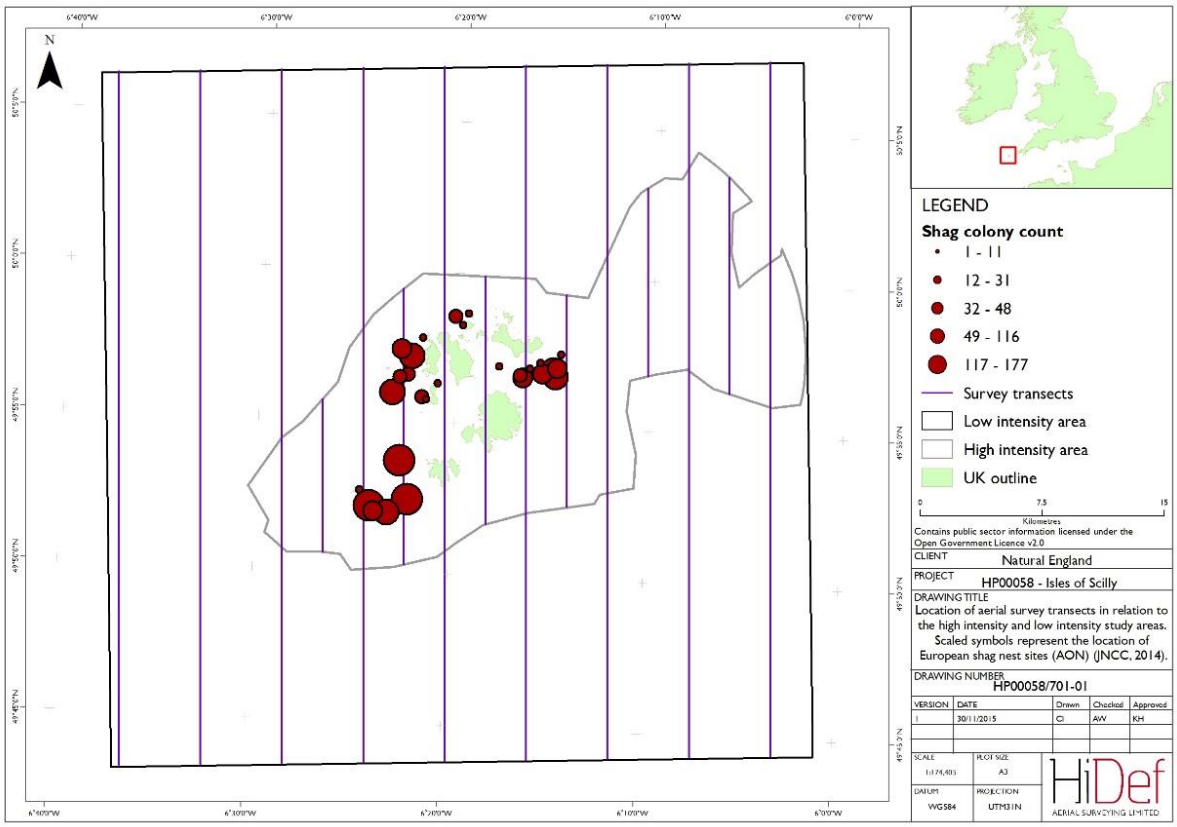
2.1 Survey flights

10 A series of transect-based surveys were flown on a monthly basis between May and July 2015, following the protocol agreed in April 2014 (HiDef document reference HP00049-001) and adopted for the 2014 survey programme. This report analyses data from the 2015 surveys.

11 Transects were spaced at 5 kilometre ("km") intervals in the low intensity area and at 2.5km in the high interest area over the Isles of Scilly. The broader transects provide contextual information for assessment of seabird and marine mammal abundance. The closer spacing of transects in the high interest area results in greater survey effort and therefore more encounters of birds and marine animals which is therefore more likely to give greater precision to abundance estimates. The full survey design is shown in Figure 1 below.

12 The limits of the high intensity survey area were defined by the likely maximum foraging range from shag nest sites of 15km (after Wanless *et al.*, 1991a) and a precautionary maximum foraging depth of 70 metres ("m") (after Wanless *et al.*, 1991b).

Figure 1 **Location of aerial survey transects in relation to the high intensity and low intensity study areas. Scaled symbols represent the location of European shag nest sites (AON) (JNCC, 2014)**



13 Surveys were undertaken using four (4) HiDef Gen II cameras with sensors set to a resolution of 2 centimetres ("cm") Ground Sample Distance ("GSD"). This means that each pixel on the camera covers 2cm on the ground, enabling a high species identification rate. 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.

14 The surveys were flown using a Diamond DA42 aircraft flying along the transect pattern shown in Figure 1 at a height of approximately 550m above sea level ("ASL") (~1800'). Flying at this height helps to reduce the risk of flushing species which are susceptible to being disturbed by the aircraft.

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

2.2 Data review and object detection

16 Data was viewed by trained reviewers; who marked any objects in the footage as requiring further analysis. For Quality Assurance ("QA"), an additional "blind" review of 20% of the raw data was carried out and the results compared with those of the original review. In the QA process, if 90% agreement is not attained then corrective action is initiated. This includes reviewing the remaining data set and if appropriate, discarding the reviewer's data. If necessary, the data is re-reviewed and additional training provided to the reviewer to improve performance.

2.3 Object Identification

17 Images marked as requiring further analysis were reviewed by specialist and experienced ornithologists and marine mammologists for identification to the lowest taxonomic level possible. This includes an assessment of approximate age and the sex of each animal, as well as any behavioural traits visible from the imagery. At least 20% of all objects are subjected to QA by a senior ornithologist not involved in the first identification process and if less than 90% agreement is attained, the ornithologist's identifications are discarded and the data re-reviewed. Disputed identifications are then passed to a third expert ornithologist for adjudication. This process ensures that HiDef can be confident in the results that are presented.

18 Species identifications were assigned a confidence rating of possible (more likely to be this taxa than any other contenders), probable (highly likely to be this taxa) or definite (as certain as is reasonably possible). The definitions of these confidence ratings do not relate to the definitions of the words used to categorise them, nor are there any specific criteria for choosing one of these categories. ID specialists also noted behaviour and travelling direction, and where possible, age, plumage and sex.

19 For marine mammals, surfacing behaviour was recorded using three categories: submerged; surfacing or snapshot surfacing, in which the dorsal fin for cetaceans or the head for seals was breaking the surface in the middle frame of the sequence where the mammal was visible (referred to as 'snapshot surfacing). The distinction of 'surfacing at red line' is important because this makes it possible to compare surfacing rates with those of studies which use data from tags attached to mammals.

2.4 Flight height analysis

20 Following identification and recording of behaviour, those individuals recorded as flying were marked in each frame of the video and their movement relative to the sea calculated to allow their height above the sea to be determined.

2.5 Final processing

21 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 shape file format, using UTM30N projection, WGS84 datum.

2.6 Data analysis

2.6.1 Data treatment

22 After basic presentation, data were processed for estimating abundance and distribution of the key species and species groups. 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 in order to simplify the interpretation.

23 For species groups which include different genus, species level identification was used to assign to species group. Where identification to species level isn't possible, a broader species group category is instead used for that record. For example, birds originally assigned to the category 'Shearwater / auk species' might be assigned to 'Shearwater species' if they were identified as a Manx shearwater *Puffinus puffinus* and to 'Auk species' if identified as a guillemot *Uria aalge*, or remain as 'Shearwater / auk species' if no species level identification was recorded.

2.6.2 Abundance Estimates

24 The abundance of each species observed was estimated separately using a design-based strip transect analysis with variance and confidence intervals ("CI") derived through 10,000 bootstraps. The bootstrapping technique uses total length of transect to limit selection rather than total number of transects. This method has a particular advantage when transects are of unequal length and provides better precision estimates.

25 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% CI and coefficient of variance ("CV") are then estimated using a non-parametric bootstrap method with replacement (Buckland *et al*. 2001).

26 The density estimate is expressed as the average number of animals per square km ("km^2") surveyed over the whole site, and the population estimate is then calculated as the average density multiplied up to the area of the whole site. The standard deviation is a measure of the variance of the population estimate, standardised by the number of samples (transects). The upper and lower CI define the range that the population estimate falls between 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. A CV value of less than 16% allows a 50% decline or 100%

increase in abundance between two samples to be detected with greater power than 0.8. This is usually regarded as the minimum precision required for monitoring effects of developments on key species.

2.6.3 Density Mapping

27 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.

28 Kernel techniques are robust but 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. Here, 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.

29 Rather than set the width parameter arbitrarily, we have used a leave-one-out cross validation method (Simonoff 1996). 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 were removed. The closer the predicted values represent the removed data, the better the model performance and the width parameter used in the model.

30 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, then the kernel width under examination is applied to the remaining data to predict the density of the missing segment. The known value is subtracted 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 of the process is a smooth density estimate which has been derived without any manual parameter selection. The whole process is repeated from scratch for each survey and species, as different kernel sizes are appropriate on a case by case basis.

31 It should be noted that several of the KDE maps are effectively flat. 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 distribution patterns, but can also happen 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 do not 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 maps were not included in the results section, and the data

presented as dot maps. Where this is relevant to the interpretation of the data, this is highlighted in the text in the results section.

2.6.4 Flying direction of seabirds

32 The direction of birds was recorded by the ID team using the heading and trajectory of the each individual between the first and last frame in the video sequence. These individual directions were summarised into eight points of the compass and presented as flight direction arrow at their geographical location for shag and lesser black-backed gull.

2.6.5 Availability bias

33 In ornithological surveys, a proportion of seabirds 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).

34 There are two main approaches to accounting for availability bias: by using double platform surveys (for example Borchers and Buckland, 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).

35 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.

36 All available data for seabirds relate to diving behaviour obtained by direct observation, or in the case of shag, to data obtained during the breeding season using data loggers. The percentage of time spent underwater for shag is 47% (Wanless *et al.*, 1993) as a proportion of the total time spent at sea not flying.

37 In order to calculate the true abundance of shag at sea, the relative abundance of birds sitting on the sea was divided by 0.47 and then added to the true abundance of flying birds.

3 Results

3.1 Survey effort

38 The date, number of transects and survey effort (as expressed by length of transects) undertaken as between May and July 2014 are shown in Table 1 and Table 2. The number of transects and the total length of transects are those used in subsequent analysis.

39 The same transect lines were used for each survey, although effort differed slightly between surveys; this was caused by minor differences in start and stop times for transects and minor deviations of the aircraft from the transect line. In a model-based sampling framework, minor variations in coverage between surveys can be accommodated. Figure 2 to Figure 4 shows the coverage achieved during each survey.

Table 1 Survey effort in the Isles of Scilly during May, June and July 2015

Survey date	Number of transects analysed	Total length of transects analysed (km)	Area covered (km²) (% cover of survey area)
12 May 2015	15	462.00	231.00 (12.57%)
16 June 2015	15	458.84	229.42 (12.48%)
29 July 2015	15	462.75	231.38 (12.59%)

Table 2 Survey effort as a percentage of the total sea area in the low and high intensity study areas during May, June and July 2015

Survey Date	Low intensity area	High intensity area
12 May 2015	10.61%	19.13%
16 June 2015	10.52%	19.04%
29 July 2015	10.63%	19.14%

Figure 2 Transects flown for Survey 1 on 12 May 2015

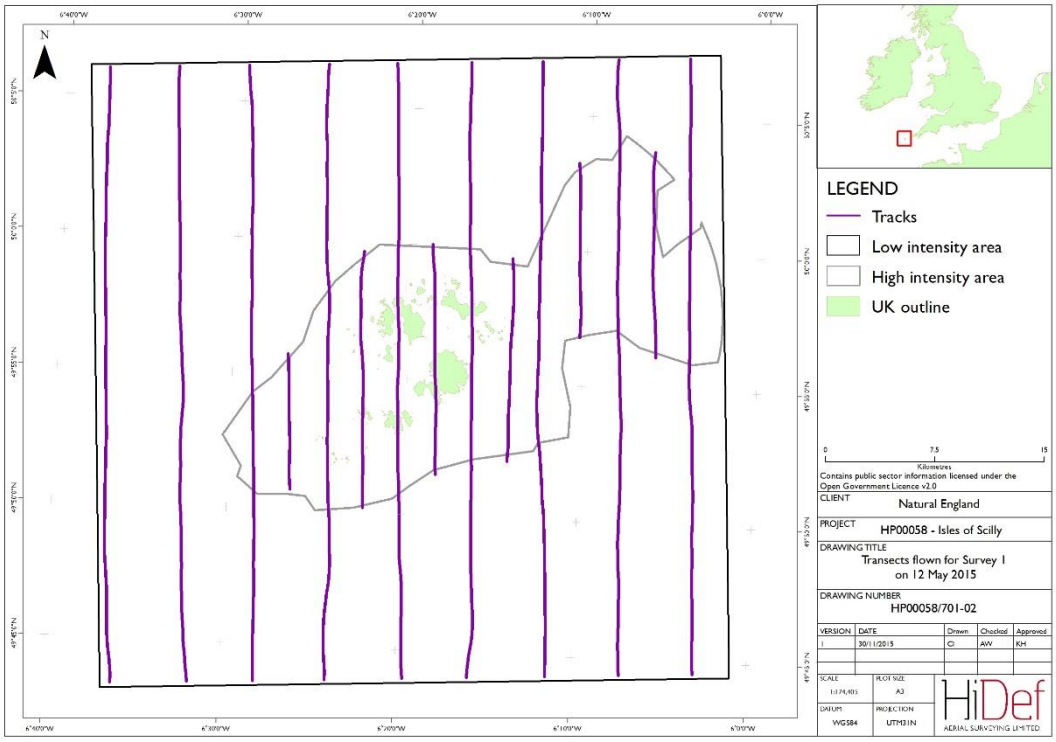


Figure 3 Transects flown for Survey 2 on 16 June 2015

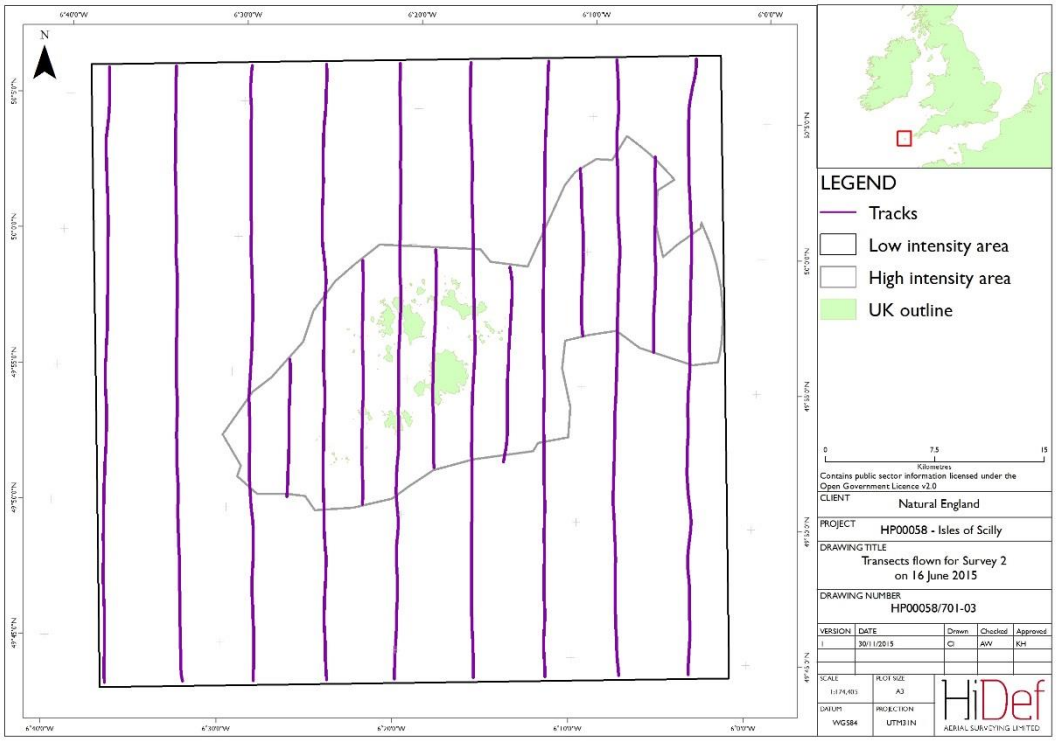
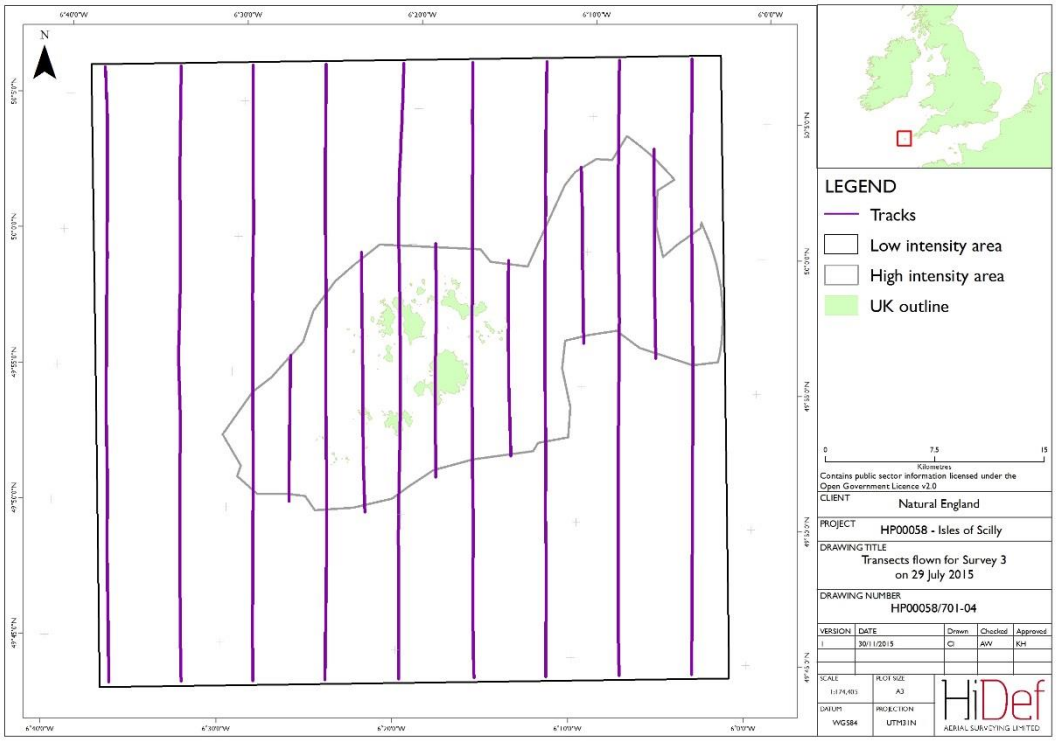


Figure 4 Transects flown for Survey 3 on 29 July 2015



3.2 Survey results

40 The total number of objects detected in each survey flight, as well as numbers of species and species group are presented in Table 3 and 4.

41 These totals include animals loafing on land (i.e. not using the sea at the time of survey) within 1m of the sea (although these were generally excluded from subsequent analysis). Each animal was assigned to at least a species group, and where possible these were also assigned a species identification 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.

42 The analysis of data to species level uses all levels of identification confidence, with the overall identification rate of birds and non-avian animals to species level for the three periods being 96.66% in May, 90.84% in June, and 93.68% in July. All animals were assigned to a species group.

43 A wide range of bird and mammal species were detected during these surveys. A number of these were shag and gull species, including lesser black-backed gulls, herring gulls and great black-backed gulls. No European storm-petrel were recorded at all during these surveys. Non-avian animals, such as blue shark *Prionace glauca* was also recorded; this was notable as this species is not recorded commonly in UK waters.

Table 3 **Number of objects detected during each entire survey assigned to species level (loafing figures are also included in the Observation columns but are excluded from the density calculations)**

Species	Scientific name	12 May 2015	16 June 2015	29 July 2015	Total
Red-throated diver	*Gavia stellata*	2	0	0	2
Fulmar	*Fulmarus glacialis*	7	23	121	151
Manx shearwater	*Puffinus puffinus*	344	51	11	406
Gannet	*Morus bassanus*	38	88	178	304
Shag	*Phalacrocorax aristotelis*	47	143	176	366
Oystercatcher	*Haematopus ostralegus*	0	13	0	13
Curlew	*Numenius arquata*	3	0	0	3
Great skua	*Stercorarius skua*	1	0	0	1
Kittiwake	*Rissa tridactyla*	1	18	1	20
Black-headed gull	*Chroicocephalus ridibundus*	0	0	2	2
Lesser black-backed gull	*Larus fuscus*	81	197	101	379
Herring gull	*Larus argentatus*	135	79	60	274
Great black-backed gull	*Larus marinus*	52	68	153	273
Common tern	*Sterna hirundo*	0	18	0	18
Guillemot	*Uria aalge*	138	128	10	276
Razorbill	*Alca torda*	3	3	0	6
Puffin	*Fratercula arctica*	0	42	0	42
Barrel jellyfish	*Rhizostoma pulmo*	1	1	0	2
Blue shark	*Prionace glauca*	0	3	0	3

Species	Scientific name	12 May 2015	16 June 2015	29 July 2015	Total
Ocean sunfish	*Mola mola*	0	38	16	54
Grey seal	*Halichoerus grypus*	2	34	1	37
Minke whale	*Balaenoptera acutorostrata*	0	1	0	1
Risso's dolphin	*Grampus griseus*	1	5	0	6
Bottle-nosed dolphin	*Tursiops truncatus*	0	0	3	3
Harbour porpoise	*Phocoena phocoena*	12	35	4	51
No ID		34	92	58	184
Total		**902**	**1080**	**895**	**2877**

Table 4 **Number of objects detected during each entire survey with no species ID assigned to species groups (loafing figures are also included in the Observation columns but are excluded from the density calculations)**

Species group (no ID)	12 May 2015	16 June 2015	29 July 2015	Total
Fulmar / gull species	4	14	16	34
Cormorant / shag	0	1	0	1
Wader species	0	0	5	5
Small gull species	1	0	0	1
Black-backed gull species	6	4	2	12
Large gull species	3	10	17	30
Gull species	8	6	15	29
Arctic / common tern	0	0	1	1
Tern species	2	2	0	4
Large auk	0	4	0	4
Auk species	2	26	0	28
Auk / small gull	1	4	1	6
Auk / shearwater species	3	18	0	21
Jellyfish	0	1	0	1
Seal species	2	0	0	2
Dolphin species	0	0	1	1
Seal / small cetacean species	2	2	0	4
Total	**34**	**92**	**58**	**184**

3.3 Abundance estimates

44 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 in Table 5 to Table 18. These estimates were for individuals at sea only (i.e. loafing animals on land were excluded from the analysis).

45 Shag was identified as the key species for observation within the surveys. The overall density of shags across all months in the high intensity area was 0.70 birds/km² with a CV of 54.38%. No shags were observed outside this high intensity area.

46 The density was highest during June 2015 with 1.41 birds/km² in the high intensity area; this was much higher than the highest density (in the high intensity area) recorded during the 2014 surveys.

47 There were lower densities of shag in the May and July 2015 surveys in the high intensity area. Abundance estimates were adjusted to accommodate availability bias, which resulted in a density across all months of 1.35 birds/km².

48 Adjusted density across the high intensity area was highest in June 2015 at 2.92 birds/km², with the surveys in May and July 2015 having an adjusted density estimate of 1.07 and 0.13 birds/km² respectively.

49 Highlights for other species observed in the entire survey area are listed below:

- Red-throated diver *Gavia stellata* was only recorded during the May 2015 survey;
- Fulmar *Fulmarus glacialis* was recorded as increasing in density between 0.03 birds/km² in May 2015 to 0.54 birds/km² in July 2015;
- Manx shearwater peaked during the May 2015 survey;
- Gannet *Morus bassanus* densities increased from 0.18 birds/km² in May 2015 to 0.82 birds/km² in July 2015;
- Curlew *Numenius arquata* and great skua *Stercorarius skua* were only recorded during the May 2015 survey and oystercatcher *Haematopus ostralegus* was only observed during June 2015;
- Kittiwake *Rissa tridactyla* density varied across all months, with the highest density being in June 2015;
- Black-headed gull *Chroicocephalus ridibundus* was only recorded in July 2015, at a density of 0.01 birds/km²;
- The overall density of lesser black-backed gull over the three months was 0.58 birds/km² (an increase from 2014), with a CV of 13.67%. Density increased from 0.37 birds/km² in May 2015 to 0.93 birds/km² in June 2015, before decreasing to 0.48 birds/km² in July 2015. There was an increase in density from May to July 2015 in the high intensity area (0.80 birds/km² to 0.98 birds/km²);
- Herring gull *Larus argentatus* density increased between May and July 2015;
- The density of great black-backed gull peaked at 0.72 birds/km² in July 2015 (1.04 birds/km² in the high intensity area) but averaged 0.42 birds/km² across all months with a CV of 16.36%. The density across the entire survey area was lowest in May 2015 with 0.24 birds/km². In the high intensity area the density was lowest in June 2015 with 0.43 birds/km², however this was an increase from the 2014 data;
- Common tern *Sterna hirundo* was only observed in June 2015;
- Guillemot density was highest during May and June 2015 with 0.66 birds/km² and 0.62 birds/km² respectively. This decreased to 0.05 birds/km² in July 2015;
- Razorbill *Alca torda* was observed in May and June 2015, but was absent in July 2015;

- Puffin *Fratercula arctica* was only observed in June 2015, at a density of 0.20 birds/km²;
- Blue shark *Prionace glauca* was only recorded in June 2015;
- Ocean sunfish *Mola mola* was recorded in June and July 2015, with observations peaking during the June 2015 survey;
- Grey seal *Halichoerus grypus* was recorded at sea in all months. The lowest density was recorded in July 2015, with the highest in June 2015;
- Minke whale *Balaenoptera acutorostrata* was only observed in June 2015, while bottle-nosed dolphin *Tursiops truncatus* was only observed in July 2015;
- Harbour porpoise *Phocoena phocoena* was present in all months, with observations being highest in June 2015; and
- Risso's dolphin *Grampus griseus* was recorded in both May and June 2015, with the peak counts being in June 2015.

Table 5 **Estimated overall abundance and density f species groups across the three surveys undertaken in 2015 in the entire survey area**

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	3.85	7065	5265	8997	954	13.50%
All non-avian animals	0.22	405	308	510	52	12.85%
Species group						
Diver species	0.00	6	0	21	5	95.98%
Fulmar / gull species	0.28	521	334	760	109	20.96%
Shearwater species	0.61	1121	253	2328	539	48.13%
Gannet species	0.46	847	708	998	74	8.74%
Cormorant species	0.23	422	81	902	249	59.01%
Wader species	0.03	60	13	123	29	47.98%
Skua species	0.00	3	0	8	3	94.14%
Small gull species	0.03	63	21	120	26	41.10%
Black-backed gull species	0.22	395	204	651	117	29.56%
Large gull species	1.22	2247	1607	2995	355	15.81%
Gull species	0.06	118	57	193	35	29.79%
Arctic / common tern	0.02	43	0	118	33	75.61%
Tern species	0.01	23	5	47	11	47.97%
Large auk	0.44	812	457	1244	201	24.75%
Small auk	0.02	34	8	71	16	46.88%
Auk species	0.10	175	68	314	64	36.40%

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Auk / small gull	0.01	17	5	31	7	43.06%
Auk / shearwater species	0.06	105	24	230	55	51.91%
Jellyfish	0.00	9	0	18	5	53.49%
Fish species	0.08	154	99	217	30	19.48%
Shark species	0.00	9	0	18	5	52.90%
Seal species	0.03	54	24	91	17	30.83%
Dolphin species	0.02	28	0	65	17	60.14%
Cetacean species	0.08	143	89	206	30	21.15%
Seal / small cetacean species	0.00	8	0	18	5	53.88%

Table 6 **Estimated overall abundance and density of species across the three surveys undertaken in 2015 in the entire survey area**

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Red-throated diver	0.00	6	0	21	5	95.98%
Fulmar	0.23	416	246	635	99	23.83%
Manx shearwater	0.63	1166	293	2370	540	46.31%
Gannet	0.46	847	708	998	74	8.74%
Shag	0.23	422	65	893	251	54.97%
Oystercatcher	0.02	37	5	84	21	55.71%
Curlew	0.00	9	0	24	6	69.67%
Great skua	0.00	3	0	8	3	94.14%
Kittiwake	0.03	57	16	115	26	45.09%
Black-headed gull	0.00	6	0	13	4	66.59%
Lesser black-backed gull	0.58	1065	794	1364	146	13.67%
Herring gull	0.41	745	342	1288	246	33.03%
Great black-backed gull	0.42	764	530	1019	125	16.36%
Common tern	0.03	52	5	131	33	64.43%
Guillemot	0.43	792	444	1218	198	24.99%
Razorbill	0.01	17	3	37	8	49.09%
Puffin	0.07	120	44	214	44	36.45%
Barrel jellyfish	0.00	6	0	13	4	65.96%
Ocean sunfish	0.08	154	99	217	30	19.48%

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Grey seal	0.03	49	18	84	17	34.21%
Minke whale	0.00	3	0	8	3	94.24%
Risso's dolphin	0.01	17	0	47	14	80.30%
Bottle-nosed dolphin	0.00	9	0	24	8	94.34%
Harbour porpoise	0.08	140	86	204	30	21.67%
Blue shark	0.00	9	0	18	5	52.90%

Table 7 **Estimated overall abundance and density of species group across the three surveys undertaken in 2015 in the high intensity survey area**

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	7.47	3155	2202	4244	520	16.48%
All non-avian animals	0.29	124	86	166	21	16.84%
Species group						
Diver species	0.01	4	0	10	3	95.12%
Fulmar / gull species	0.18	75	44	109	17	22.24%
Shearwater species	1.44	609	107	1295	309	50.84%
Gannet species	0.62	264	206	329	32	11.99%
Cormorant species	0.70	297	86	651	161	54.08%
Wader species	0.07	29	2	74	19	66.99%
Small gull species	0.07	30	5	64	15	50.66%
Black-backed gull species	0.41	172	57	347	75	43.73%
Large gull species	2.28	965	611	1420	210	21.75%
Gull species	0.13	54	20	97	20	36.91%
Arctic / common tern	0.06	27	3	64	16	61.03%
Tern species	0.01	4	0	8	2	66.92%
Large auk	1.04	440	258	654	101	22.87%
Small auk	0.05	22	5	44	10	46.89%
Auk species	0.24	102	39	186	38	37.45%
Auk / small gull	0.00	2	0	5	2	96.09%
Auk / shearwater species	0.15	62	7	158	44	71.25%

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Jellyfish	0.01	4	0	8	2	66.41%
Fish species	0.08	34	18	52	9	25.01%
Shark species	0.00	2	0	7	2	96.39%
Seal species	0.08	32	12	60	13	38.89%
Cetacean species	0.11	49	20	84	16	33.86%
Seal / small cetacean species	0.01	4	0	8	2	66.62%

Table 8 Estimated overall abundance and density of species across the three surveys undertaken in 2015 in the high intensity survey area

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Red-throated diver	0.01	4	0	10	3	95.12%
Fulmar	0.11	45	27	65	10	22.04%
Manx shearwater	1.51	637	134	1326	309	48.56%
Gannet	0.62	264	206	329	32	11.99%
Shag	0.70	295	86	648	161	54.38%
Oystercatcher	0.06	23	2	57	14	61.91%
Curlew	0.01	5	0	15	5	94.28%
Kittiwake	0.06	27	2	60	15	57.49%
Black-headed gull	0.01	4	0	8	2	66.61%
Lesser black-backed gull	0.91	386	257	534	70	18.22%
Herring gull	1.00	423	178	770	154	36.40%
Great black-backed gull	0.69	290	190	428	62	21.37%
Common tern	0.07	28	3	67	17	58.77%
Guillemot	1.01	428	250	639	98	23.04%
Razorbill	0.03	11	2	22	5	48.11%
Puffin	0.17	72	25	131	27	37.88%
Barrel jellyfish	0.00	2	0	5	2	95.47%
Ocean sunfish	0.08	34	18	52	9	25.01%
Grey seal	0.07	29	7	57	13	43.81%
Harbour porpoise	0.11	49	20	84	16	33.86%

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Blue shark	0.00	2	0	7	2	96.39%

Table 9 Estimated overall abundance and density of species groups during May 2015 survey in the entire survey area

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	4.12	7573	2403	14,221	3055	40.35%
All non-avian animals	0.09	174	94	266	42	24.38%
Species group						
Diver species	0.01	18	0	47	16	92.64%
Fulmar / gull species	0.05	97	39	172	34	35.52%
Shearwater species	1.64	3019	23	7459	1963	65.02%
Gannet species	0.18	325	203	470	69	21.34%
Cormorant species	0.18	338	98	583	133	39.41%
Wader species	0.01	27	0	70	25	92.64%
Skua species	0.00	9	0	23	8	91.33%
Small gull species	0.00	9	0	23	8	92.29%
Black-backed gull species	0.31	573	70	1471	379	66.17%
Large gull species	0.94	1722	321	3929	966	56.06%
Gull species	0.05	88	23	172	38	43.19%
Tern species	0.01	17	0	39	11	60.95%
Large auk	0.67	1232	235	2512	594	48.24%
Auk species	0.01	26	8	55	13	49.60%
Auk / small gull	0.00	9	0	31	8	92.73%

Category	Density estimate (n/km²)	Abundance estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Auk / shearwater species	0.01	26	0	70	24	91.14%
Jellyfish	0.00	9	0	23	8	91.26%
Seal species	0.02	35	8	70	15	43.04%
Dolphin species	0.00	9	0	23	8	91.76%
Cetacean species	0.06	104	31	188	40	38.14%
Seal / small cetacean species	0.01	17	0	39	11	62.98%

Table 10 Estimated overall abundance and density of species during May 2015 survey in the entire survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Red-throated diver	0.01	18	0	47	16	92.64%
Fulmar	0.03	62	23	110	21	34.83%
Manx shearwater	1.64	3019	23	7459	1963	65.02%
Gannet	0.18	325	203	470	69	21.34%
Shag	0.18	338	75	632	159	39.41%
Curlew	0.01	27	0	70	25	92.64%
Great skua	0.00	9	0	23	8	91.33%
Kittiwake	0.00	9	0	23	8	92.29%
Lesser black-backed gull	0.37	682	211	1284	276	40.41%
Herring gull	0.61	1120	86	2880	780	69.68%
Great black-backed gull	0.24	441	55	1096	295	66.83%
Guillemot	0.66	1214	211	2505	595	49.04%
Razorbill	0.01	26	0	70	18	67.69%
Barrel jellyfish	0.00	9	0	23	8	91.26%
Grey seal	0.01	18	0	47	11	64.51%
Risso's dolphin	0.00	9	0	23	8	91.76%
Harbour porpoise	0.06	104	31	188	40	38.14%

Table 11 Estimated overall abundance and density of species groups during May 2015 survey in the high intensity survey area.

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	9.80	4142	1317	7648	1626	39.26%
All non-avian animals	0.10	43	20	70	13	30.27%
Species group						
Diver species	0.03	11	0	30	10	92.98%
Fulmar / gull species	0.08	32	0	75	20	62.03%
Shearwater species	4.20	1775	80	4329	1138	64.10%
Gannet species	0.23	97	50	146	24	25.01%
Cormorant species	0.54	230	96	377	73	31.63%
Wader species	0.04	16	0	45	15	92.98%
Small gull species	0.01	5	0	15	5	92.11%
Black-backed gull species	0.72	304	25	774	225	73.89%
Large gull species	2.26	955	146	2212	569	59.54%
Gull species	0.10	43	15	75	15	35.74%
Large auk	1.52	641	156	1267	285	44.36%
Auk species	0.03	11	0	25	7	61.59%
Auk / small gull	0.01	5	0	15	5	92.22%
Auk / shearwater species	0.04	16	0	45	15	92.20%
Seal species	0.05	21	5	40	8	39.03%
Cetacean species	0.04	16	0	40	11	66.58%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Seal / small cetacean species	0.01	5	0	15	5	91.71%

Table 12 Estimated overall abundance and density of species during May 2015 survey in the high intensity survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Red-throated diver	0.03	11	0	30	10	92.98%
Fulmar	0.05	22	0	45	11	52.07%
Manx shearwater	4.20	1775	80	4329	1138	64.10%
Gannet	0.23	97	50	146	24	25.01%
Shag	0.54	230	96	377	73	31.63%
Curlew	0.04	16	0	45	15	92.98%
Kittiwake	0.01	5	0	15	5	92.11%
Lesser black-backed gull	0.80	336	70	674	156	46.29%
Herring gull	1.55	655	50	1649	465	70.93%
Great black-backed gull	0.58	246	25	613	176	71.49%
Guillemot	1.49	631	141	1257	286	45.38%
Razorbill	0.04	16	0	40	11	65.78%
Grey seal	0.03	11	0	25	7	62.13%
Harbour porpoise	0.04	16	0	40	11	66.58%

Table 13 Estimated overall abundance and density of species group during June 2015 survey in the entire survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	4.43	8138	4672	12,385	1979	24.31%
All non-avian animals	0.47	859	559	1198	164	19.03%
Species Group						
Fulmar / gull species	0.19	352	173	599	111	31.37%
Shearwater species	0.17	309	47	678	167	54.02%
Gannet species	0.42	777	481	1111	163	20.96%
Cormorant species	0.48	876	23	2212	700	79.89%
Wader species	0.06	117	16	276	69	59.09%
Small gull species	0.09	159	16	378	98	62.07%
Black-backed gull species	0.34	627	339	1016	177	28.32%
Large gull species	1.30	2395	1591	3293	435	18.14%
Gull species	0.05	88	32	158	33	37.00%
Arctic / common tern	0.07	123	0	331	97	78.34%
Tern species	0.03	52	16	102	22	42.67%
Large auk	0.65	1188	441	2222	463	38.96%
Small auk	0.06	107	16	221	51	47.78%
Auk species	0.28	520	102	1135	270	51.91%
Auk / small gull	0.02	35	8	79	18	51.90%
Auk / shearwater species	0.17	306	24	898	231	75.50%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Jellyfish	0.01	18	0	47	12	63.06%
Fish species	0.18	333	213	481	69	20.71%
Shark species	0.01	26	8	55	13	48.70%
Seal species	0.07	125	0	299	76	60.84%
Dolphin species	0.02	44	0	118	40	90.45%
Cetacean species	0.17	304	158	496	86	28.44%
Seal / small cetacean species	0.00	9	0	24	8	91.39%

Table 14 Estimated overall abundance and density of species during June 2015 survey in the entire survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Fulmar	0.11	202	95	370	75	37.06%
Manx shearwater	0.25	454	95	890	203	44.81%
Gannet	0.42	777	481	1111	163	20.96%
Shag	0.48	876	23	2222	703	79.90%
Oystercatcher	0.06	117	16	276	69	59.09%
Kittiwake	0.09	159	16	378	98	62.07%
Lesser black-backed gull	0.93	1703	969	2592	417	24.51%
Herring gull	0.37	676	370	1024	166	24.51%
Great black-backed gull	0.32	581	355	843	124	21.39%
Common tern	0.09	158	16	394	105	66.30%
Guillemot	0.62	1143	441	2119	436	38.12%
Razorbill	0.01	27	0	63	18	66.69%
Puffin	0.20	375	87	741	169	45.03%
Barrel jellyfish	0.00	9	0	32	8	90.63%
Ocean sunfish	0.18	333	213	481	69	20.71%
Grey seal	0.07	125	0	299	76	60.84%
Minke whale	0.00	9	0	24	8	89.82%
Risso's dolphin	0.02	44	0	118	40	90.45%
Harbour porpoise	0.16	295	150	481	85	28.92%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Blue shark	0.01	26	8	55	13	48.70%

Table 15 Estimated overall abundance and density of species groups during June 2015 survey in the high intensity survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	7.46	3154	1268	5475	1078	34.18%
All non-avian animals	0.64	270	141	409	67	24.99%
Species group						
Fulmar / gull species	0.15	64	15	126	29	44.46%
Gannet species	0.32	135	51	232	47	34.43%
Cormorant species	1.42	600	15	1566	456	76.01%
Wader species	0.17	70	10	157	40	57.55%
Small gull species	0.17	70	0	192	59	84.11%
Black-backed gull species	0.47	199	56	414	96	48.48%
Large gull species	1.76	745	404	1131	184	24.70%
Gull species	0.05	22	5	40	9	39.58%
Arctic / common tern	0.18	76	0	202	59	78.35%
Tern species	0.03	11	0	25	7	63.00%
Large auk	1.49	631	222	1207	254	40.28%
Small auk	0.15	64	15	126	30	45.78%
Auk species	0.70	296	56	641	154	51.98%
Auk / shearwater species	0.41	172	10	449	137	79.53%
Jellyfish	0.03	11	0	25	7	61.85%
Fish species	0.13	54	15	101	23	41.91%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Shark species	0.01	5	0	15	5	92.10%
Seal species	0.18	75	10	177	45	60.23%
Cetacean species	0.28	119	30	227	50	42.01%
Seal / small cetacean species	0.01	5	0	15	5	92.04%

Table 16 Estimated overall abundance and density of species during June 2015 survey in the high intensity survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Fulmar	0.06	27	5	51	11	42.37%
Manx shearwater	0.20	86	0	242	79	91.99%
Gannet	0.32	135	51	232	47	34.43%
Shag	1.41	594	10	1561	456	76.78%
Oystercatcher	0.17	70	10	157	40	57.55%
Kittiwake	0.17	70	0	192	59	84.11%
Lesser black-backed gull	0.97	410	162	717	143	34.87%
Herring gull	0.73	307	157	480	81	26.37%
Great black-backed gull	0.43	183	86	293	54	29.50%
Common tern	0.20	87	0	227	65	74.84%
Guillemot	1.43	604	222	1141	238	39.49%
Razorbill	0.04	16	0	40	11	65.86%
Puffin	0.51	215	51	429	97	45.17%
Barrel jellyfish	0.01	5	0	15	5	93.50%
Ocean sunfish	0.13	54	15	101	23	41.91%
Grey seal	0.18	75	10	177	45	60.23%
Harbour porpoise	0.28	119	30	227	50	42.01%
Blue shark	0.01	5	0	15	5	92.10%

Table 17 Estimated overall abundance and density of species group during July 2015 survey in the entire survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	3.27	6006	4532	7626	789	13.14%
All non-avian animals	0.12	217	133	320	49	22.67%
Species group						
Fulmar / gull species	0.62	1130	531	1938	363	32.12%
Shearwater species	0.05	99	0	313	82	82.90%
Gannet species	0.82	1498	1117	1922	206	13.78%
Cormorant species	0.76	1393	90	2805	801	57.50%
Wader species	0.02	44	0	117	39	90.60%
Small gull species	0.01	26	0	63	18	67.05%
Black-backed gull species	0.01	18	0	39	11	61.26%
Large gull species	1.51	2779	1656	4008	600	21.60%
Gull species	0.10	183	31	391	92	50.38%
Arctic / common tern	0.00	9	0	23	8	91.94%
Large auk	0.05	86	0	234	79	91.76%
Auk / small gull	0.00	8	0	23	8	91.86%
Fish species	0.08	139	78	211	34	24.63%
Seal species	0.00	9	0	23	8	90.40%
Dolphin species	0.02	34	0	94	32	91.76%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Cetacean species	0.02	35	8	78	19	53.90%

Table 18 Estimated overall abundance and density of species during July 2015 survey in the entire survey area.

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Fulmar	0.54	990	453	1742	335	33.86%
Manx shearwater	0.05	99	0	313	82	82.90%
Gannet	0.82	1498	1117	1922	206	13.78%
Shag	0.03	63	1	124	36	57.50%
Kittiwake	0.00	9	0	23	8	90.70%
Black-headed gull	0.01	18	0	47	16	91.91%
Lesser black-backed gull	0.48	887	477	1367	227	25.61%
Herring gull	0.27	491	70	1016	245	49.93%
Great black-backed gull	0.72	1321	766	2024	327	24.72%
Guillemot	0.05	86	0	234	79	91.76%
Ocean sunfish	0.08	139	78	211	34	24.63%
Grey seal	0.00	9	0	23	8	90.40%
Bottle-nosed dolphin	0.01	26	0	70	24	91.76%
Harbour porpoise	0.02	35	8	78	19	53.90%

Table 19 Estimated overall abundance and density of species groups during July 2015 survey in the high intensity survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Broad category						
All birds	5.19	2191	1582	2904	336	15.32%
All non-avian animals	0.14	59	30	90	17	28.12%
Species group						
Fulmar / gull species	0.30	128	50	221	42	32.71%
Shearwater species	0.14	59	0	161	50	85.17%
Gannet species	1.32	558	377	754	97	17.37%
Cormorant species	0.18	76	15	151	34	45.46%
Small gull species	0.04	16	0	40	11	66.42%
Black-backed gull species	0.03	11	0	25	7	61.71%
Large gull species	2.81	1189	633	1839	308	25.88%
Gull species	0.23	96	20	201	47	49.06%
Arctic / common tern	0.01	5	0	15	5	93.03%
Large auk	0.13	54	0	151	52	95.48%
Fish species	0.11	49	20	80	16	32.69%
Cetacean species	0.03	11	0	30	10	91.64%

Table 20 Estimated overall abundance and density of species during July 2015 survey in the high intensity survey area

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of abundance (number)	Upper 95% confidence limit of abundance (number)	Standard deviation abundance estimate (number)	CV (%)
Species						
Fulmar	0.20	86	40	136	24	28.36%
Manx shearwater	0.14	59	0	161	50	85.17%
Gannet	1.32	558	377	754	97	17.37%
Shag	0.18	76	15	151	34	45.46%
Kittiwake	0.01	5	0	15	5	92.58%
Black-headed gull	0.03	11	0	30	10	93.37%
Lesser black-backed gull	0.98	412	206	653	113	27.48%
Herring gull	0.71	299	50	613	144	48.30%
Great black-backed gull	1.04	440	256	658	103	23.36%
Guillemot	0.13	54	0	151	52	95.48%
Ocean sunfish	0.11	49	20	80	16	32.69%
Harbour porpoise	0.03	11	0	30	10	91.64%

3.4 Distribution patterns

50 The distribution pattern of the most abundant species and species groups are presented as density maps, in which a density surface depicts the estimated density of individuals per km² (Figure 5 to Figure 50 and Figure 57 to Figure 67). Loafing birds have been removed so that the distribution maps display only the distribution of animals at sea.

51 Species or species groups for which there were few observations are presented as dot maps only (Figure 51 to Figure 56 and Figure 68 to Figure 73).

52 The monthly maps for all bird species combined show that observations were largely on, or over, the water around the shoreline of the Isles of Scilly. Visual inspection of the kernel density maps for May and July 2015 suggest a lower overall density in these months than in June (Figure 5 to Figure 8).

53 Shag were concentrated within the high intensity survey area for the Isles of Scilly, with no individuals recorded outside this area. In the combined months (Figure 9), May and June, (Figure 10 and Figure 11), shag were concentrated around all of the islands, but with the highest number of observations in the south-west of the archipelago. In July (Figure 12), the same pattern was evident from raw observations, but these were too few for any pattern to be discernible in the kernel density estimation plots.

54 These same patterns are evident in density plots that take account of availability bias for shag (Figure 13 to Figure 16).

55 Shag were recorded sitting on the water's surface in high densities near the Isles of Scilly during the May 2015 survey (Figure 18); however, during June 2015 (Figure 19) and July 2015 (Figure 20) analysis was unable to determine an obvious distribution pattern. There is no change to this pattern when availability bias calculations are included, as might be expected given that it is a non-spatially explicit scaling factor that is applied (Figure 21 to Figure 24). In general, sitting shag were recorded in a few very large groups, which were likely to be dense, feeding concentrations.

56 Across the three surveys (Figure 25), flying shag were concentrated around the Isles of Scilly islands in the high intensity survey area. Surveys completed in May (Figure 26), June (Figure 27) and July 2015 (Figure 28) showed a concentrated distribution around the centre of the Isles of Scilly.

57 As can be observed in the flight direction maps, the predominant flight direction recorded for shag was mainly north-east to east in May 2015 (Figure 74), while in June 2015 (Figure 75) more shag were recorded as flying west to north-west. During July 2015 (Figure 76) the predominant flight direction was north-westerly direction.

58 Low numbers of fulmar were recorded during May 2015 (Figure 29) with observations showing no obvious pattern. Fulmar were more concentrated during June 2015 (Figure 30) with some clustering into small hotspots in the south-west of the survey area. The July 2015 survey (Figure 31) showed a more widely spread distribution, with multiple hotspots in the north-west, east and south.

59 Manx shearwater distributions changed over the survey period. In the May 2015 survey (Figure 32), distribution was close inshore to the north of the islands. Fewer numbers were recorded inshore during the June survey (Figure 33) with distribution patterns suggesting more were

observed in the north-west of the survey area, while in July 2015 (Figure 34), there was a small hotspot of the species in the east.

60 Gannet distribution also differed during the survey period, with an increase in density over time (Figure 35 to Figure 37).

61 Density patterns for lesser black-backed gull show highly concentrated observations near the shoreline of the island over all thee months (Figure 38 to Figure 41). There were more observations in May 2015 (Figure 39) with these than being more evenly spread across the survey are in June 2015, with a higher density in the south-west (Figure 40). Observations were then more widely distributed around the islands during the July 2015 survey (Figure 41).

62 Herring gull showed a similar distribution patterns (Figure 42 to Figure 44) with the majority of sightings recorded within the high intensity survey area. The June 2015 survey demonstrated a higher number offshore; however, the majority of observations were still close to the shoreline with hotspots over the islands in May and July 2015.

63 Great black-backed gull alternated between occurring mainly on or near the shoreline in May 2015, to a more widely distributed pattern in June 2015 (Figure 45 and Figure 46). A wider dispersal offshore occurred throughout the study area in July 2015, with a higher concentration towards the south of the survey area (Figure 47).

64 Guillemot distribution varied greatly across surveys, although high density areas were recorded near the shoreline to the north-east and west during surveys in May and June 2015 respectively (Figure 48 and Figure 49). There were fewer observations in the July 2015 survey (Figure 50) with observations seen to the east of the low intensity survey area.

65 Non-avian animals were widely dispersed throughout the survey area with varied patterns between surveys, both inshore and offshore; June had the highest concentrations of non-avian animals (Figure 59). Blue sharks were observed in June 2015, (Figure 61) although these observations showed no obvious pattern.

66 Grey seal were recorded at the highest density in June 2015 (Figure 63), with this being primarily in the south-west of the high intensity survey area.

67 Harbour porpoise were widely dispersed, but concentrated in the south-west of the low intensity area in May 2015 (Figure 65) and concentrated to the north-east of the high intensity survey area in June 2015 (Figure 66). The July 2015 survey showed no obvious distribution pattern (Figure 67).

3.4.1 All birds

69 Densities of all avian observations are shown in Figures 5 to 8. Loafing birds are excluded from all density maps.

Figure 5 Density of all birds (number/km²) and number of detections per segment between May and July 2015

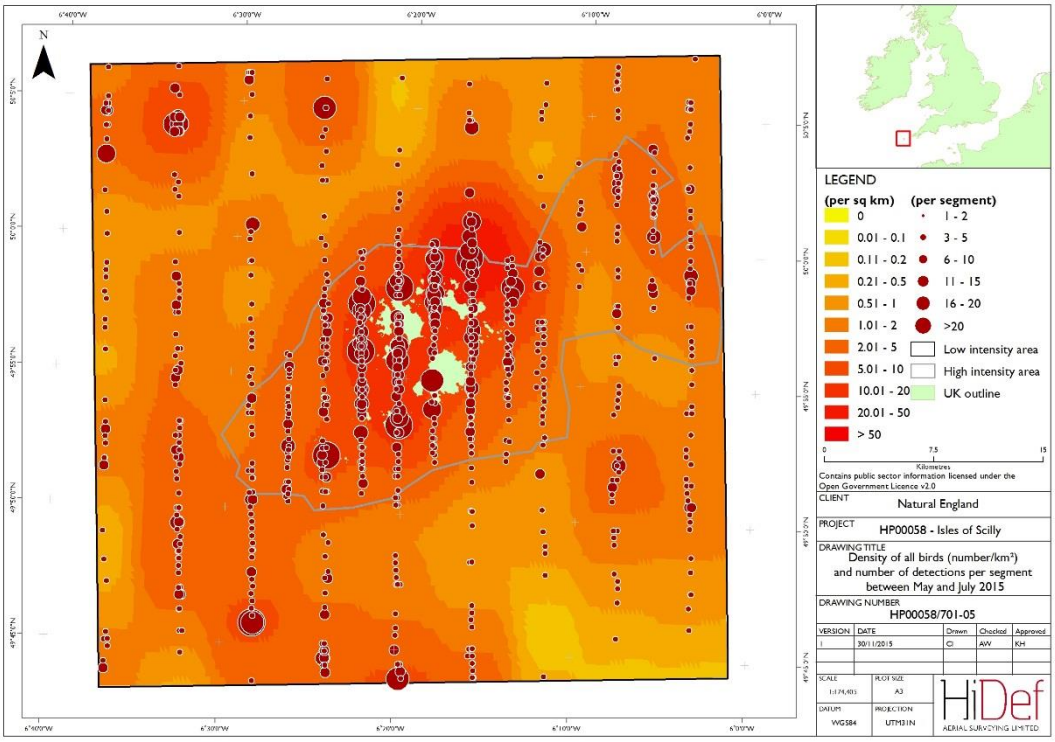


Figure 6 **Density of all birds (number/km²) and number of detections per segment during Survey 1 on 12 May 2015**

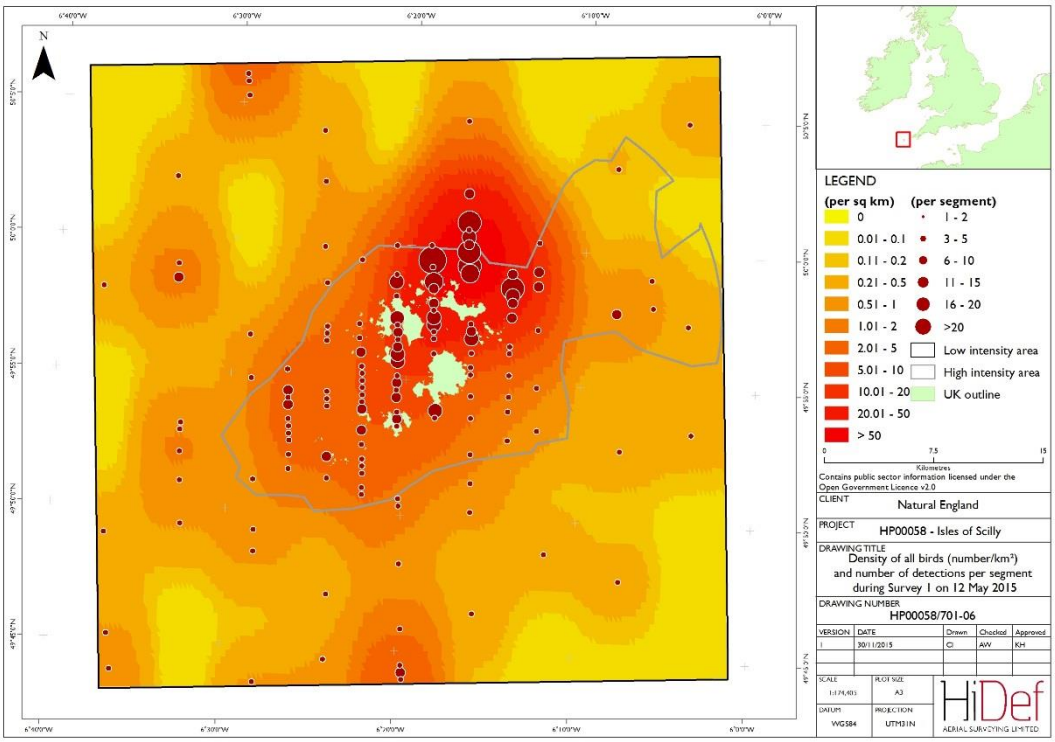


Figure 7 **Density of all birds (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

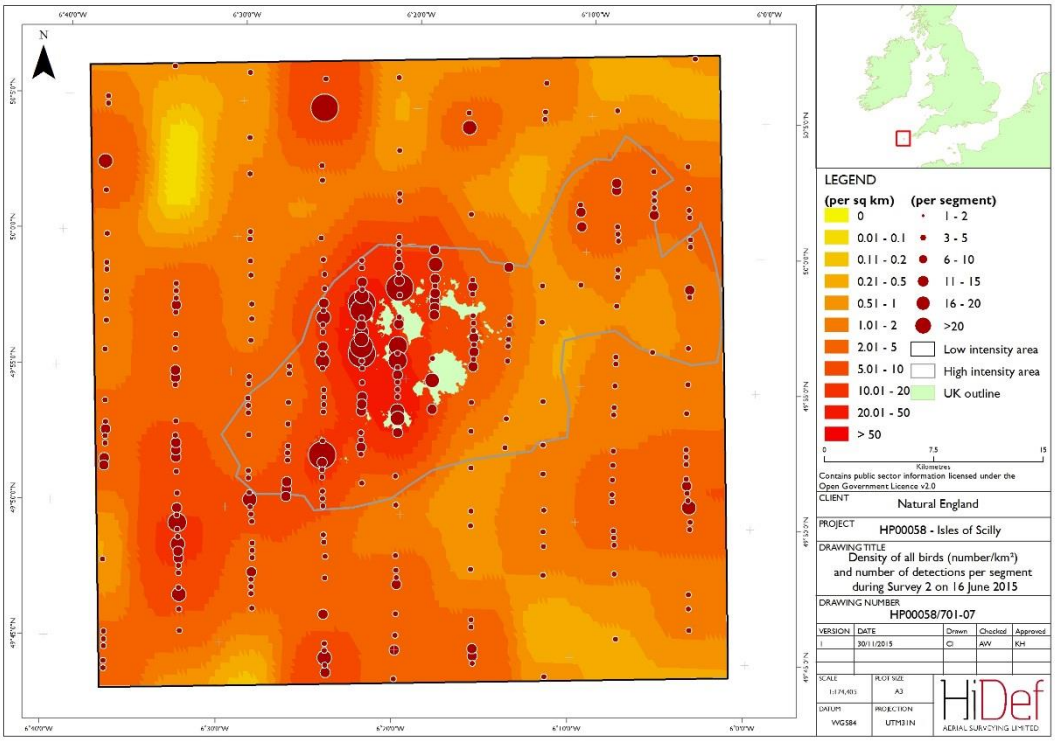
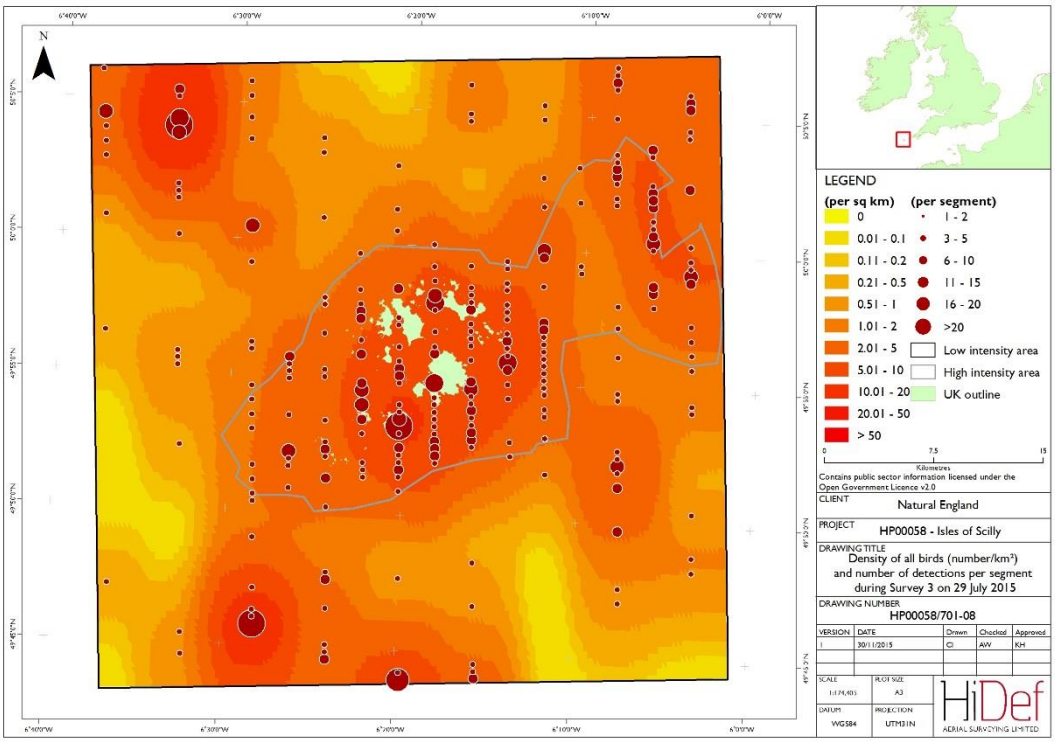


Figure 8 **Density of all birds (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.2 Shag (no availability bias estimates included)

70 Densities of shag (without availability bias estimates included) are shown in Figures 9 to 12. Loafing birds are excluded from all density maps.

Figure 9 **Density of shag (number/km²) and number of detections per segment between May and July 2015**

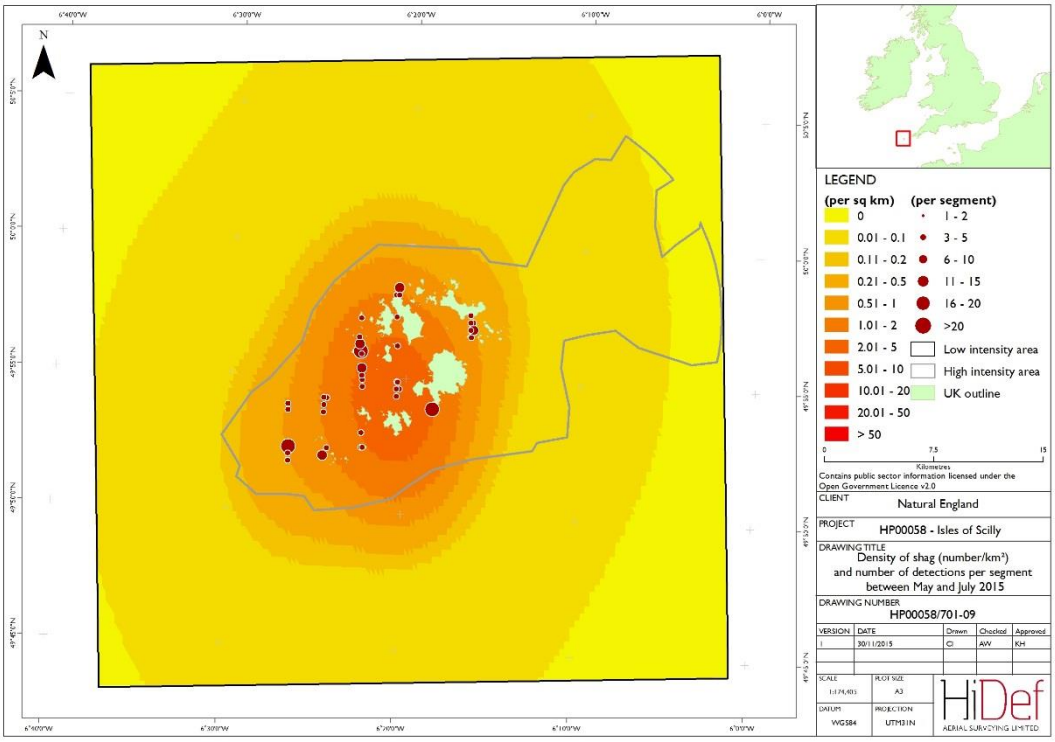


Figure 10 **Density of shag (number/km²) and number of detections per segment during Survey 1 on 12 May 2015**

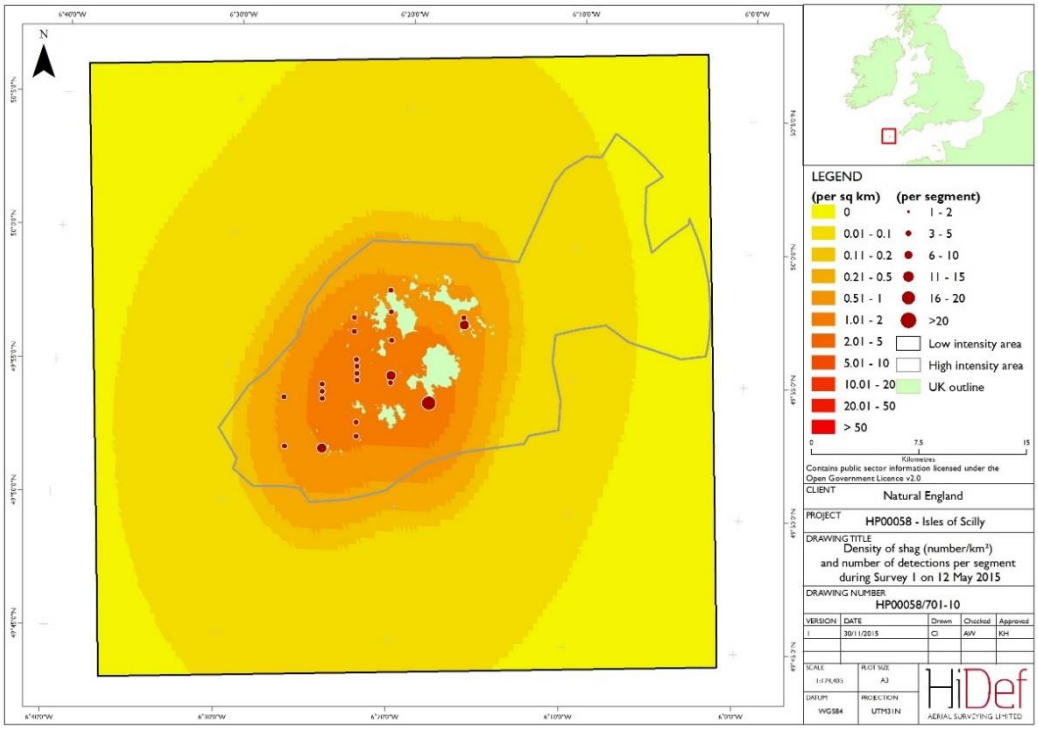


Figure 11 **Density of shag (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

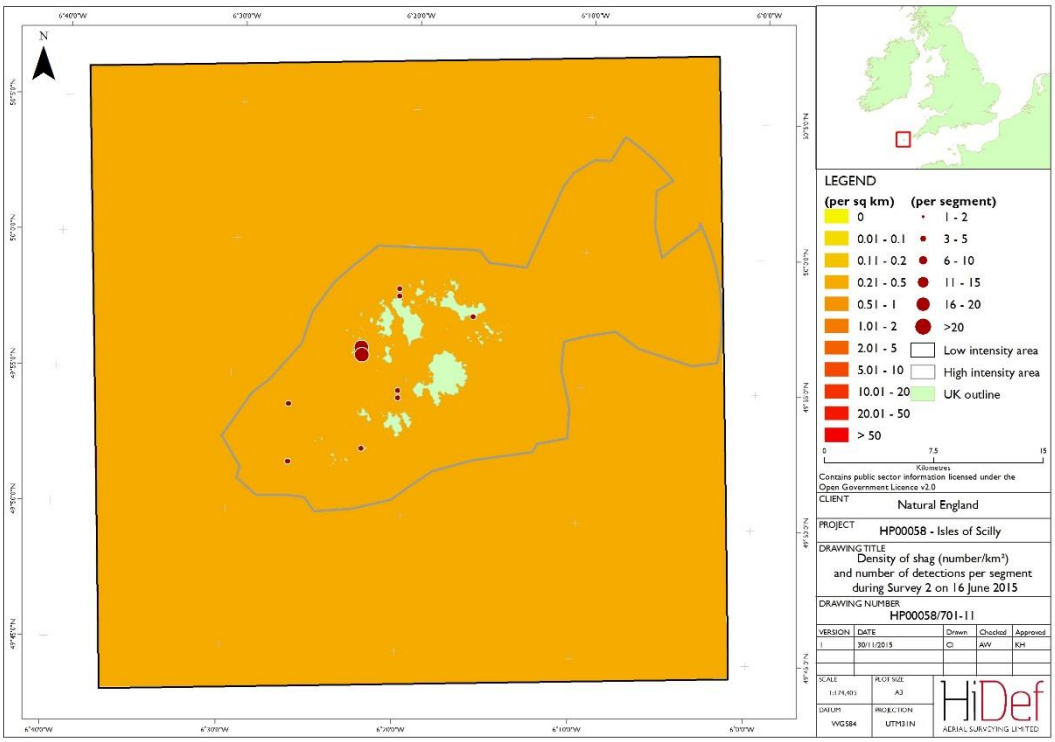
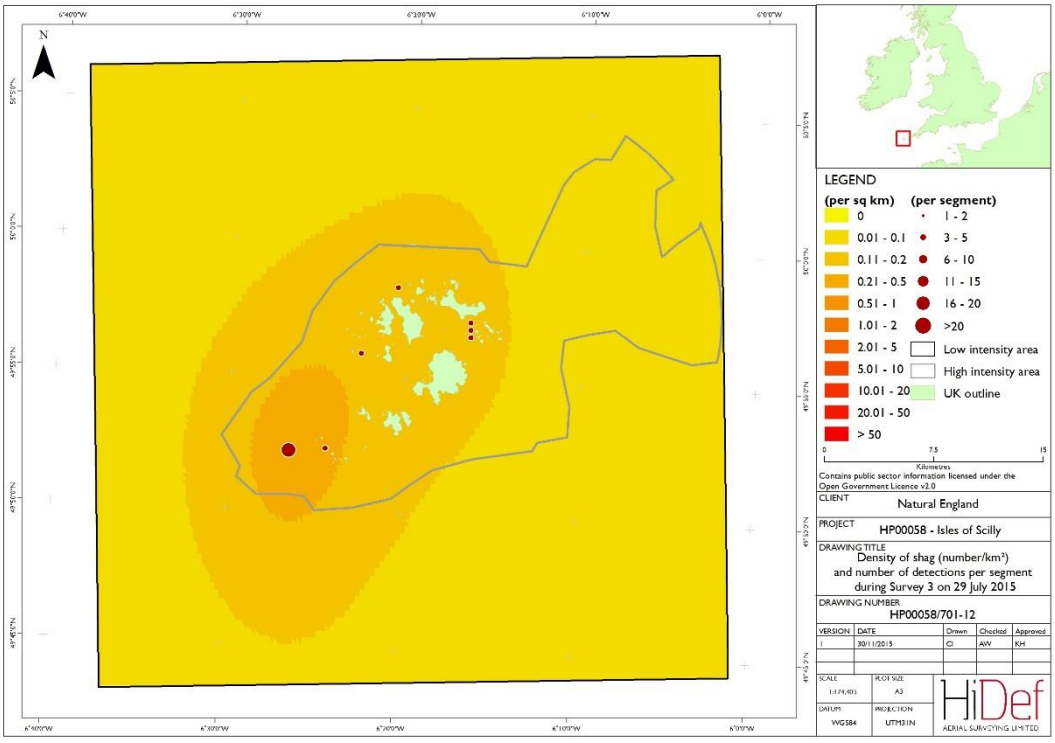


Figure 12 **Density of shag (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.3 Shag (with availability bias estimates included)

71 Densities of shag (with availability bias estimates included) are shown in Figures 13 to 16. Loafing birds are excluded from all density maps.

Figure 13 **Density of shag (number/km²) and number of detections per segment between May and July 2015. Abundance estimates adjusted for availability bias**

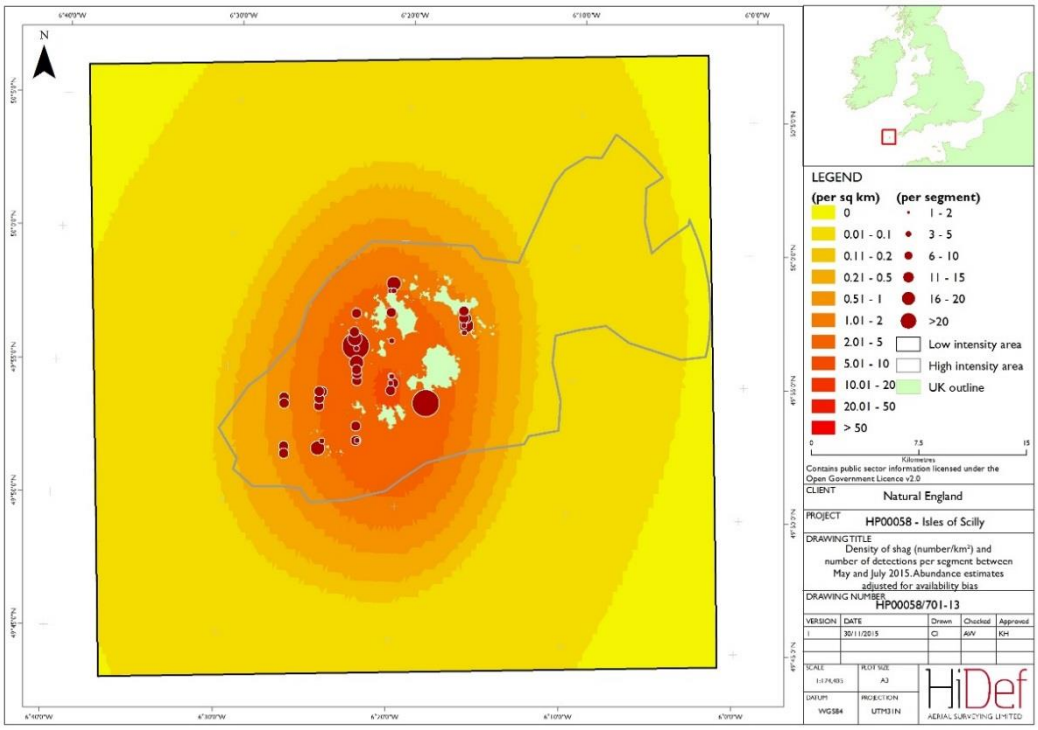


Figure 14 **Density of shag (number/km²) and number of detections per segment during Survey 1 on 12 May 2015. Abundance estimates adjusted for availability bias**

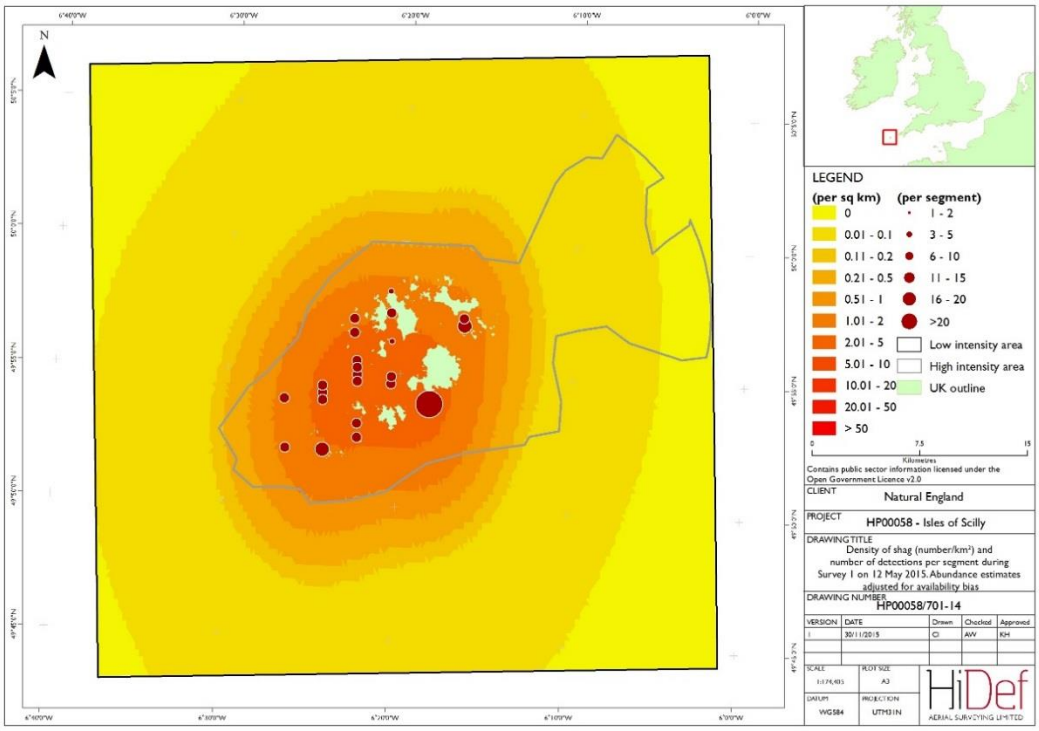


Figure 15 **Density of shag (number/km²) and number of detections per segment during Survey 2 on 16 June 2015. Abundance estimates adjusted for availability bias**

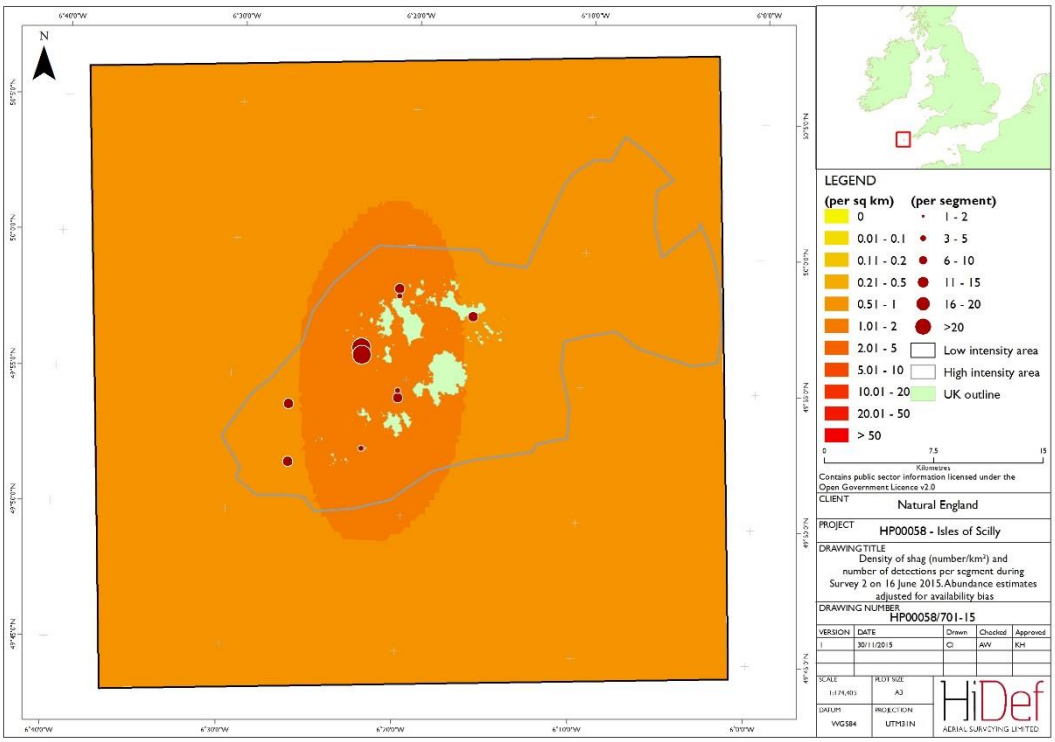
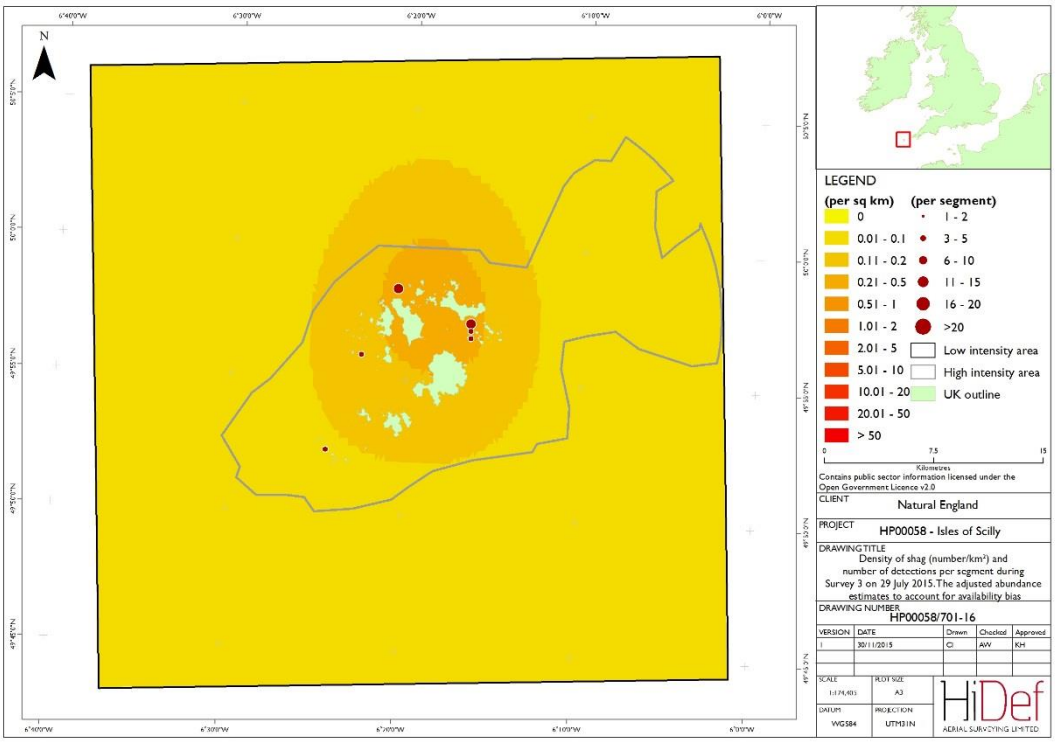


Figure 16 **Density of shag (number/km²) and number of detections per segment during Survey 3 on 29 July 2015. Abundance estimates adjusted for availability bias**



3.4.4 Sitting shag (no availability bias estimates included)

72 Densities of shag sitting on the water's surface (without availability bias estimates included) are shown in Figures 17 to 20. Loafing birds are excluded from all density maps.

Figure 17 Density of sitting shag (number/km²) and number of detections per segment between May and July 2015

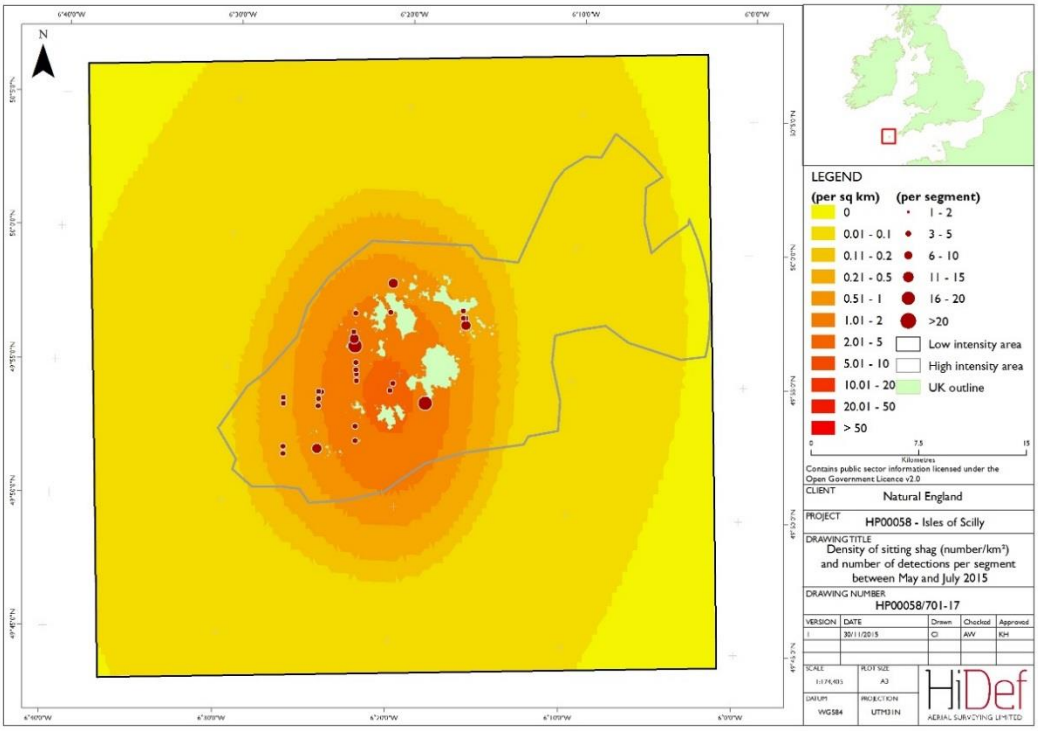


Figure 18 Density of sitting shag (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

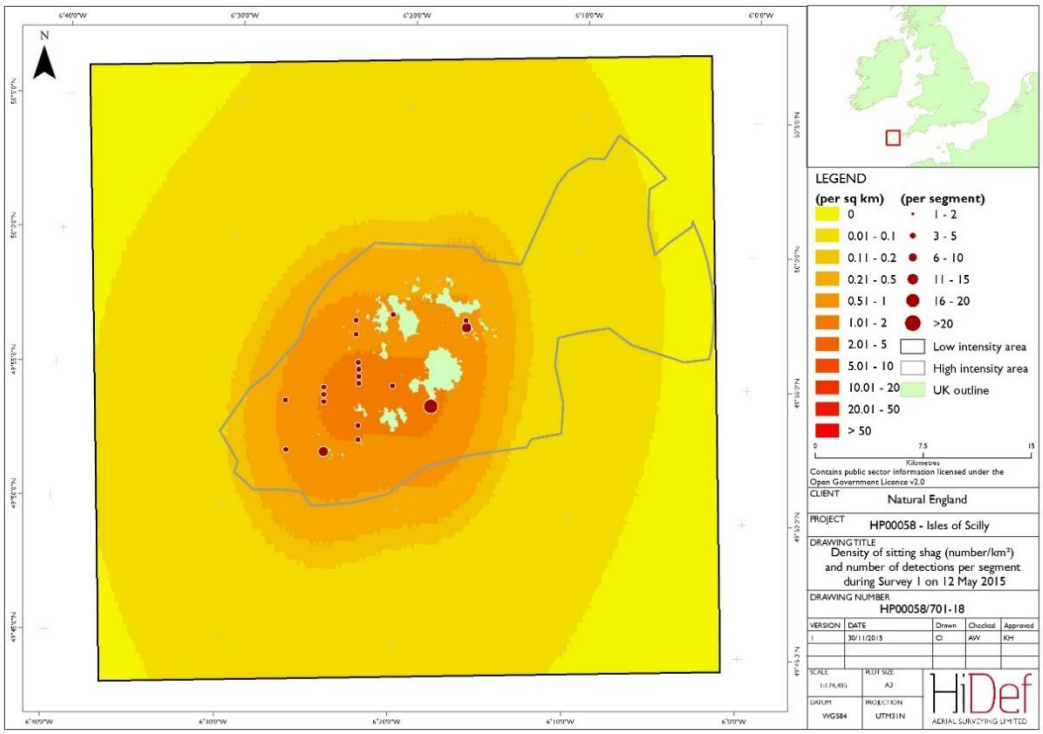


Figure 19 **Density of sitting shag (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

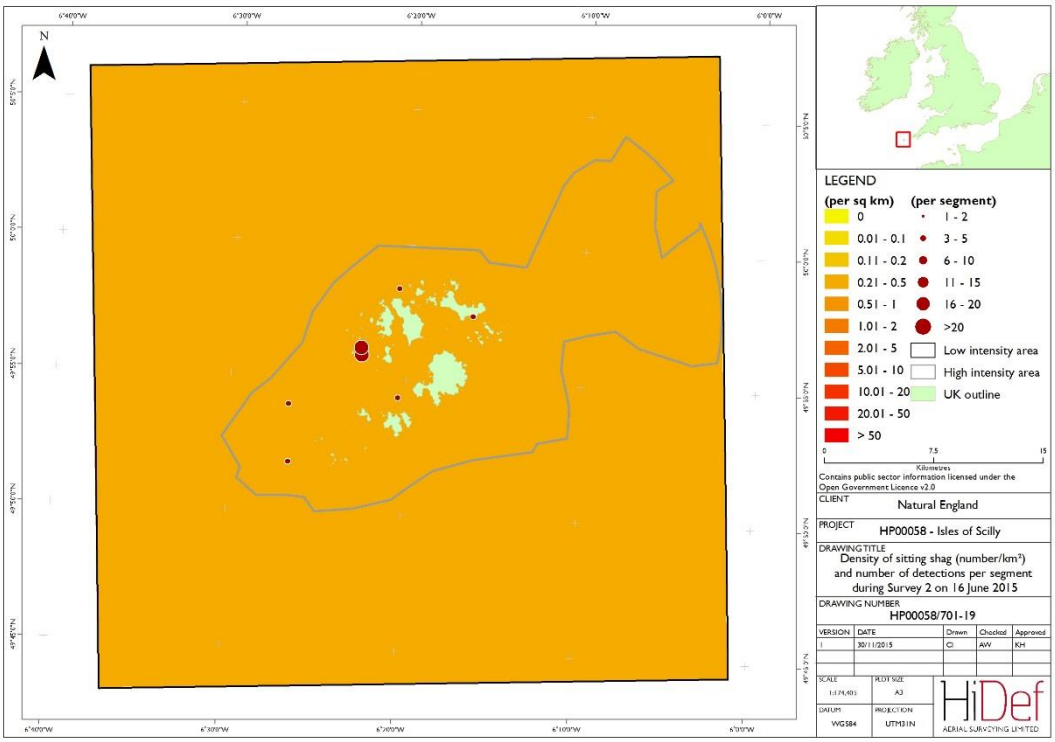
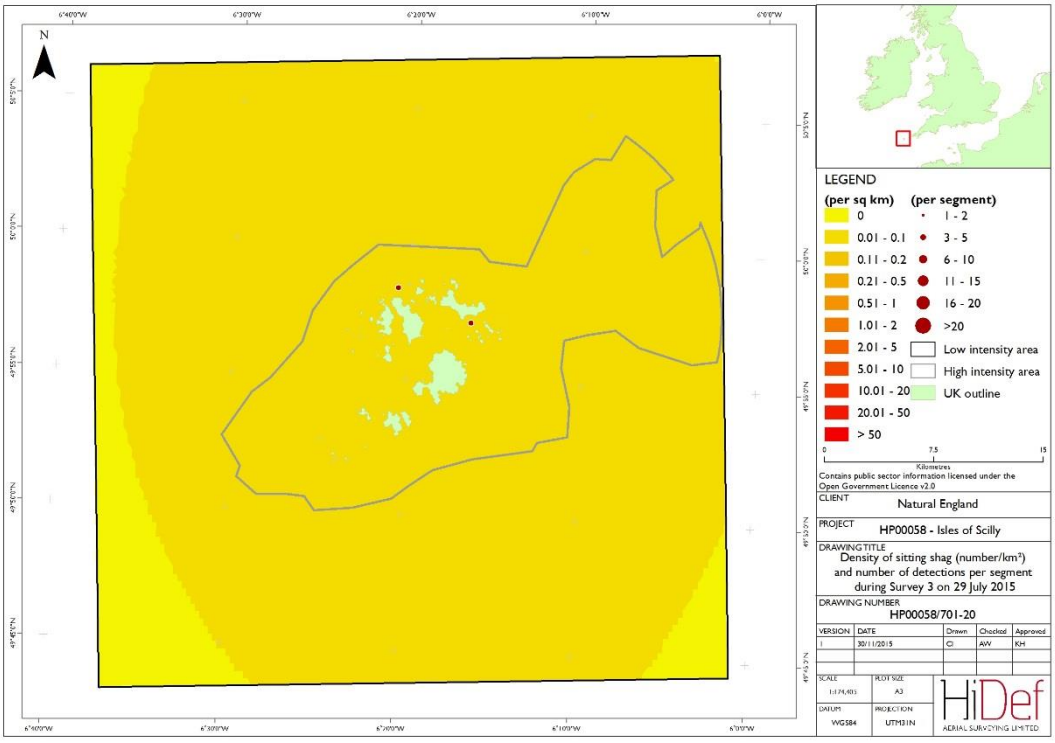


Figure 20 **Density of sitting shag (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.5 Sitting shag (with availability bias estimates included)

73 Densities of shag sitting on the water's surface (with availability bias estimates included) are shown in Figures 21 to 24. Loafing birds are excluded from all density maps.

Figure 21 Density of sitting shag (number/km²) and number of detections per segment between May and July 2015. Abundance estimates adjusted for availability bias

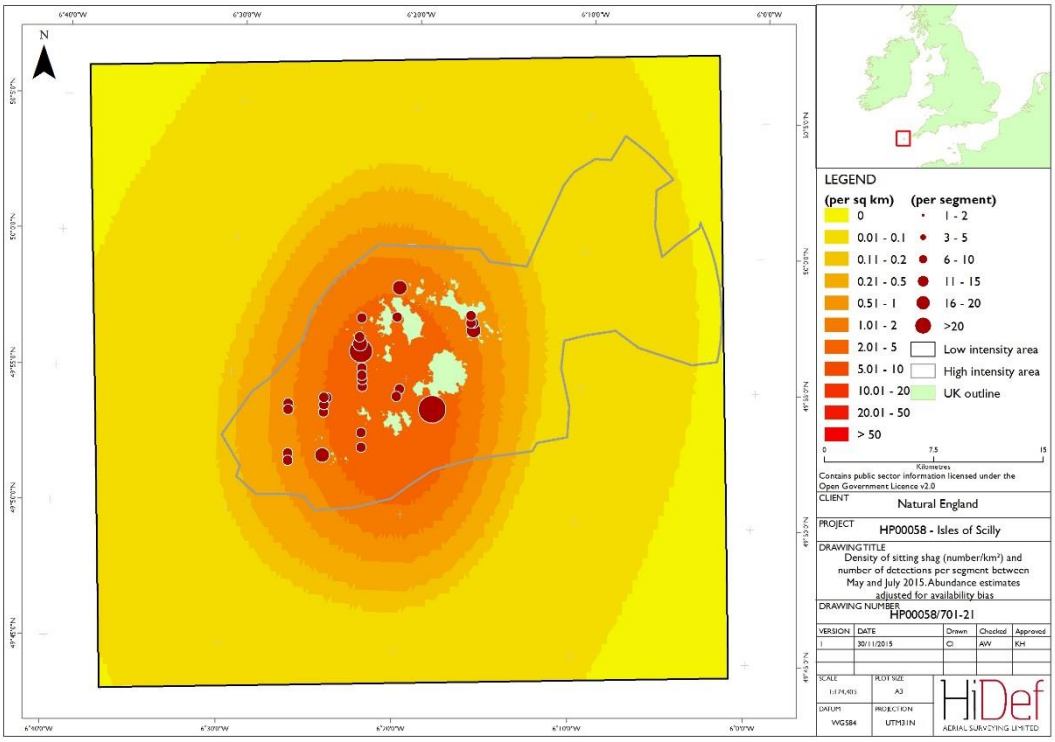


Figure 22 **Density of sitting shags (number/km²) and number of detections per segment during Survey 1 on 12 May 2015. Abundance estimates adjusted for availability bias**

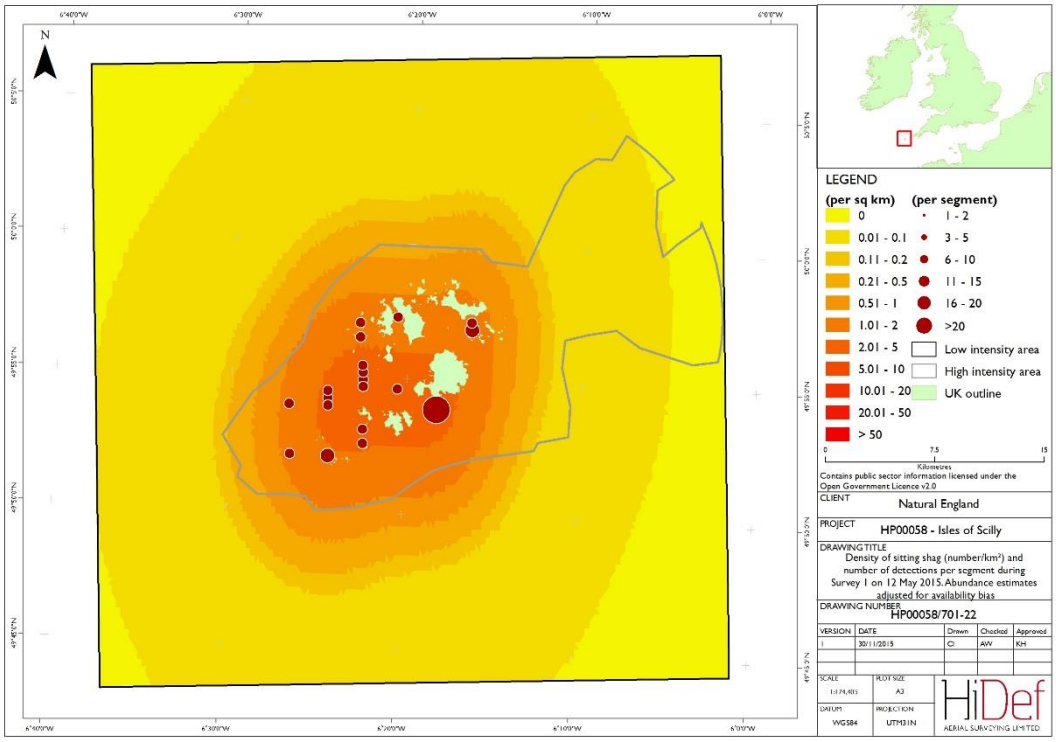


Figure 23 **Density of sitting shag (number/km²) and number of detections per segment during Survey 2 on 16 June 2015. Abundance estimates adjusted for availability bias**

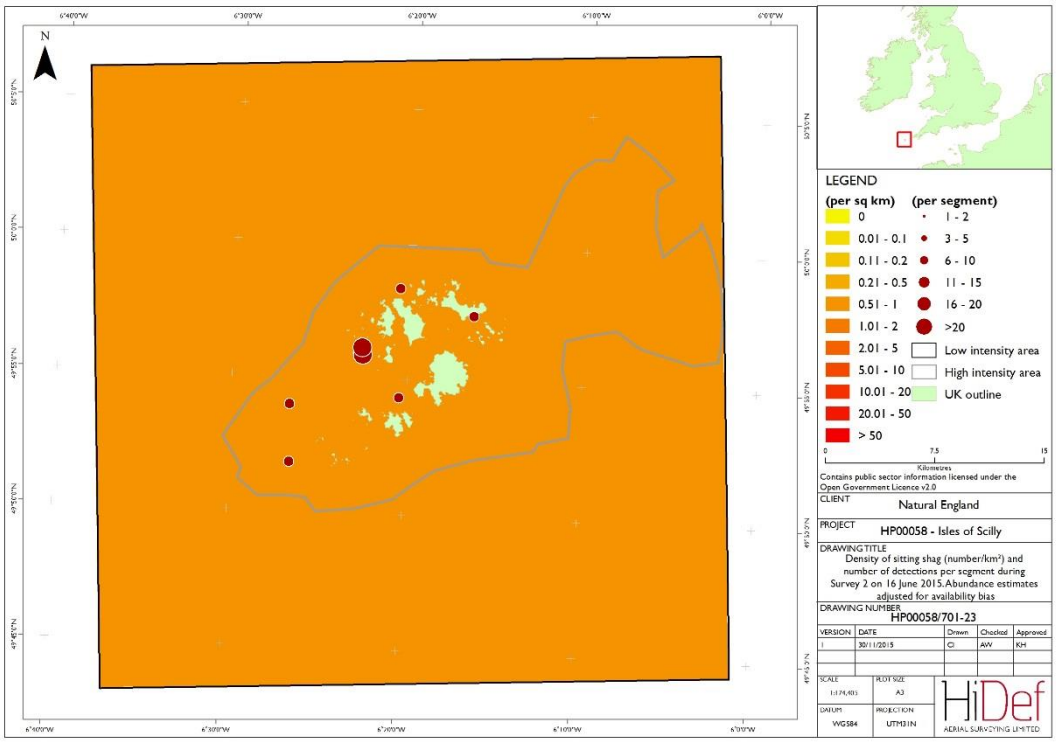
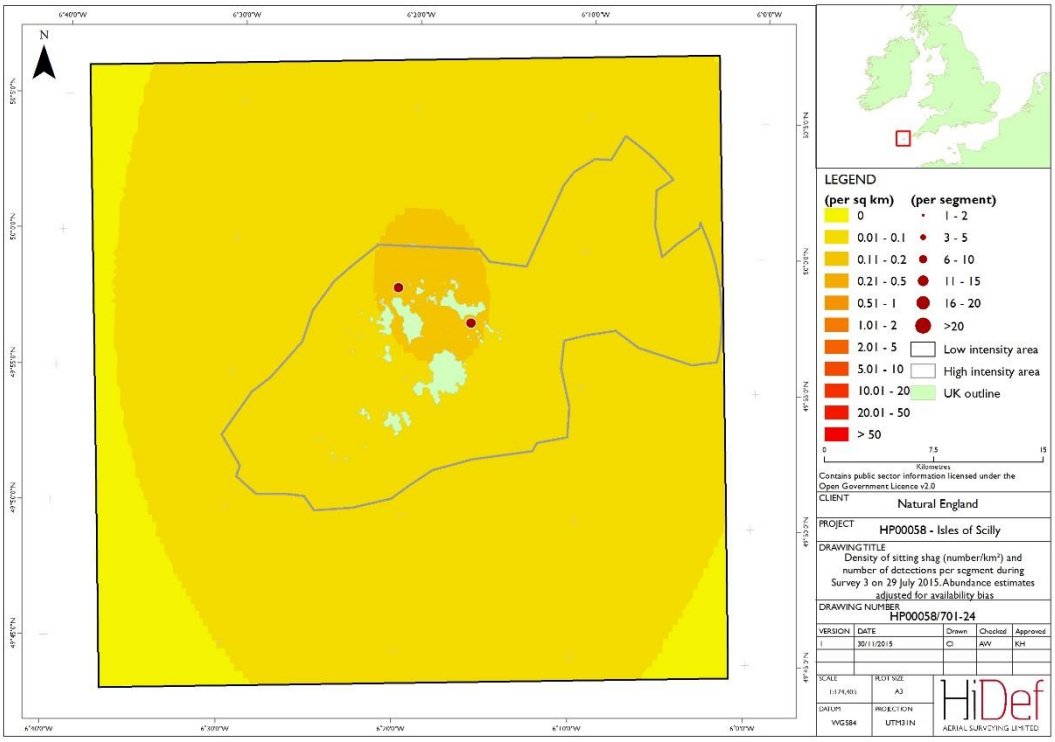


Figure 24 **Density of sitting shags (number/km²) and number of detections per segment during Survey 3 on 29 July 2015. Abundance estimates adjusted for availability bias**



3.4.6 Flying shag

74 Densities of flying shag are shown in Figures 25 to 28. Loafing birds are excluded from all density maps.

Figure 25 Density of flying shag (number/km²) and number of detections per segment between May and July 2015

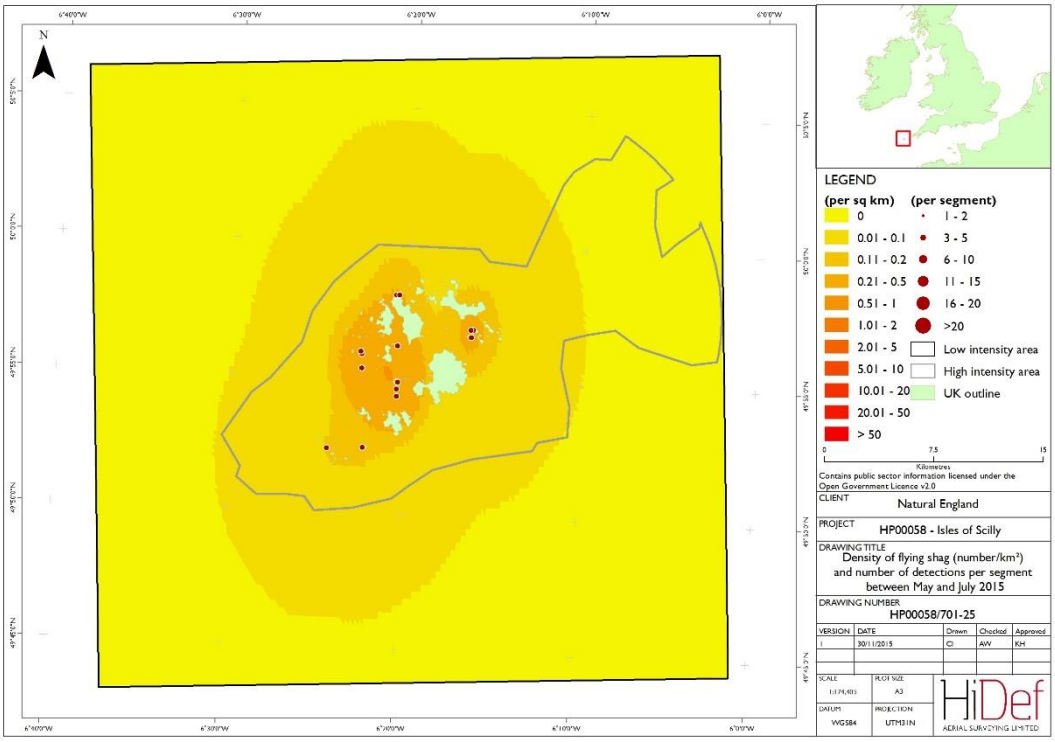


Figure 26 **Density of flying shag (number/km²) and number of detections per segment during Survey 1 on 12 May 2015**

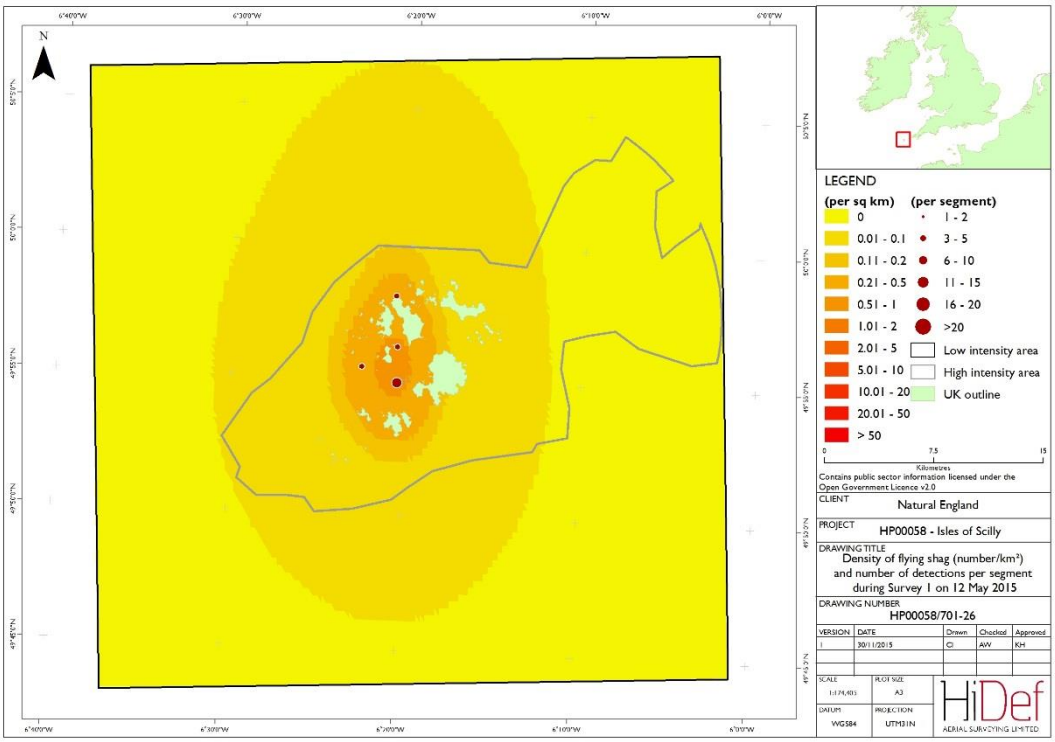


Figure 27 **Density of flying shags (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

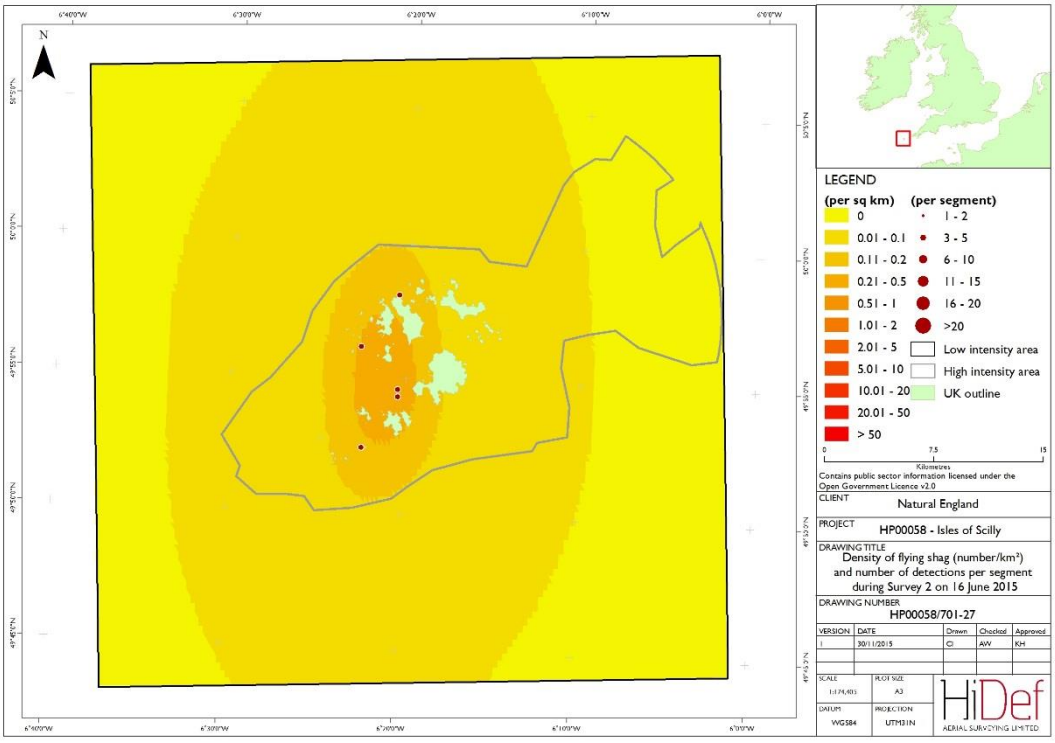
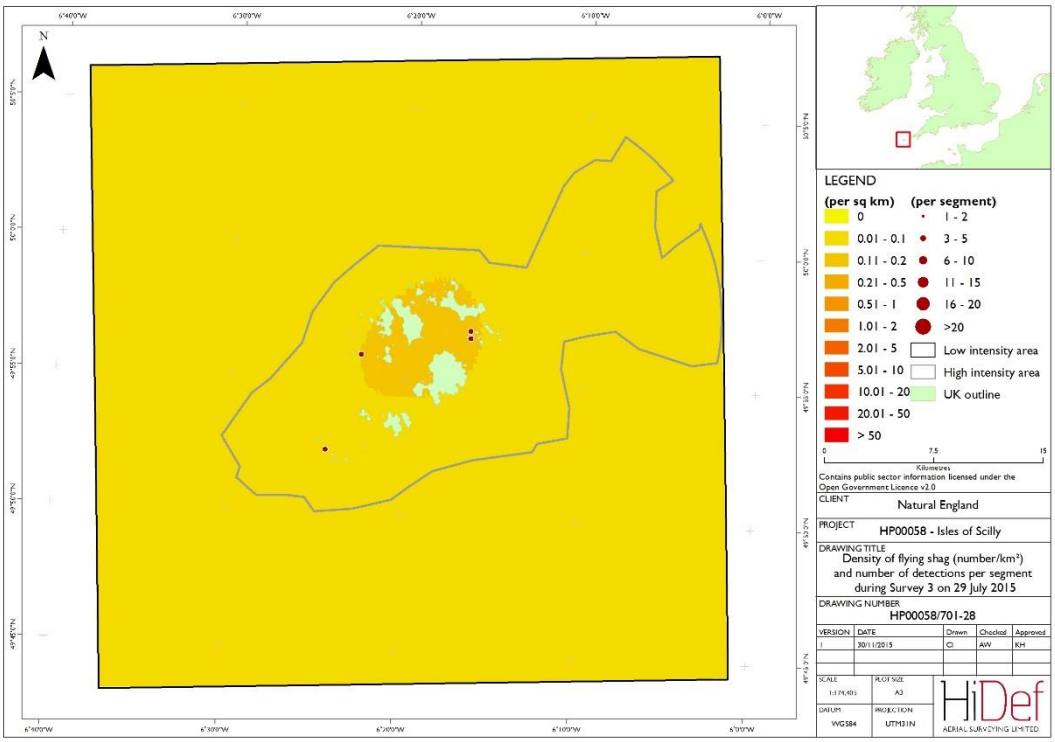


Figure 28 **Density of flying shags (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.7 Fulmar

75 Densities of fulmar are shown in Figures 29 to 31. Loafing birds are excluded from all density maps.

Figure 29 Density of fulmar (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

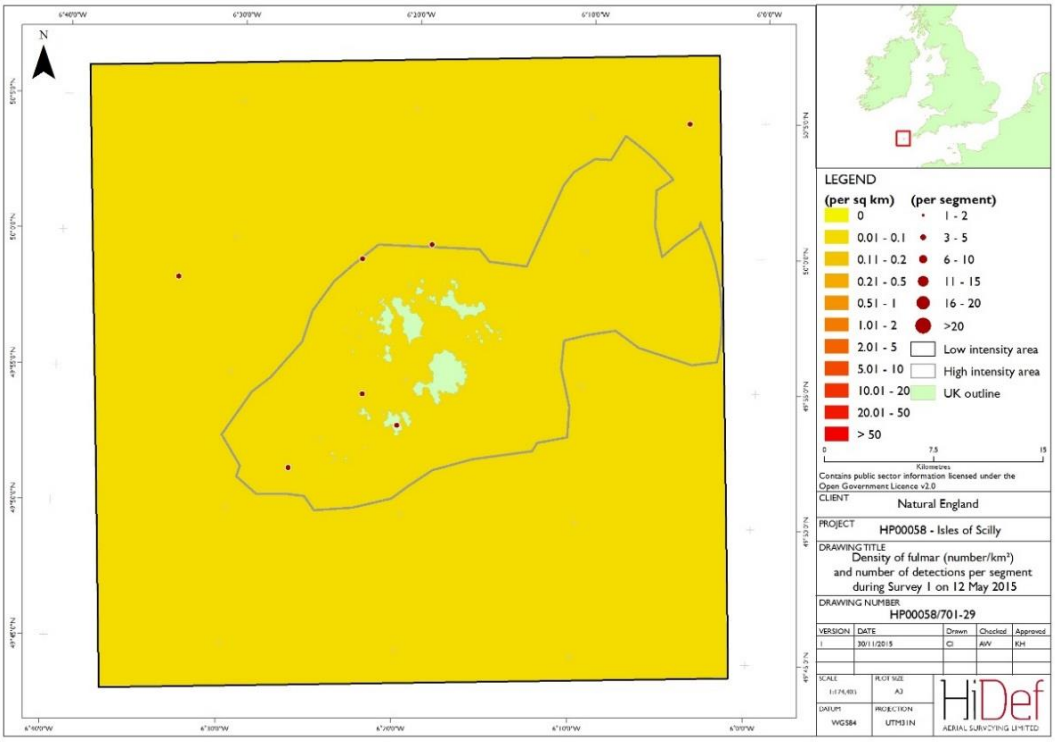


Figure 30 **Density of fulmar (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

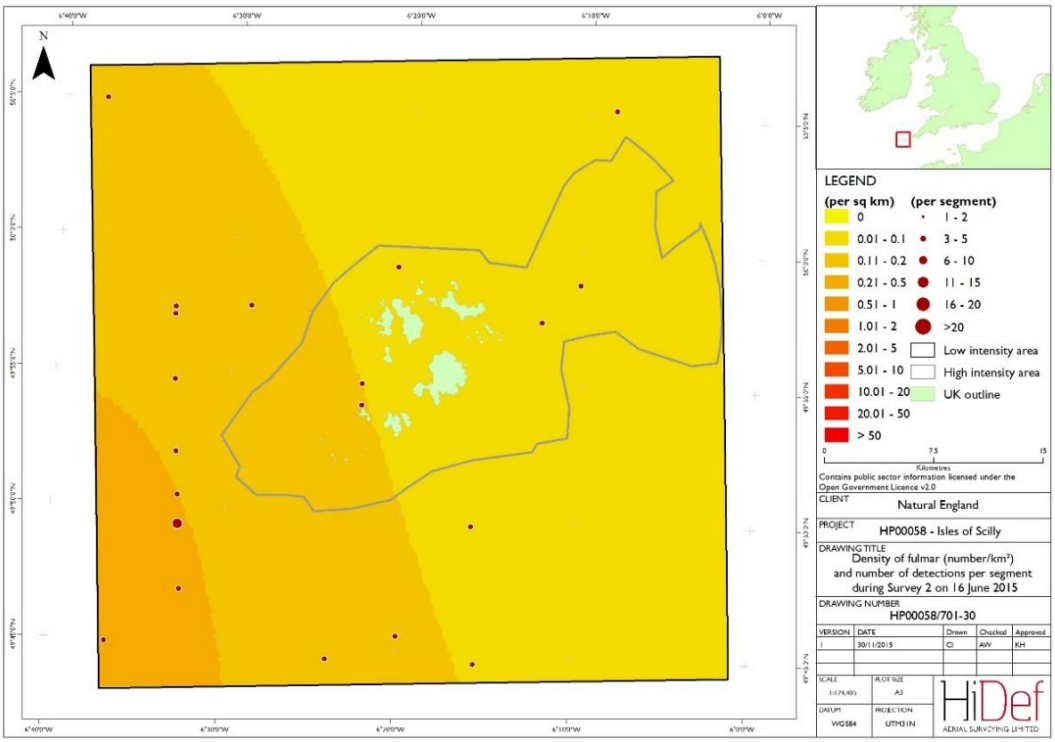
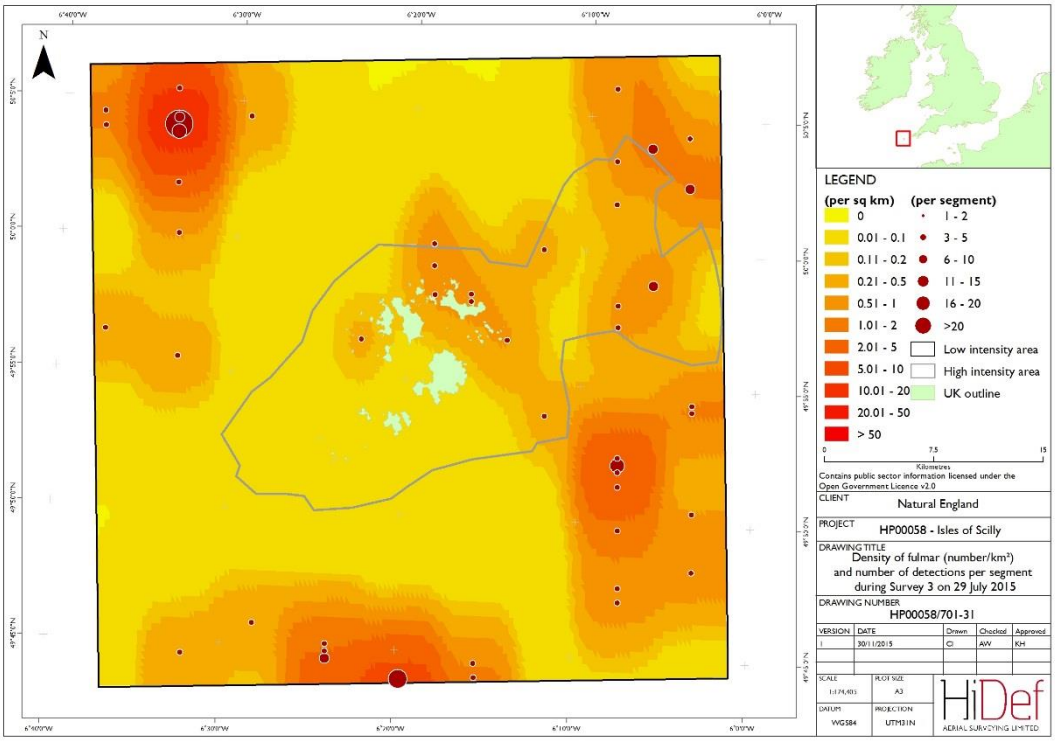


Figure 31 **Density of fulmar (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.8 Manx shearwater

76 Densities of Manx shearwater are shown in Figures 32 to 34. Loafing birds are excluded from all density maps.

Figure 32 Density of Manx shearwater (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

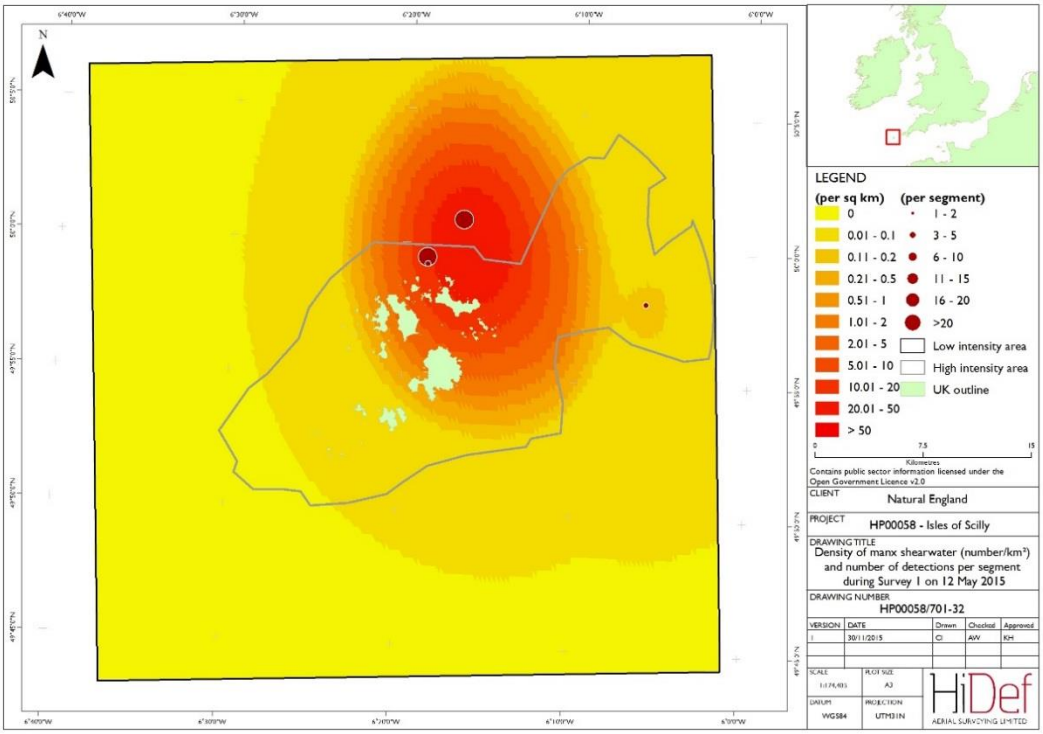


Figure 33 Density of Manx shearwater (number/km²) and number of detections per segment during Survey 2 on 16 June 2015

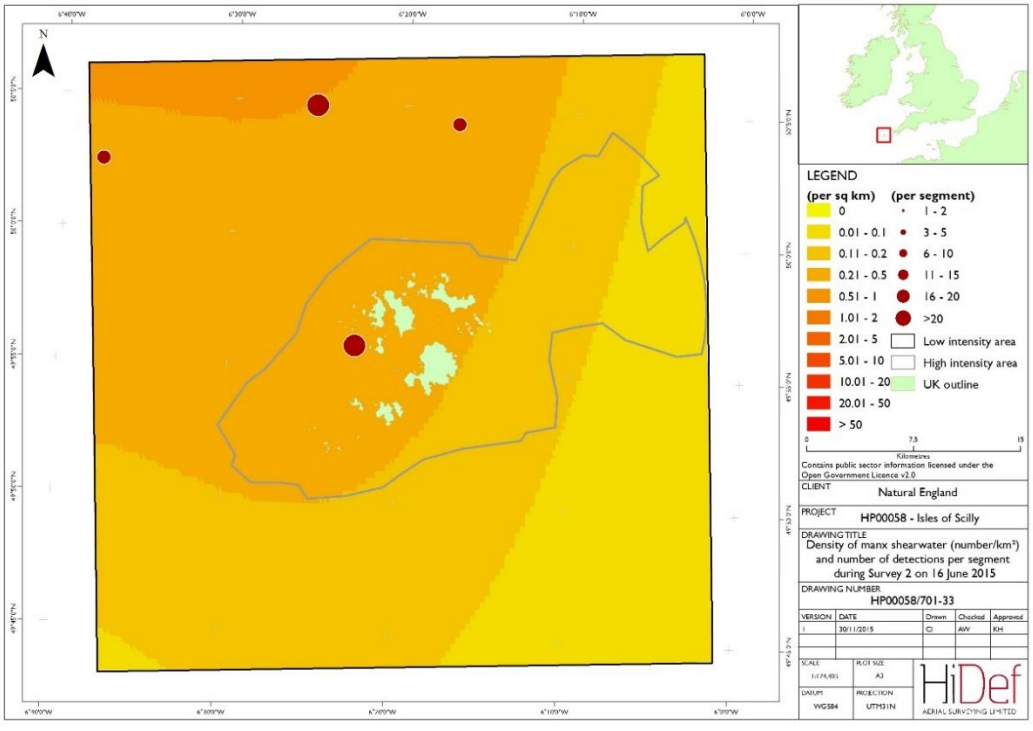
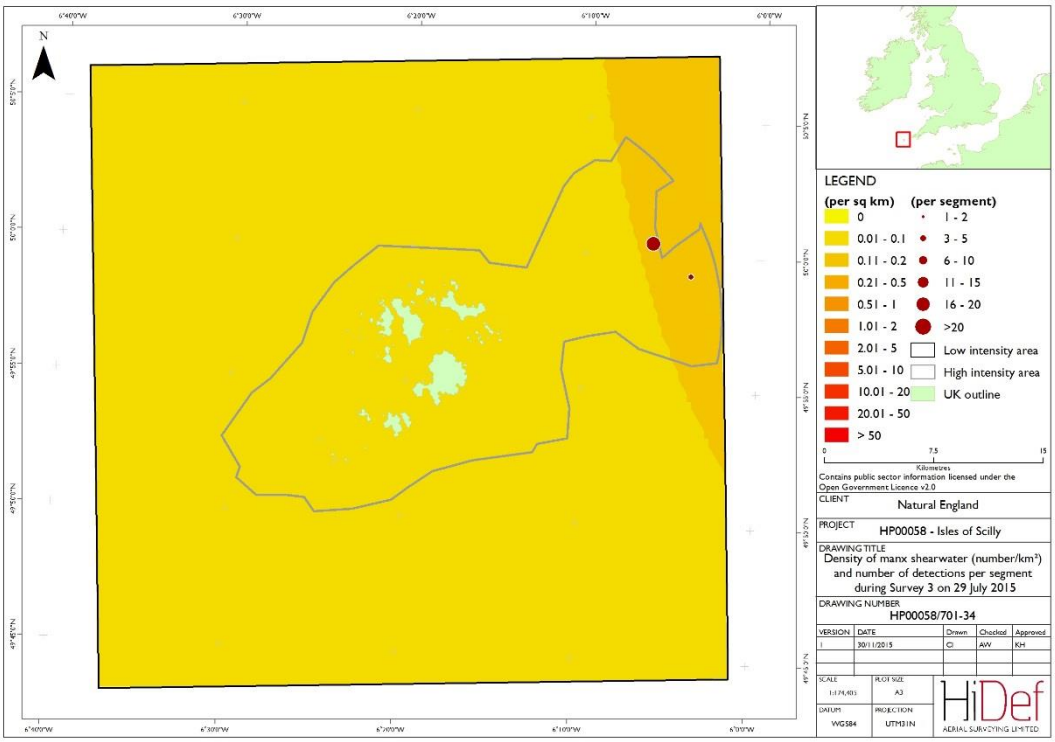


Figure 34 **Density of Manx shearwater (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.9 Gannet

77 Densities of Gannet are shown in Figures 35 to 37. Loafing birds are excluded from all density maps.

Figure 35 Density of gannet (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

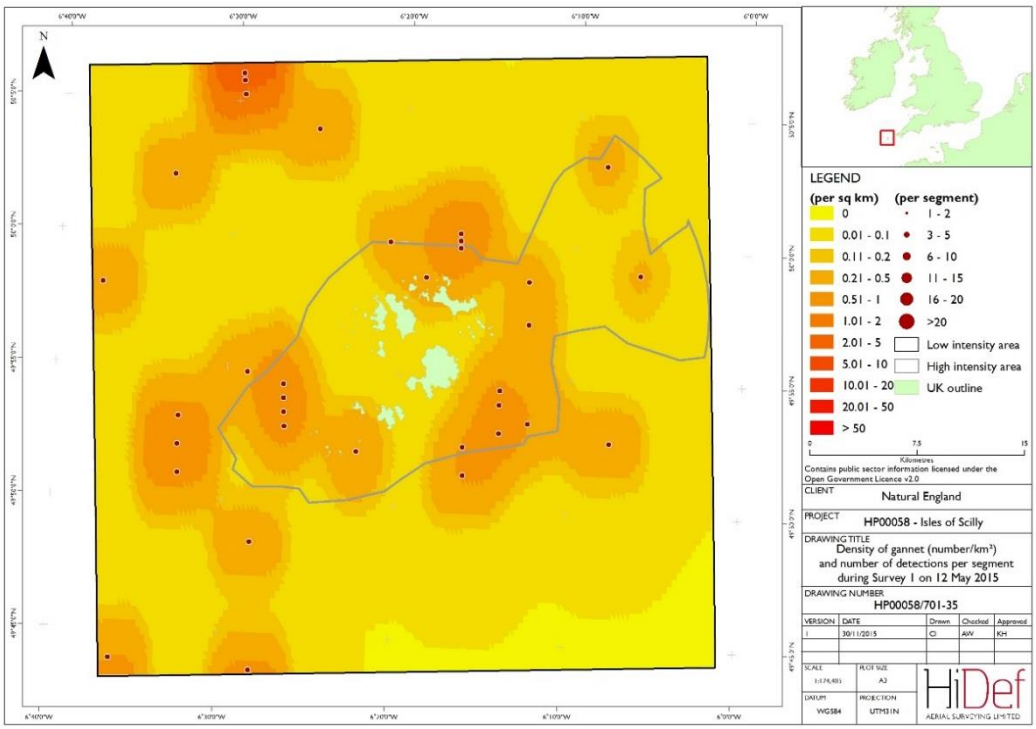


Figure 36 **Density of gannet (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

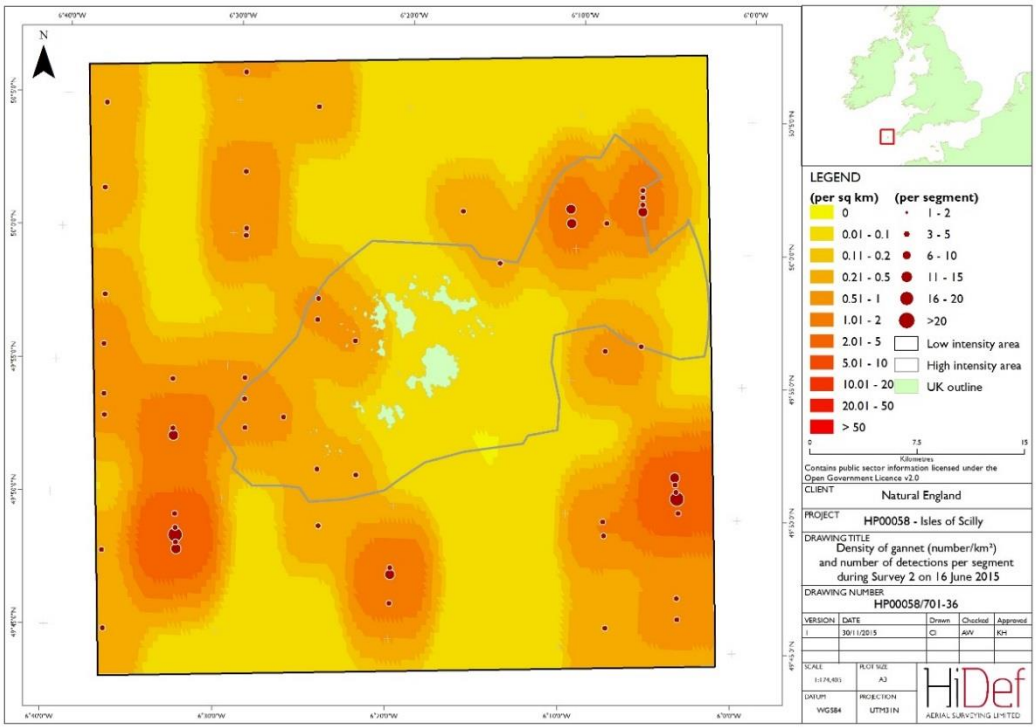
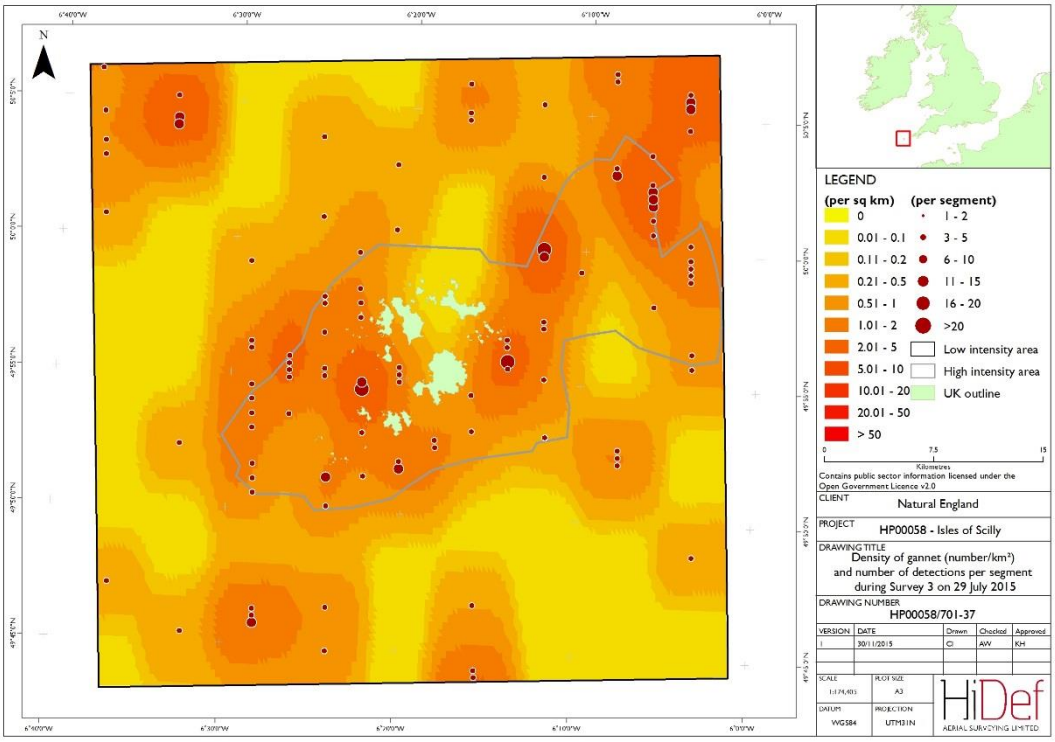


Figure 37 **Density of gannet (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.10 Lesser black-backed gull

78 Densities of lesser black-backed gull are shown in Figures 38 to 41. Loafing birds are excluded from all density maps.

Figure 38 Density of lesser black-backed gull (number/km²) and number of detections per segment between May and July 2015

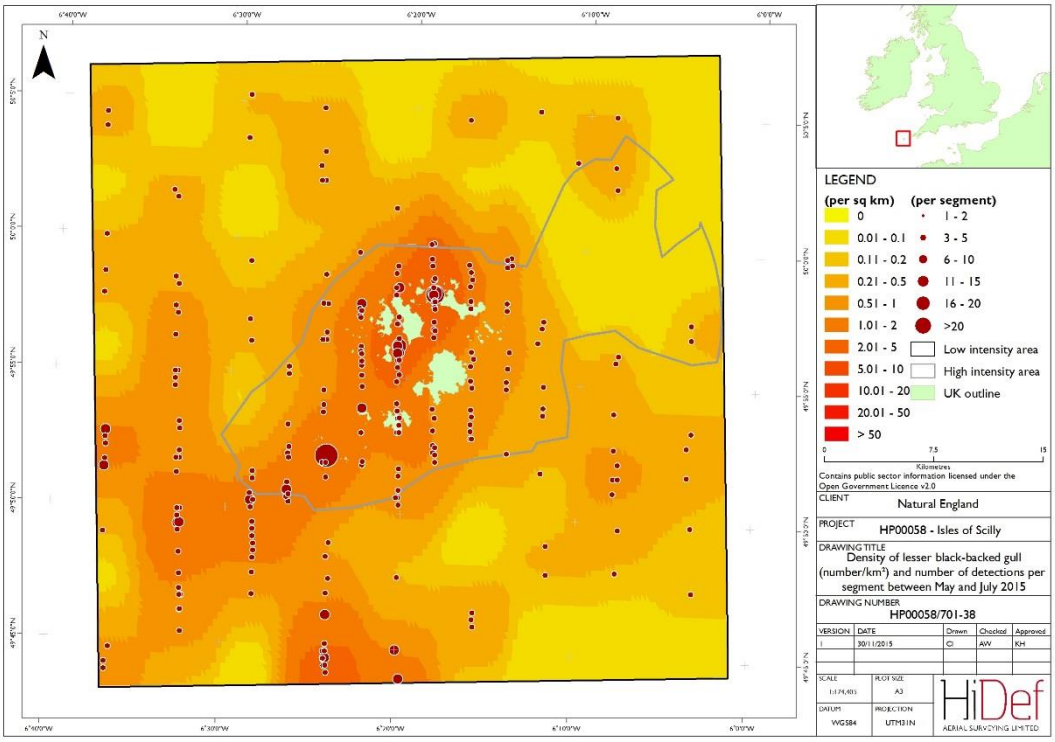


Figure 39 **Density of lesser black-backed gull (number/km²) and number of detections per segment during Survey 1 on 12 May 2015**

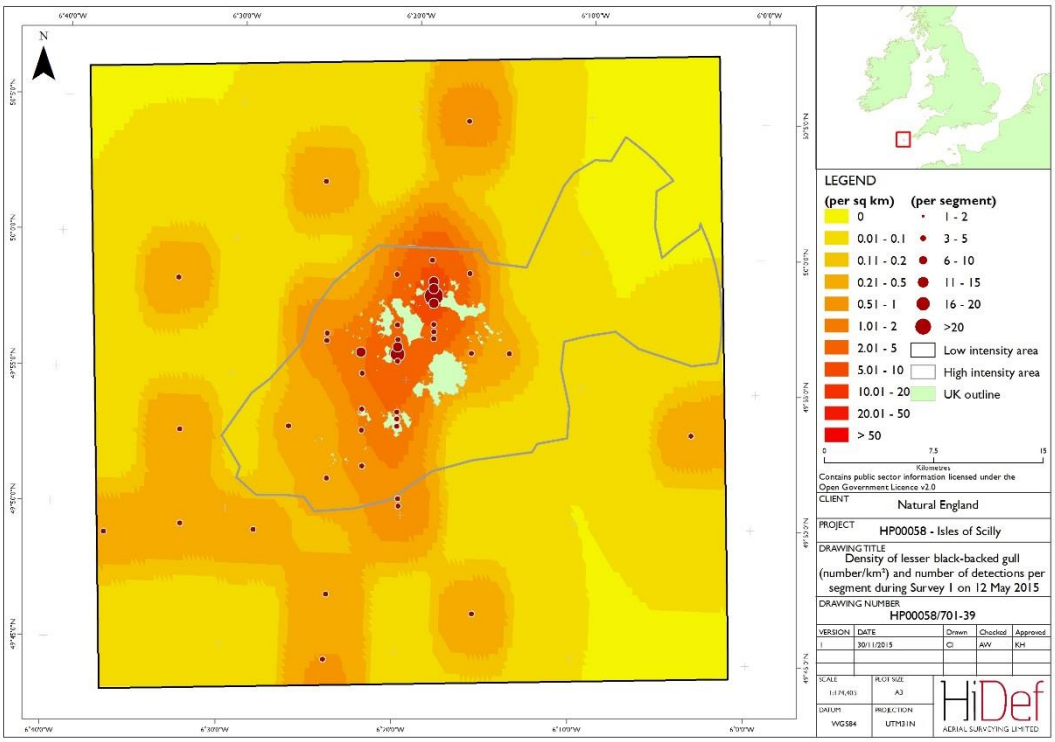


Figure 40 **Density of lesser black-backed gull (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

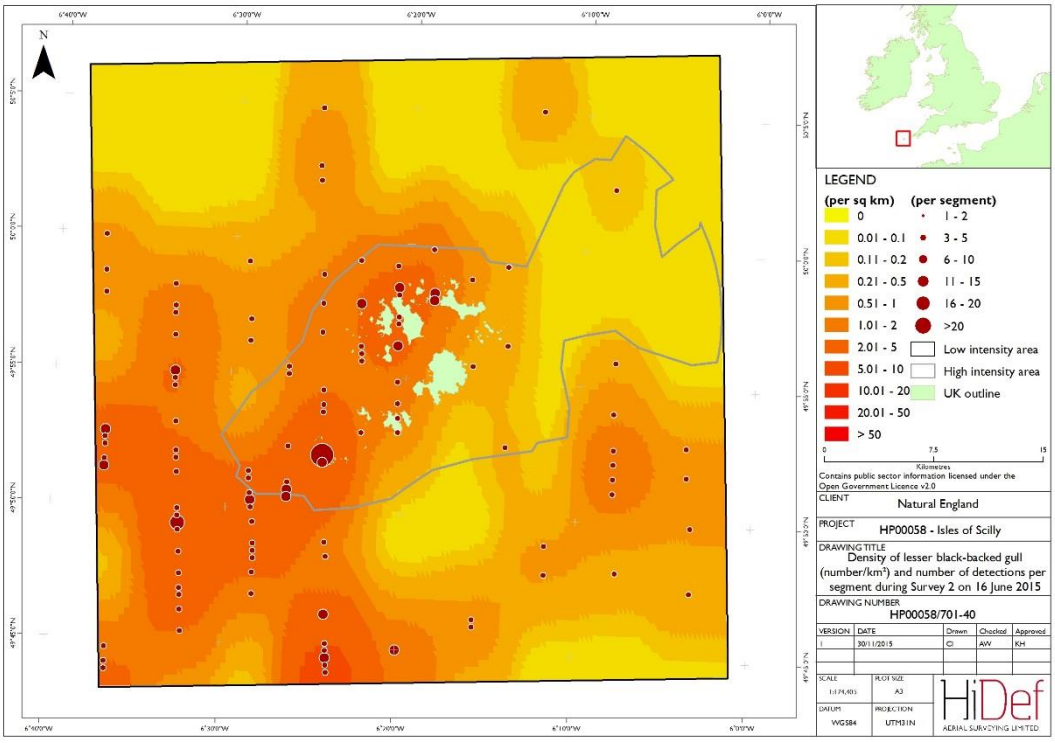
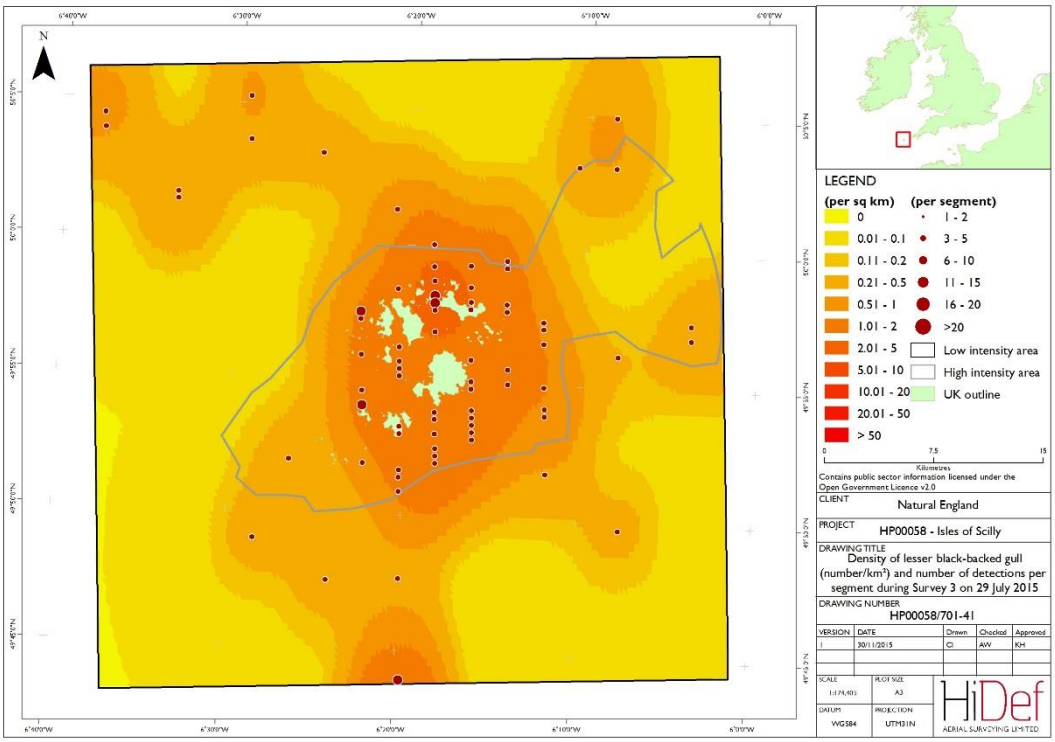


Figure 41 **Density of lesser black-backed gull (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.11 Herring gull

79 Densities of herring gull are shown in Figures 42 to 44. Loafing birds are excluded from all density maps.

Figure 42 Density of herring gull (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

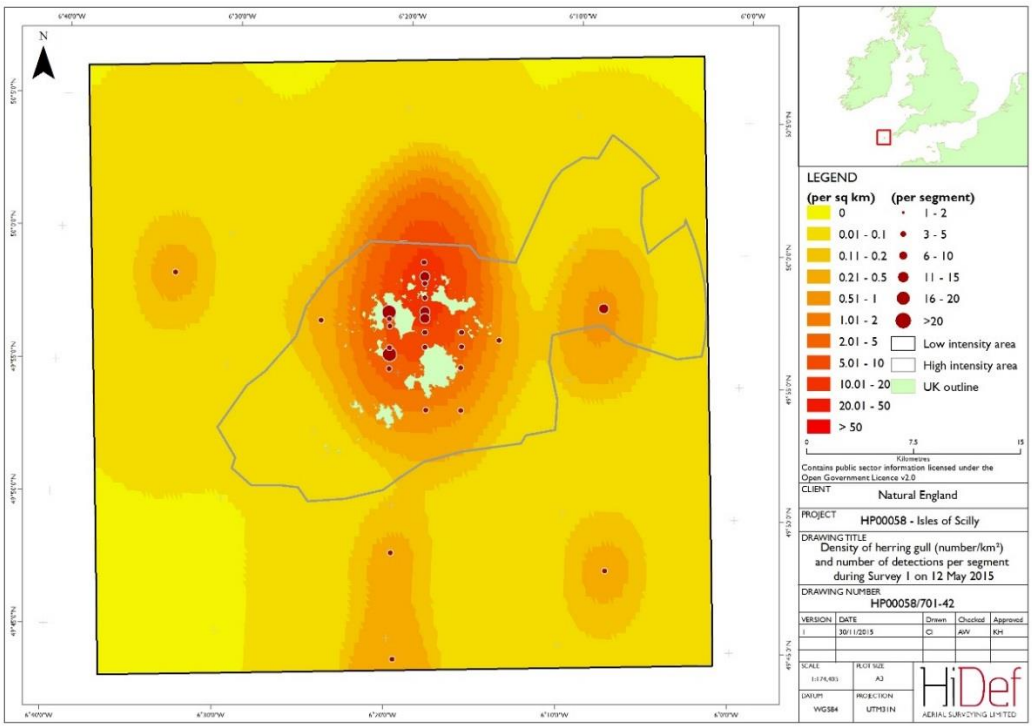


Figure 43 Density of herring gull (number/km²) and number of detections per segment during Survey 2 on 16 June 2015

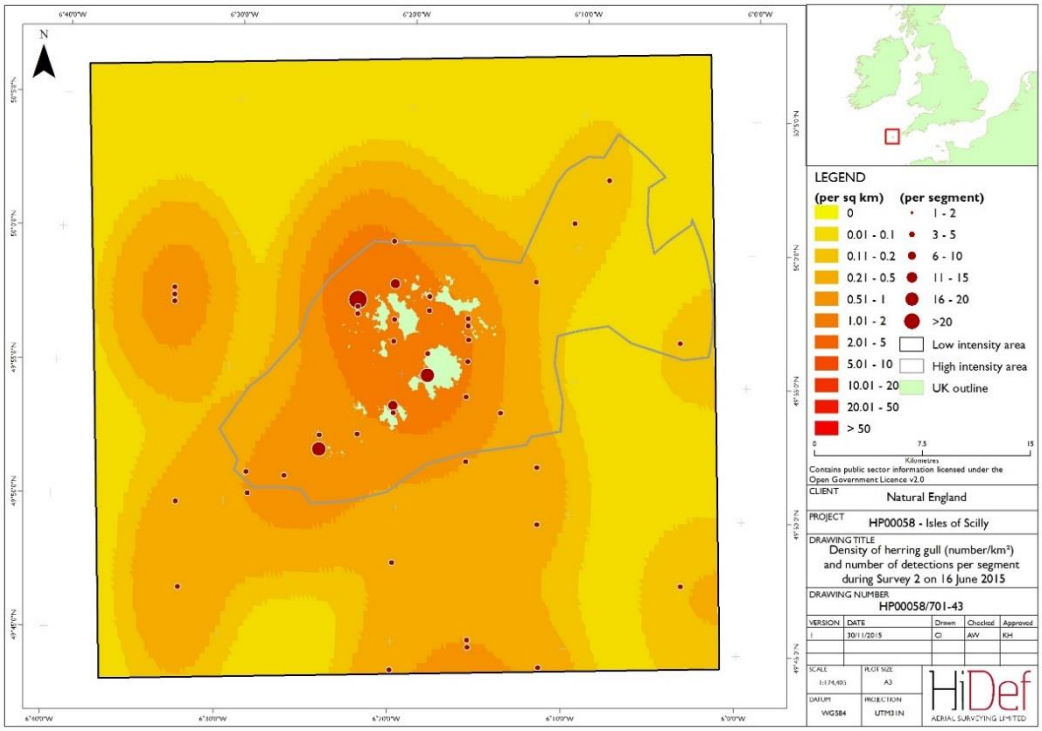
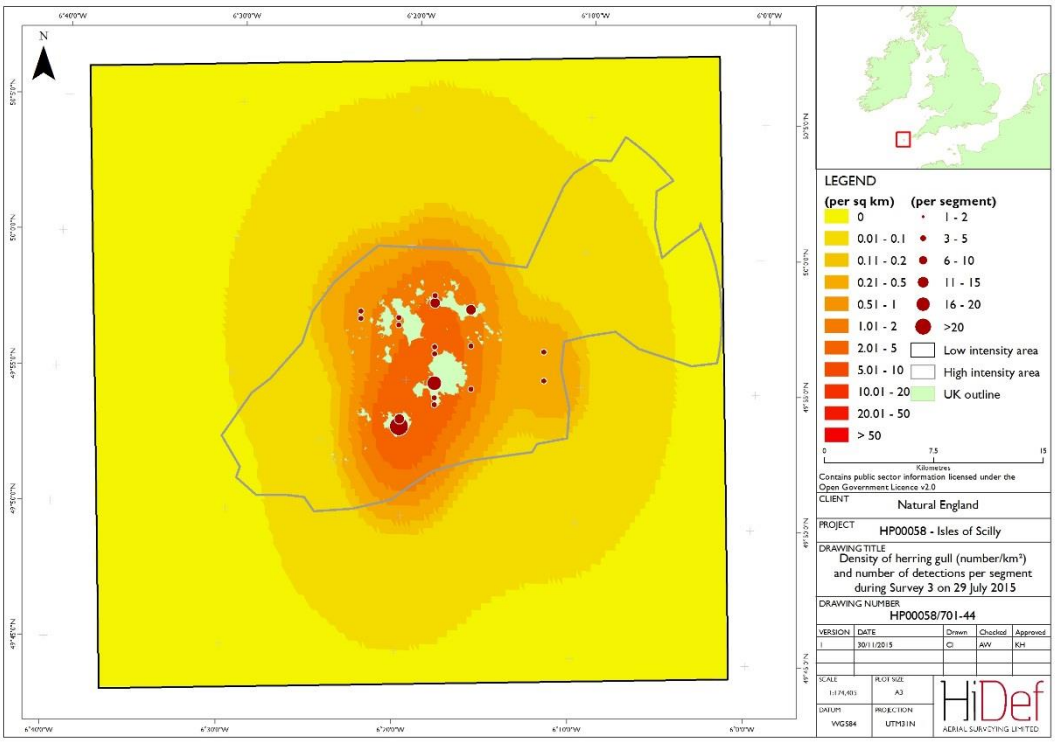


Figure 44 **Density of herring gull (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.12 Great black-backed gull

80 Densities of great black-backed gull are shown in Figures 45 to 47. Loafing birds are excluded from all density maps.

Figure 45 Density of great black-backed gull (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

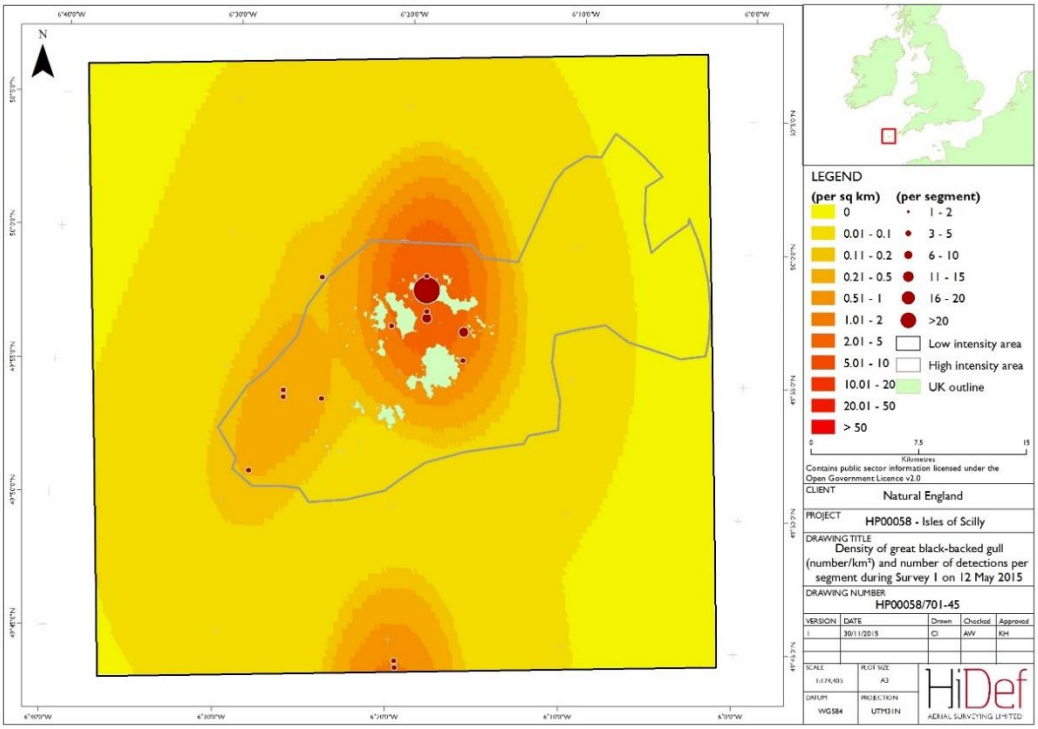


Figure 46 Density of great black-backed gull (number/km²) and number of detections per segment during Survey 2 on 16 June 2015

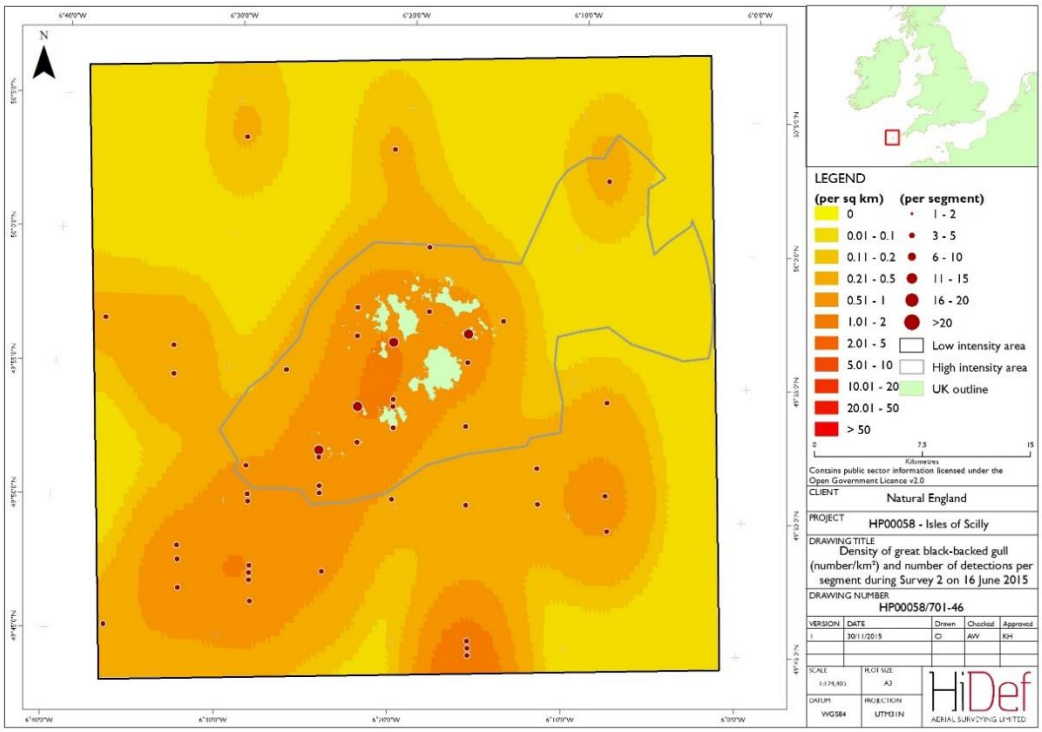
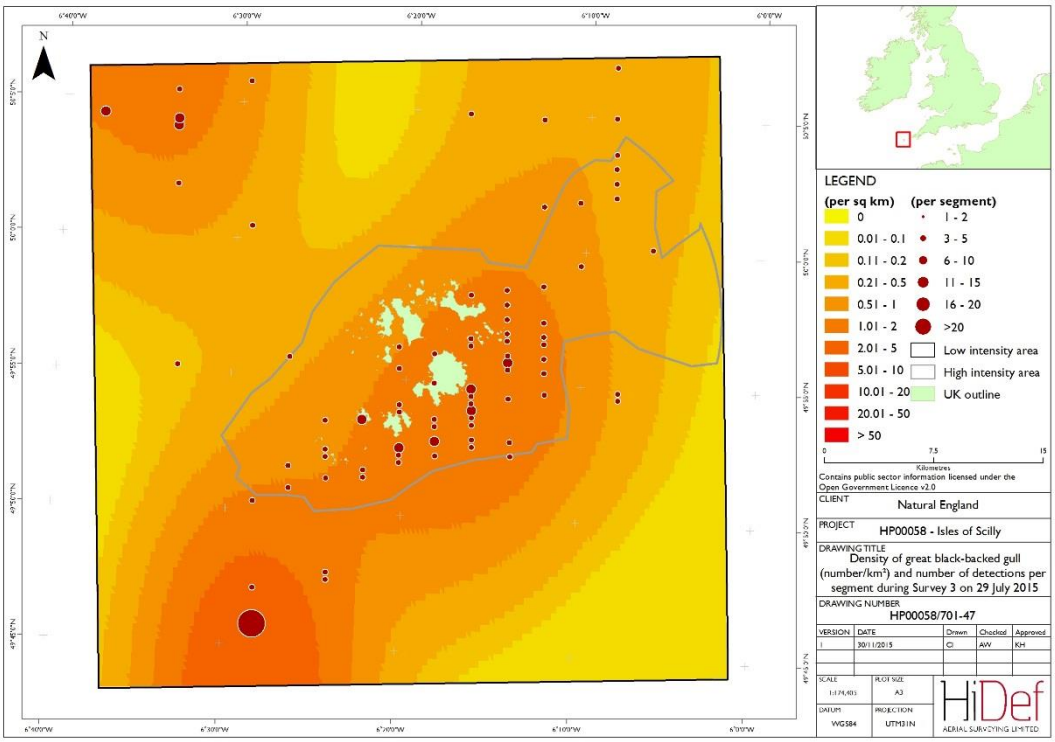


Figure 47 **Density of great black-backed gulls (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.13 Guillemot

81 Densities of guillemot are shown in Figures 48 to 50. Loafing birds are excluded from all density maps.

Figure 48 Density of guillemot (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

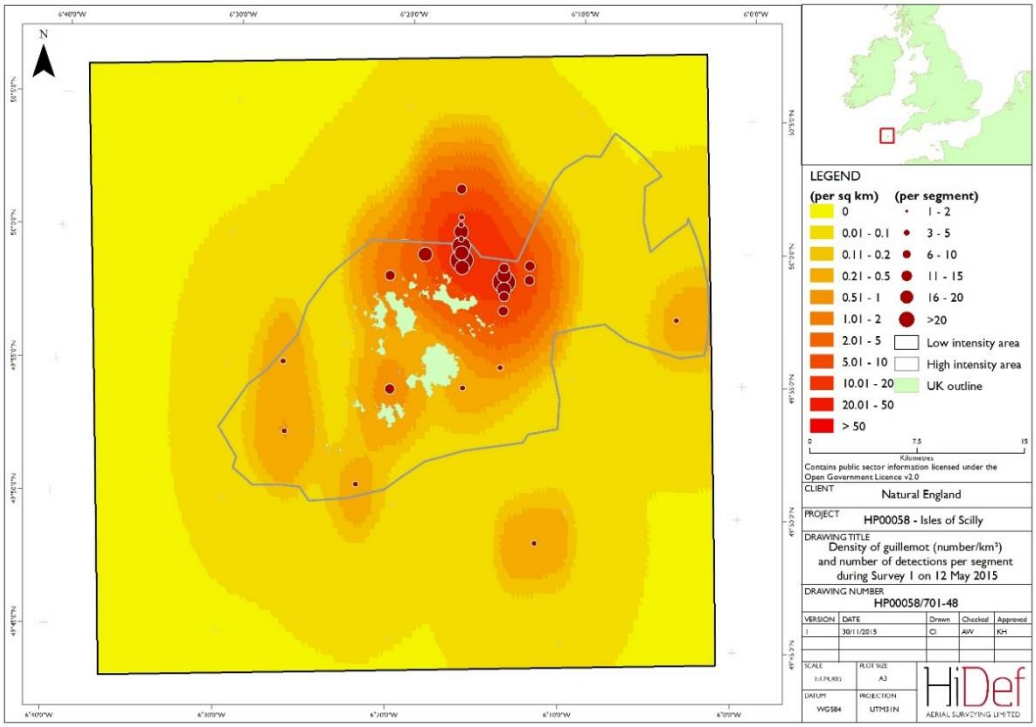


Figure 49 Density of guillemot (number/km²) and number of detections per segment during Survey 2 on 16 June 2015

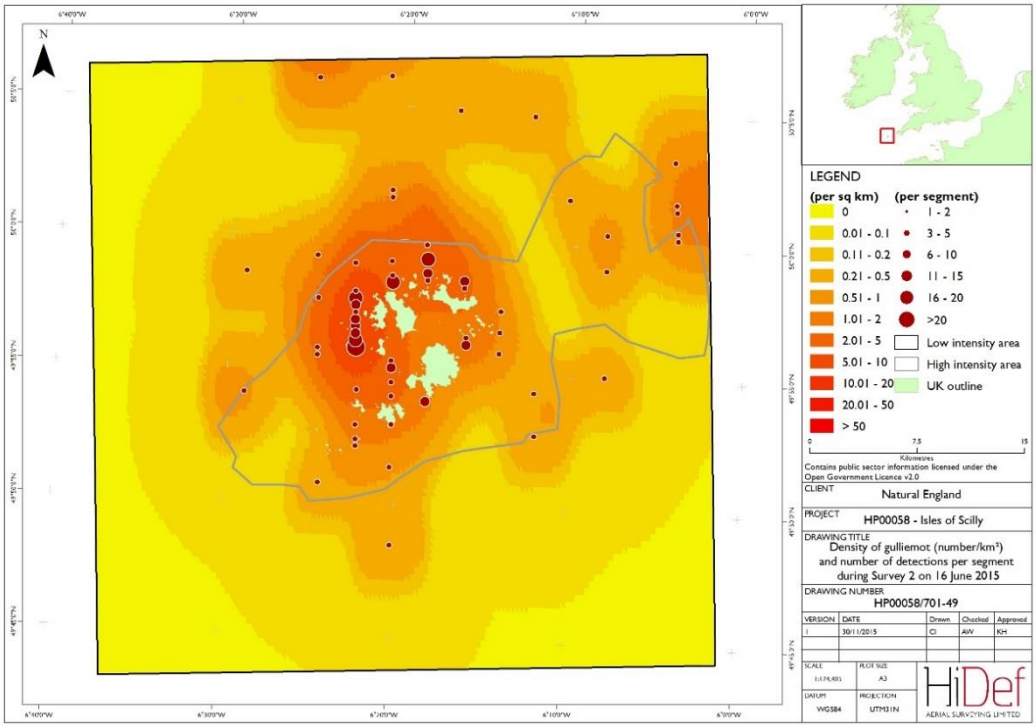
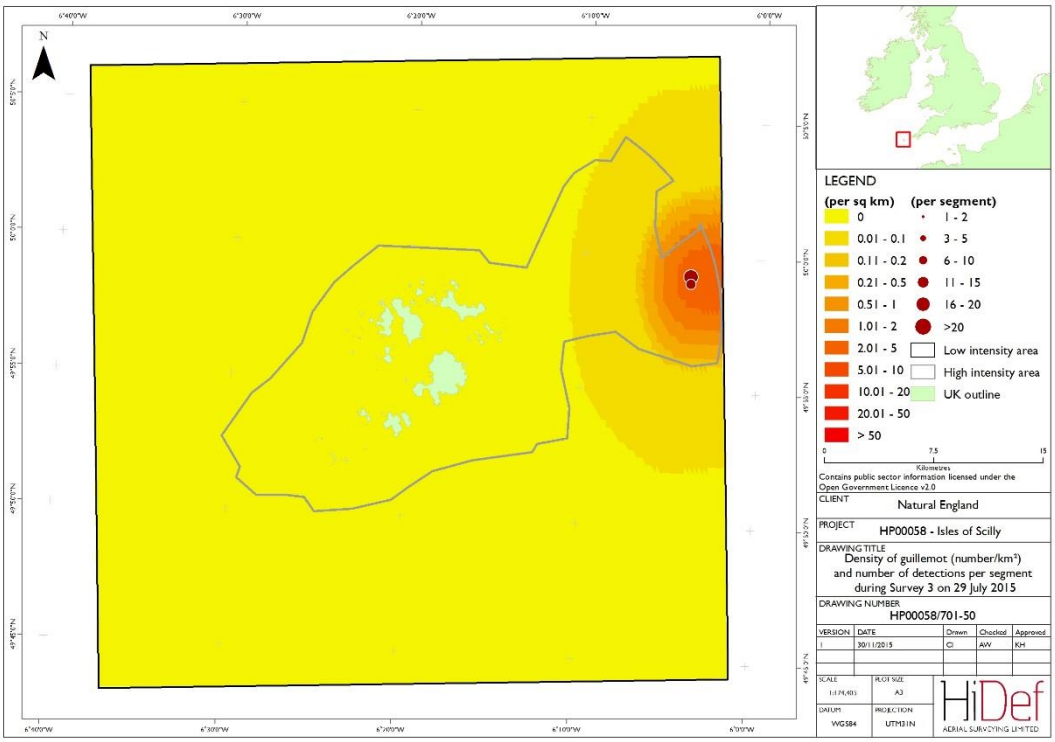


Figure 50 **Density of guillemot (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.14 Less abundant bird species

82 Dot maps for less abundant bird species are provided across Figures 51 to 53. Loafing birds are excluded from all density maps.

Figure 51 Detections of less abundant bird species (number/km²) during Survey 1 on 12 May 2015

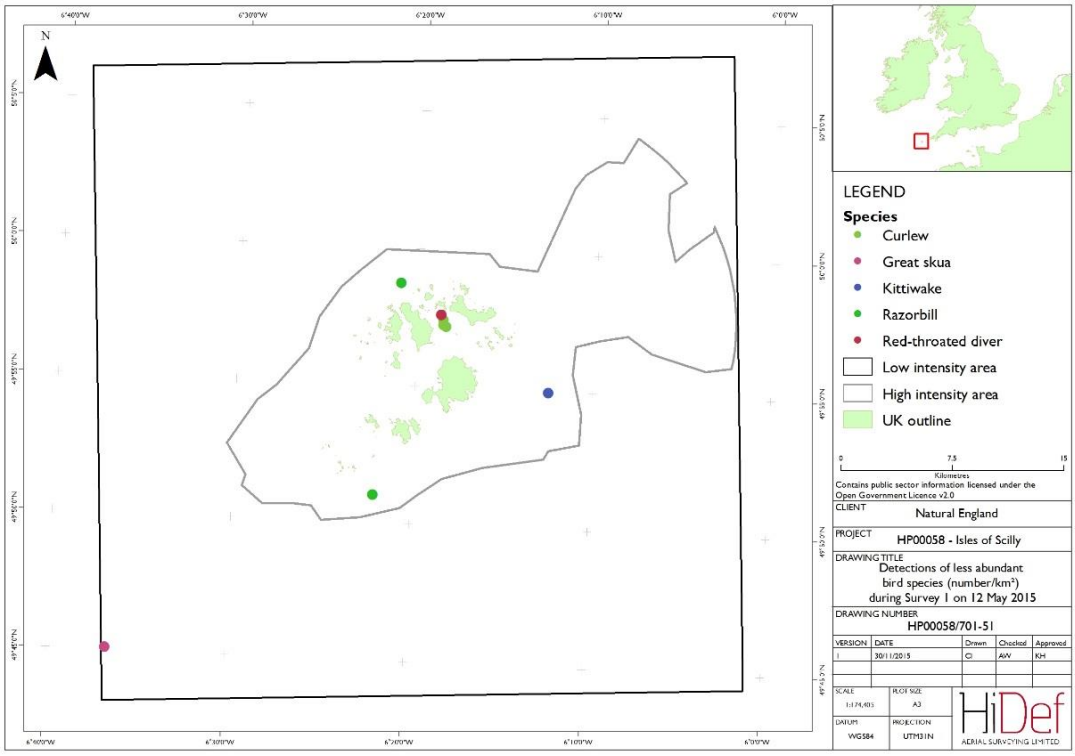


Figure 52 **Detections of less abundant bird species (number/km²) during Survey 2 on 16 June 2015**

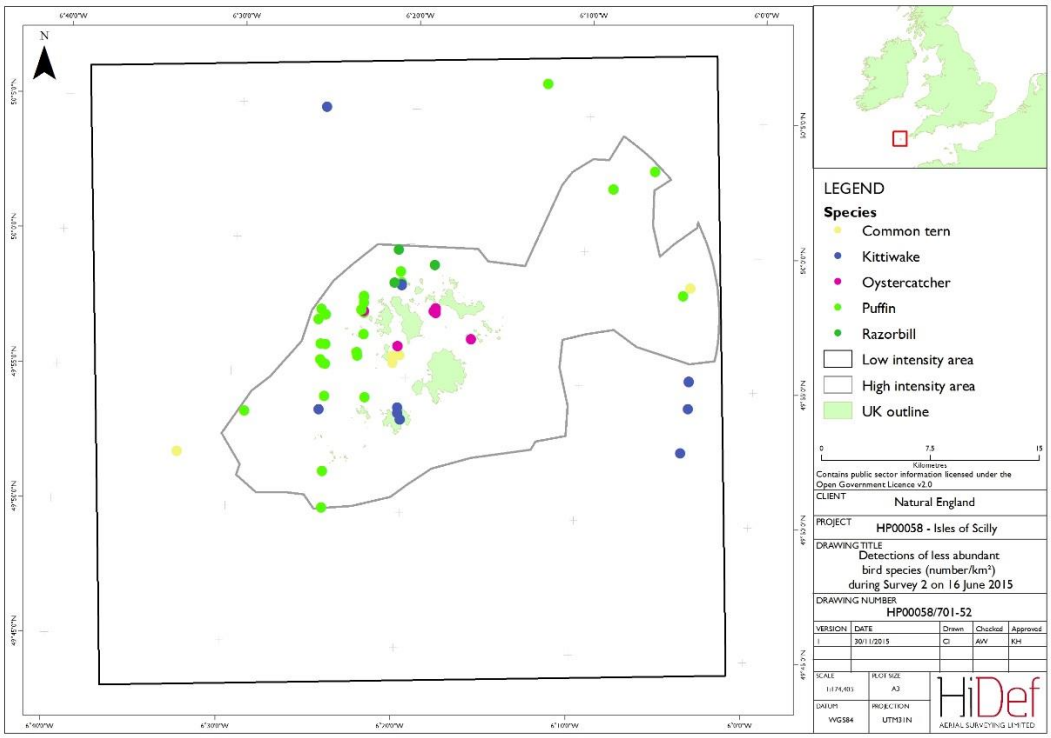
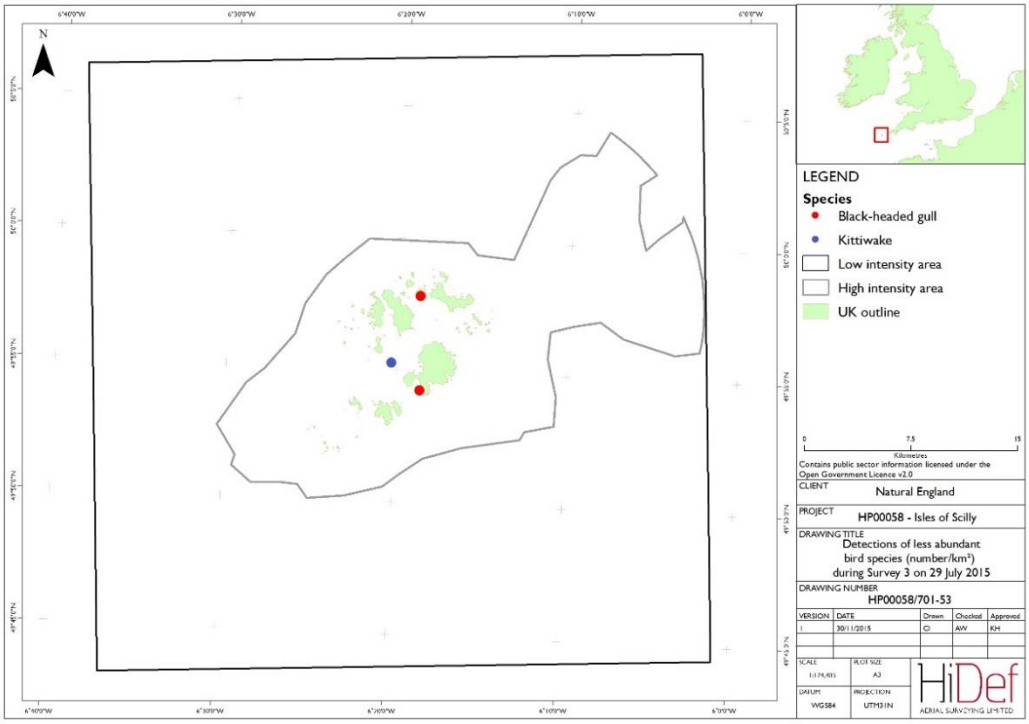


Figure 53 **Detections of less abundant bird species (number/km²) during Survey 3 on 29 July 2015**



3.4.15 Less abundant unidentified bird species

83 Dot maps for unidentified bird species are provided across Figures 54 to 56. Loafing birds are excluded from all density maps.

Figure 54 Detections of unidentified bird species (number/km²) during Survey 1 on 12 May 2015

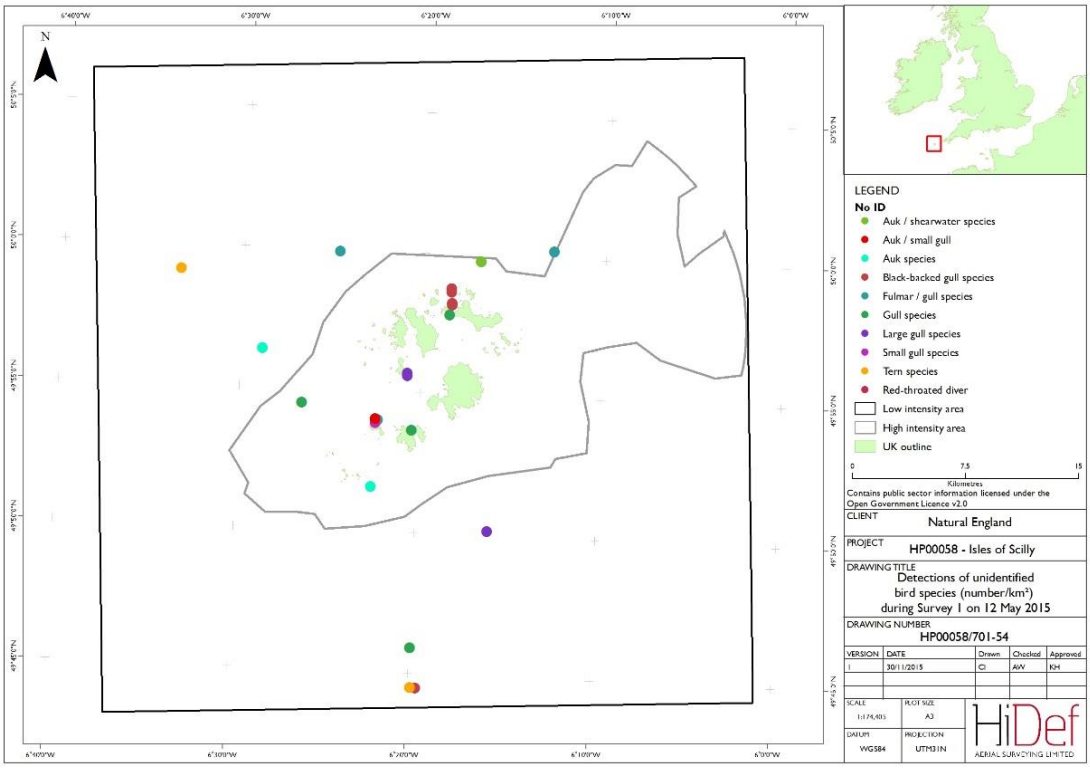


Figure 55 **Detections of unidentified bird species (number/km²) during Survey 2 on 16 June 2015**

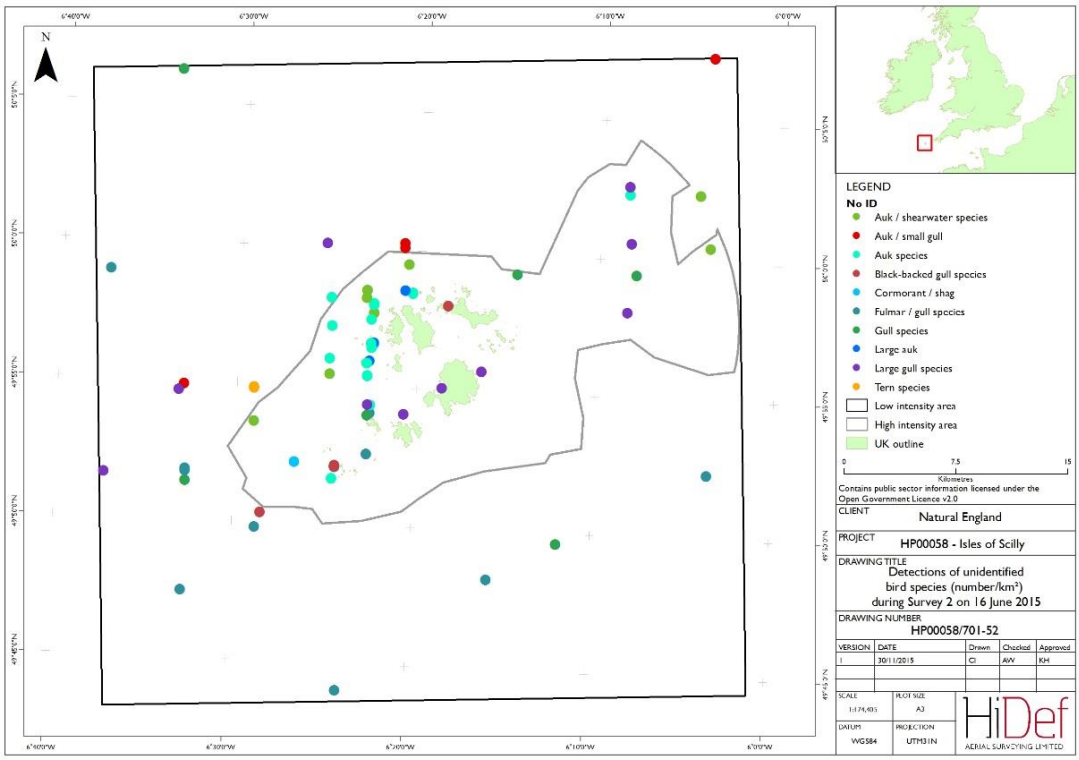
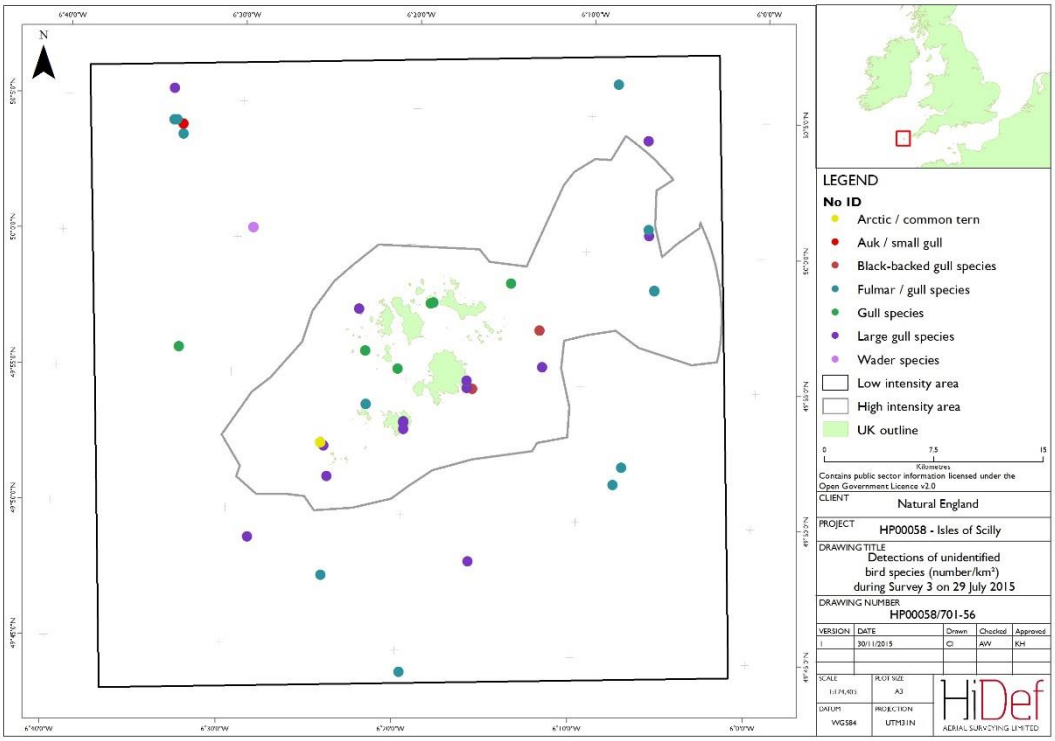


Figure 56 **Detections of unidentified bird species (number/km²) during Survey 3 on 29 July 2015**



3.4.16 All non-avian animals

84 Density maps for all non-avian animals are provided across Figures 57 to 60.

Figure 57 Density of all non-avian animals (number/km²) and number of detections per segment between May and July 2015

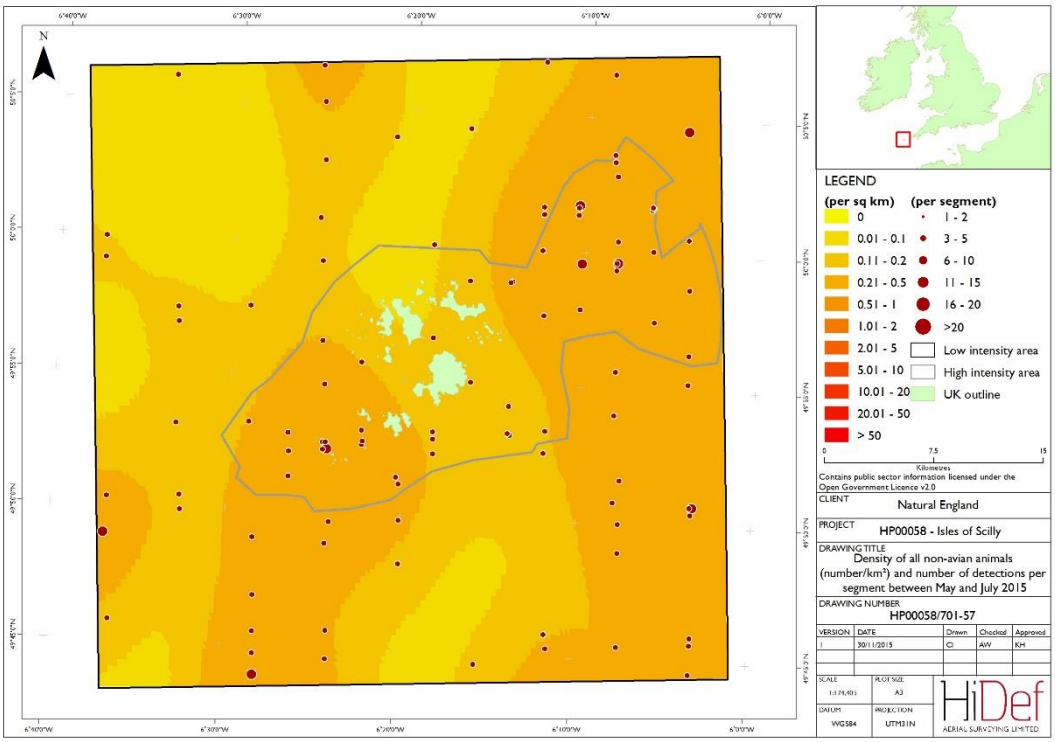


Figure 58 Density of all non-avian animals (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

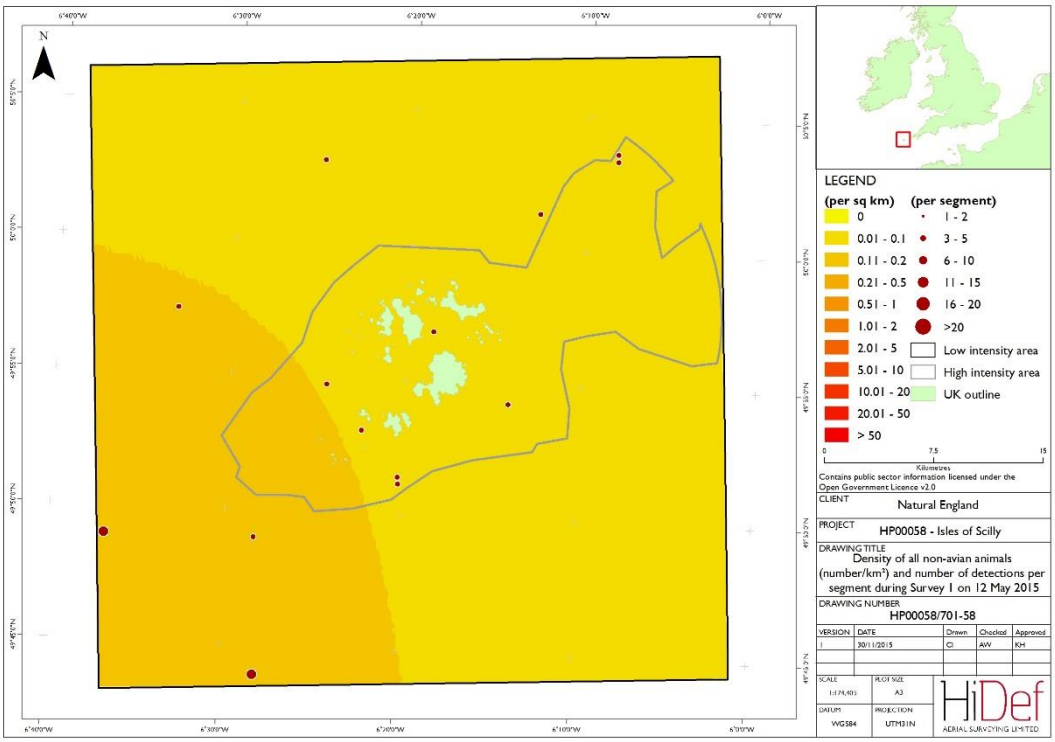


Figure 59 **Density of all non-avian animals (number/km²) and number of detections per segment during Survey 2 on 16 June 2015**

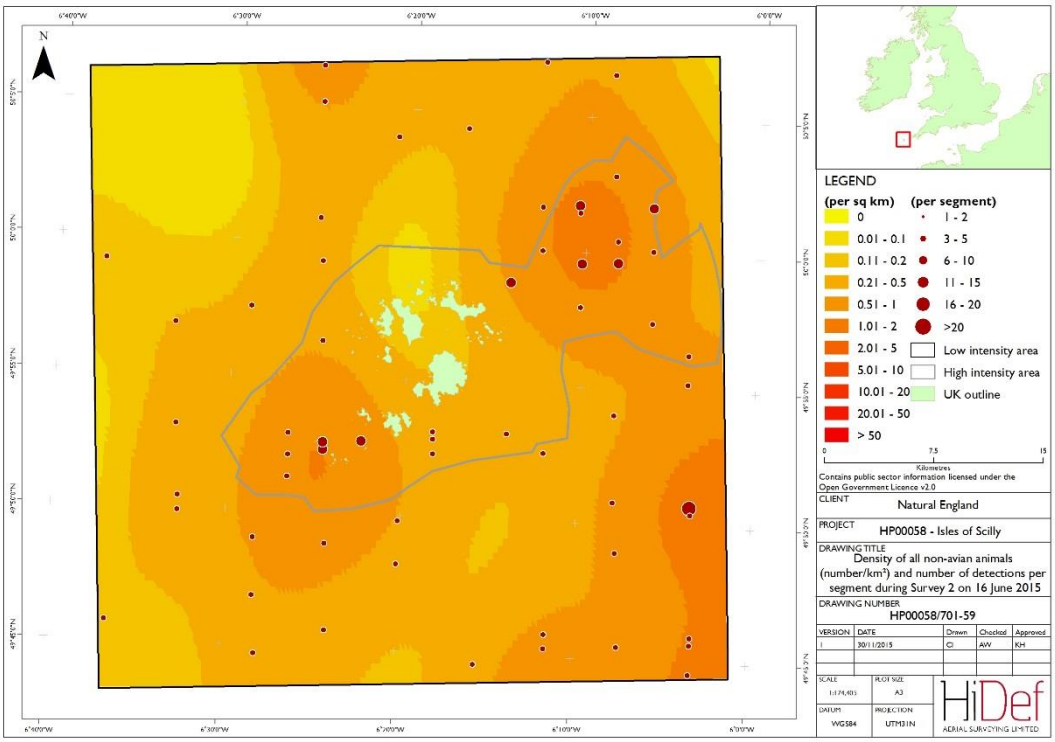
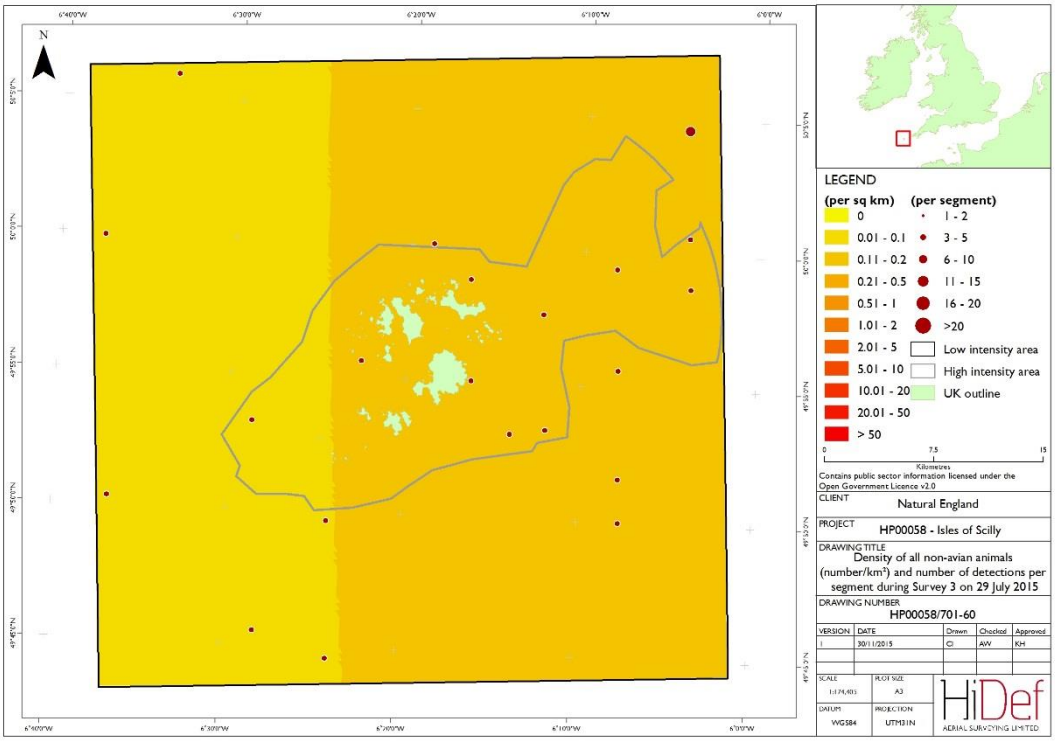


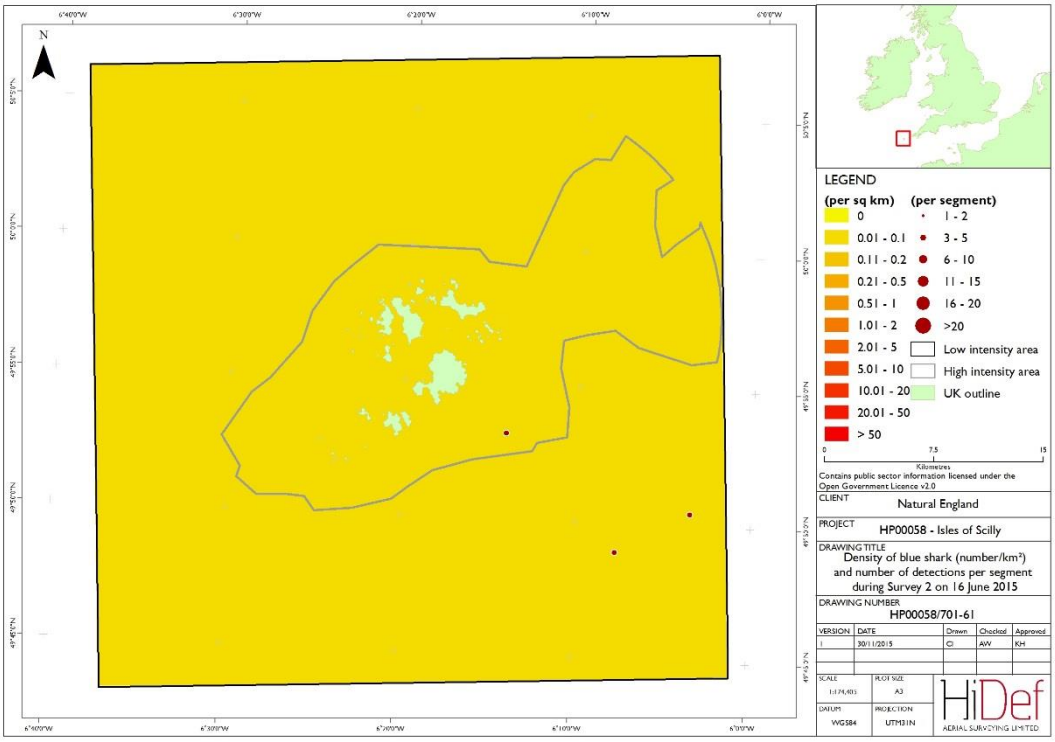
Figure 60 **Density of all non-avian animals (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.17 Blue shark

85 Densities of blue shark are shown in Figure 61. It should be noted that there were no observations of blue shark in either May or July 2015.

Figure 61 Density of blue shark (number/km²) and number of detections per segment during Survey 2 on 16 June 2015



3.4.18 Grey seal

86 Densities of grey seal are shown in Figures 62 to 64.

Figure 62 Density of grey seal (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

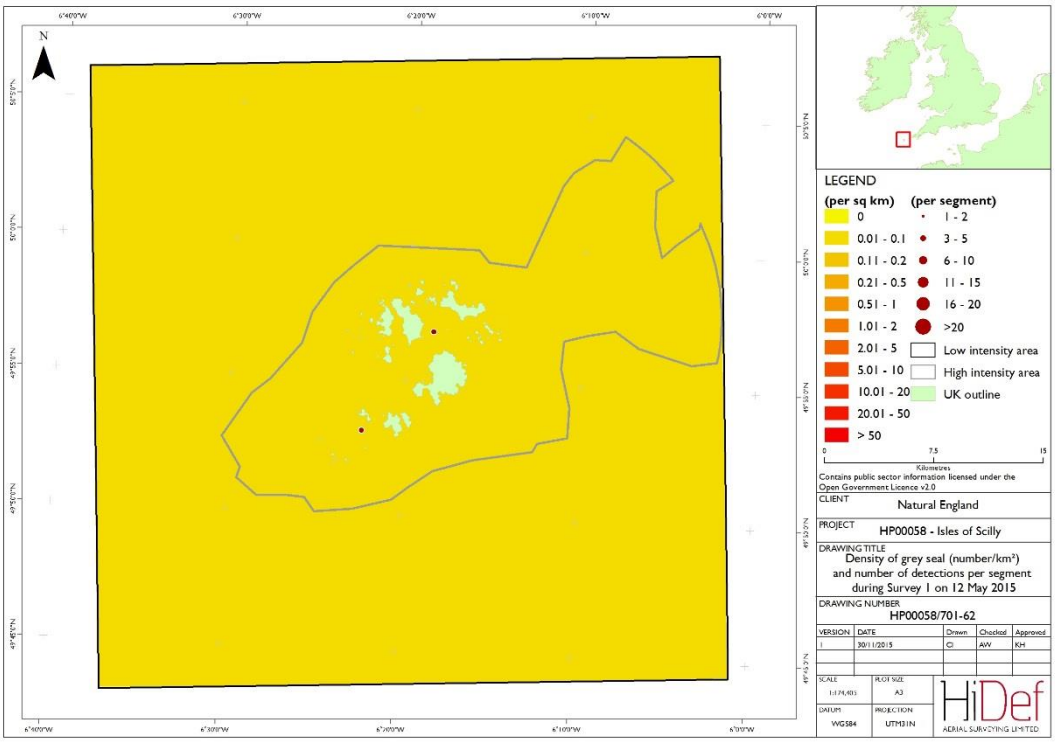


Figure 63 Density of grey seal (number/km²) and number of detections per segment during Survey 2 on 16 June 2015

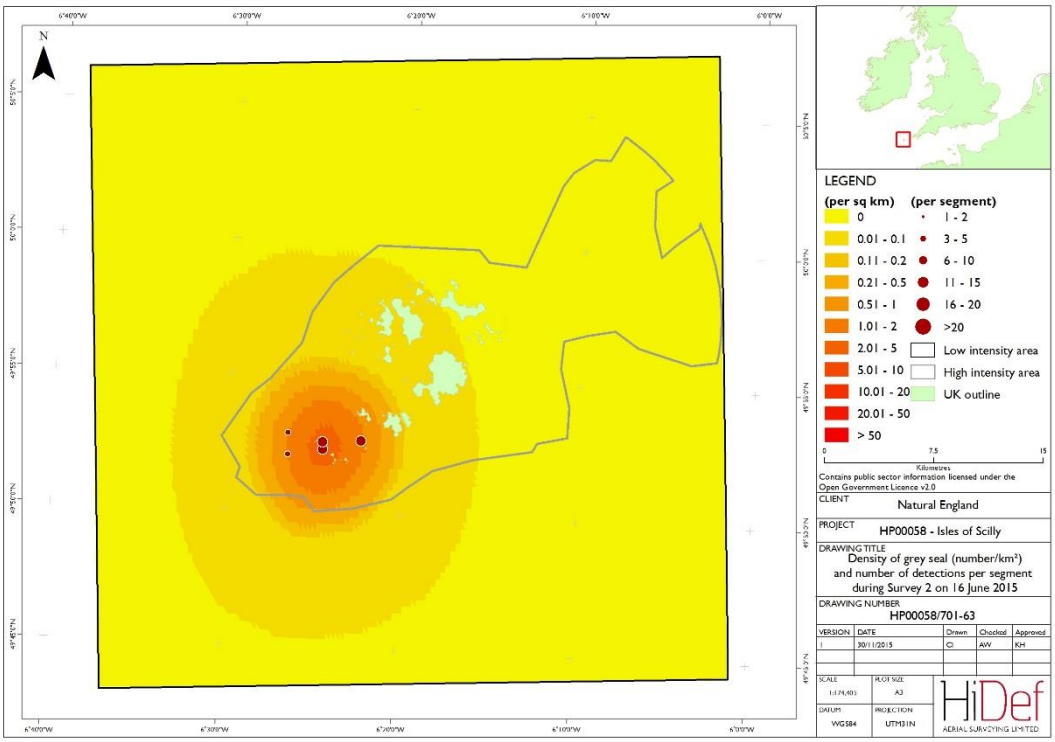
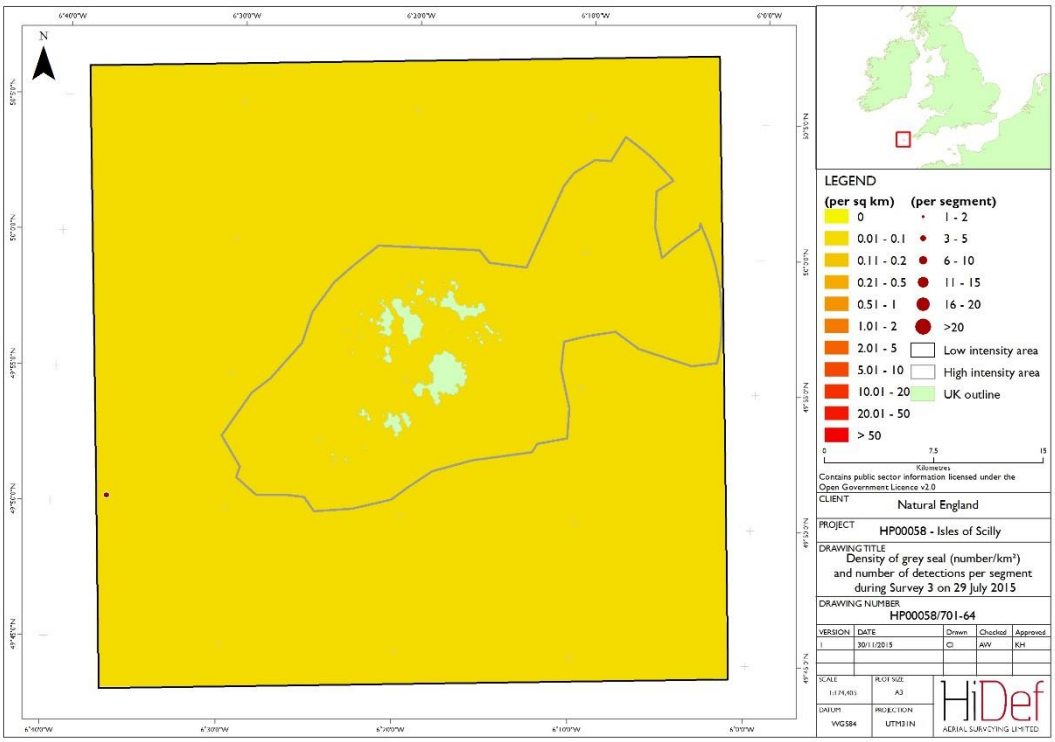


Figure 64 **Density of grey seal (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.19 Harbour porpoise

87 Densities of harbour porpoise are shown in Figures 65 to 67.

Figure 65 Density of harbour porpoise (number/km²) and number of detections per segment during Survey 1 on 12 May 2015

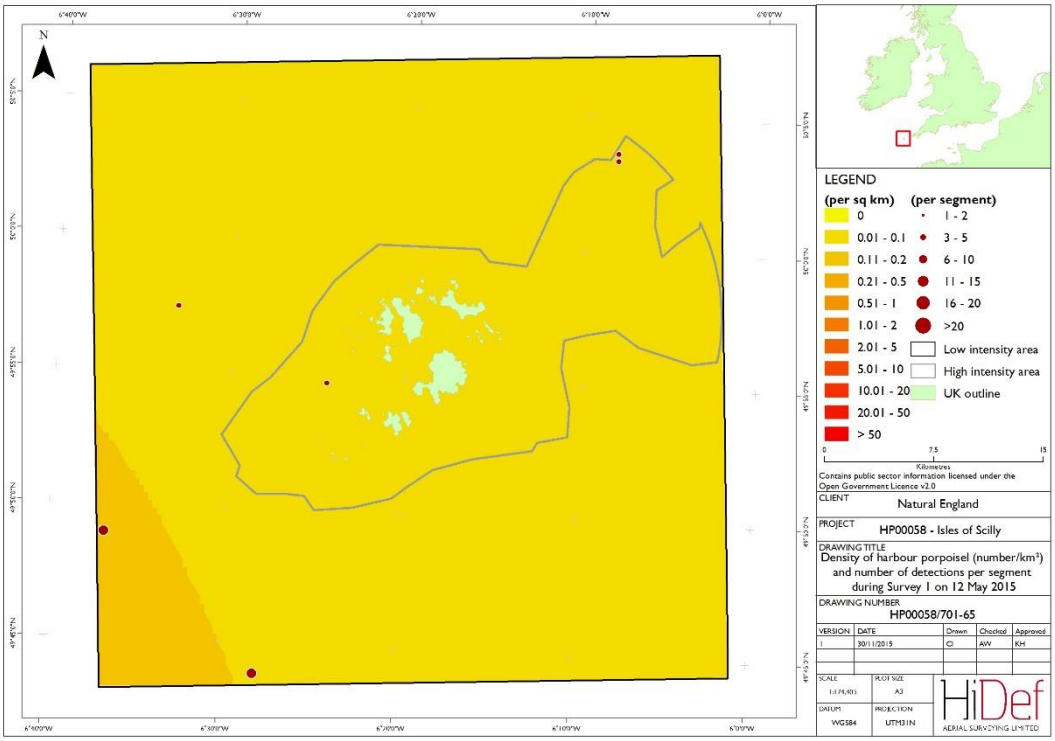


Figure 66 Density of harbour porpoise (number/km²) and number of detections per segment during Survey 2 on 16 June 2015

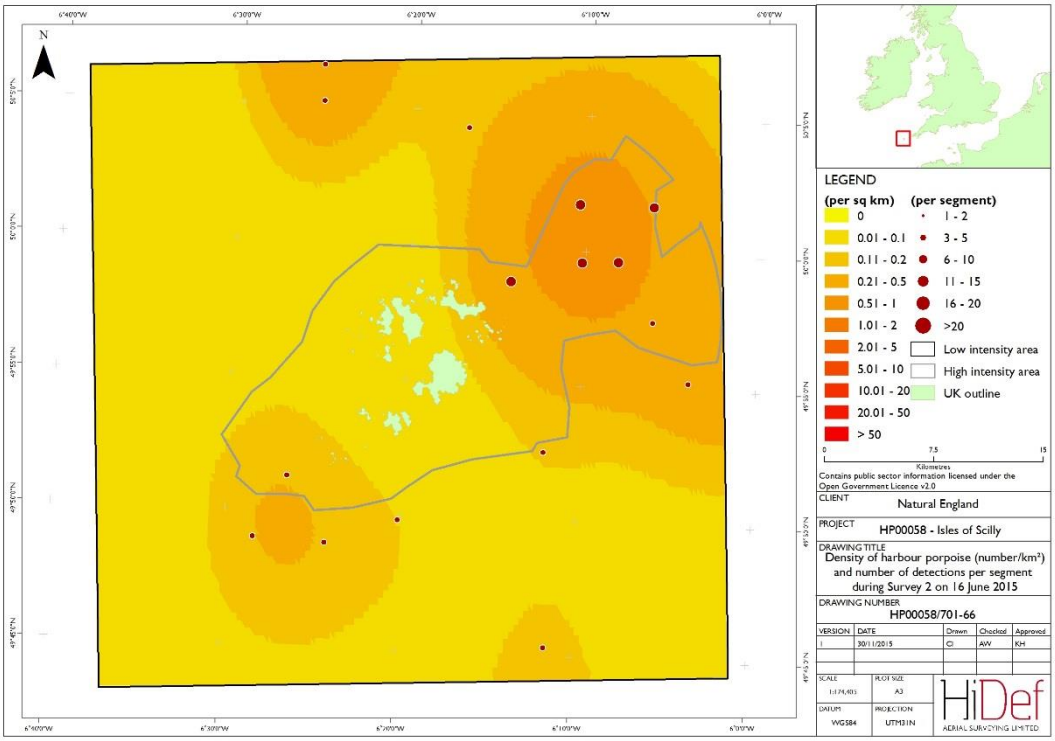
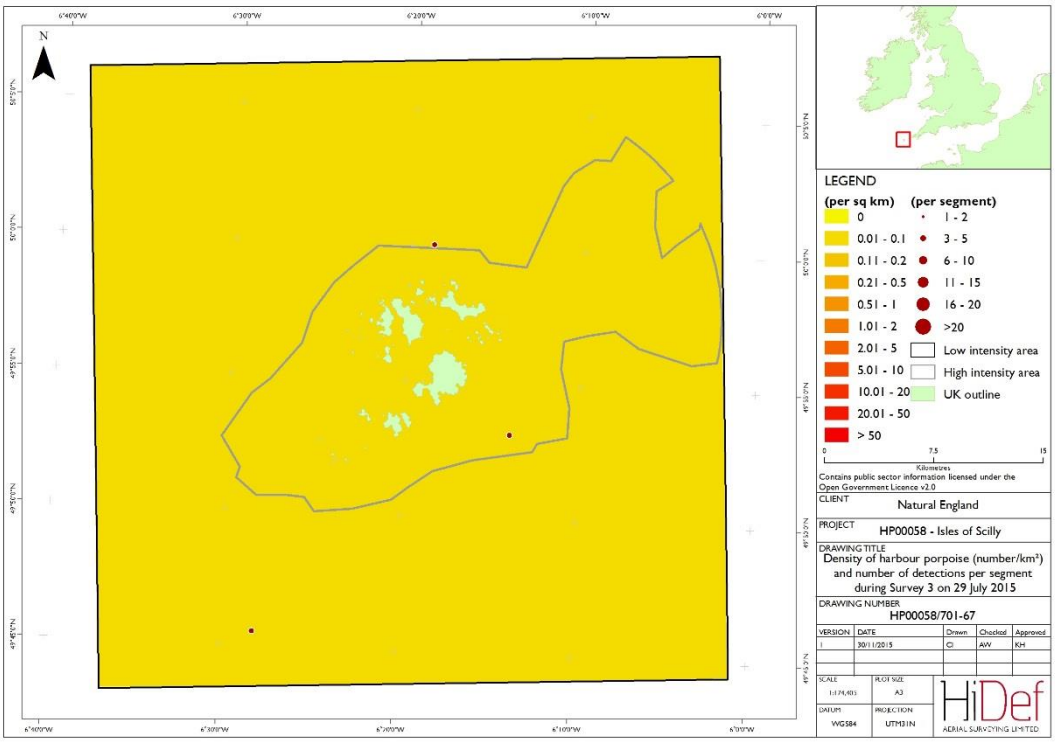


Figure 67 **Density of harbour porpoise (number/km²) and number of detections per segment during Survey 3 on 29 July 2015**



3.4.21 Less abundant non-avian animals

88 Dot of less abundant non-avian animals are shown in Figures 68 to 70.

Figure 68 Detections of less common non-avian animal species (number/km²) during Survey 1 on 12 May 2015

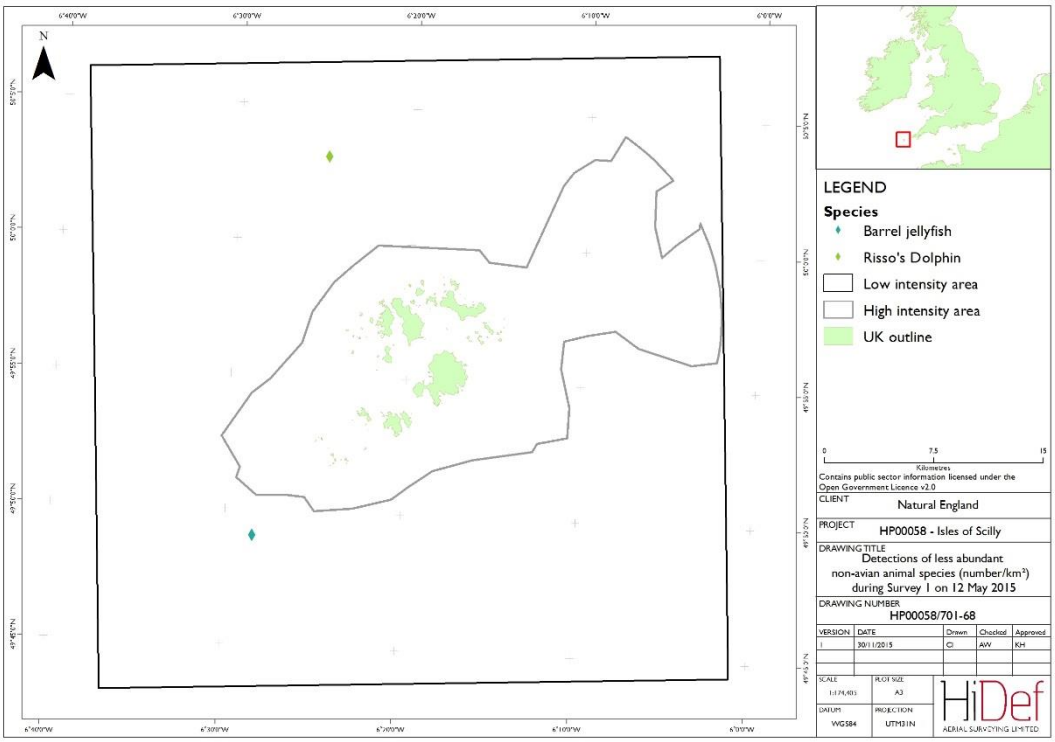


Figure 69 Detections of less common non-avian animal species (number/km²) during Survey 2 on 16 June 2015

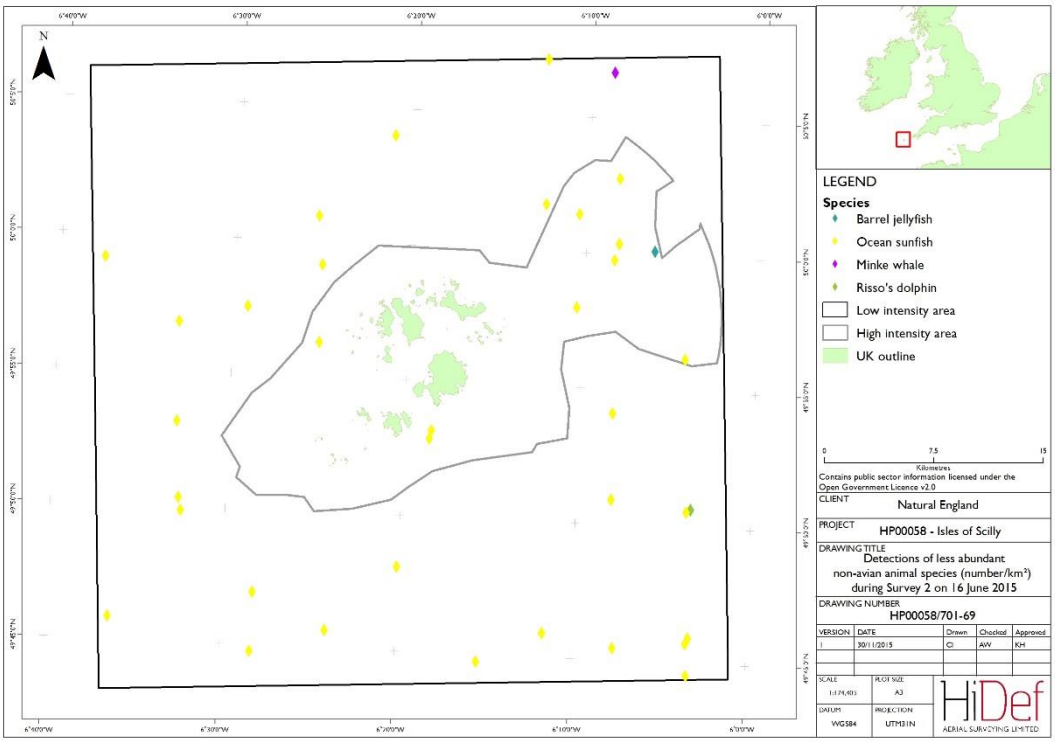
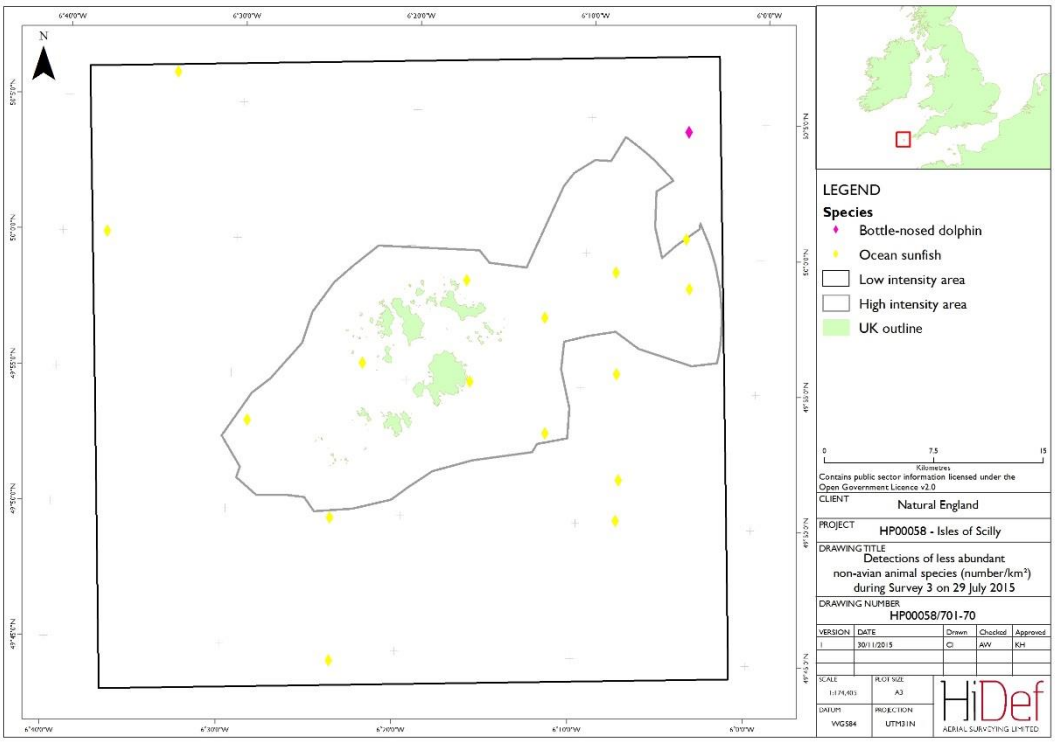


Figure 70 **Detections of less common non-avian animal species (number/km²) during Survey 3 on 29 July 2015**



3.4.22 Unidentified non-avian animals

89 Dot of unidentified non-avian animals are shown in Figures 71 to 73.

Figure 71 Detections of unidentified non-avian animal species (number/km²) during Survey 1 on 12 May 2015

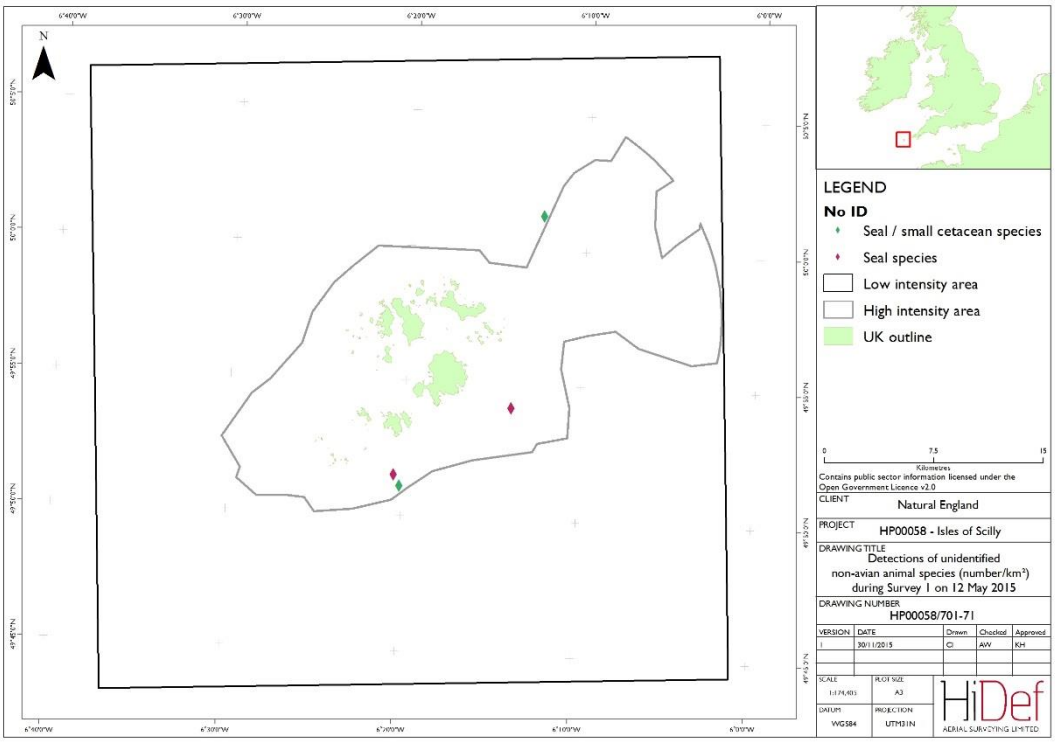


Figure 72 Detections of unidentified non-avian animal species (number/km²) during Survey 2 on 16 June 2015

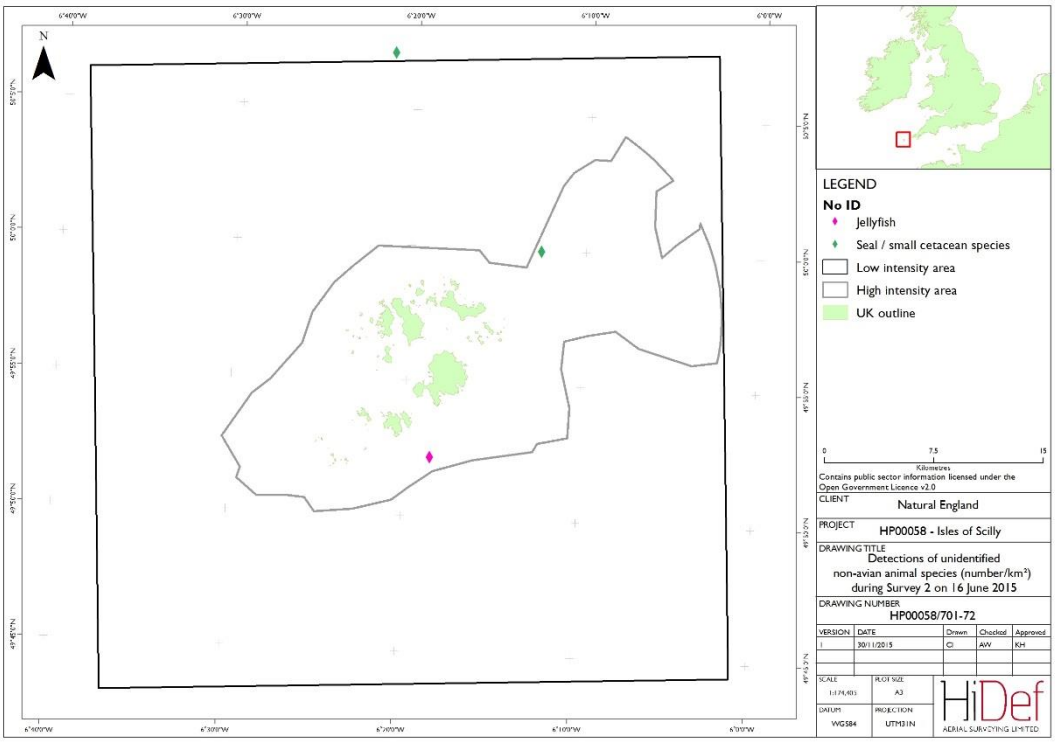
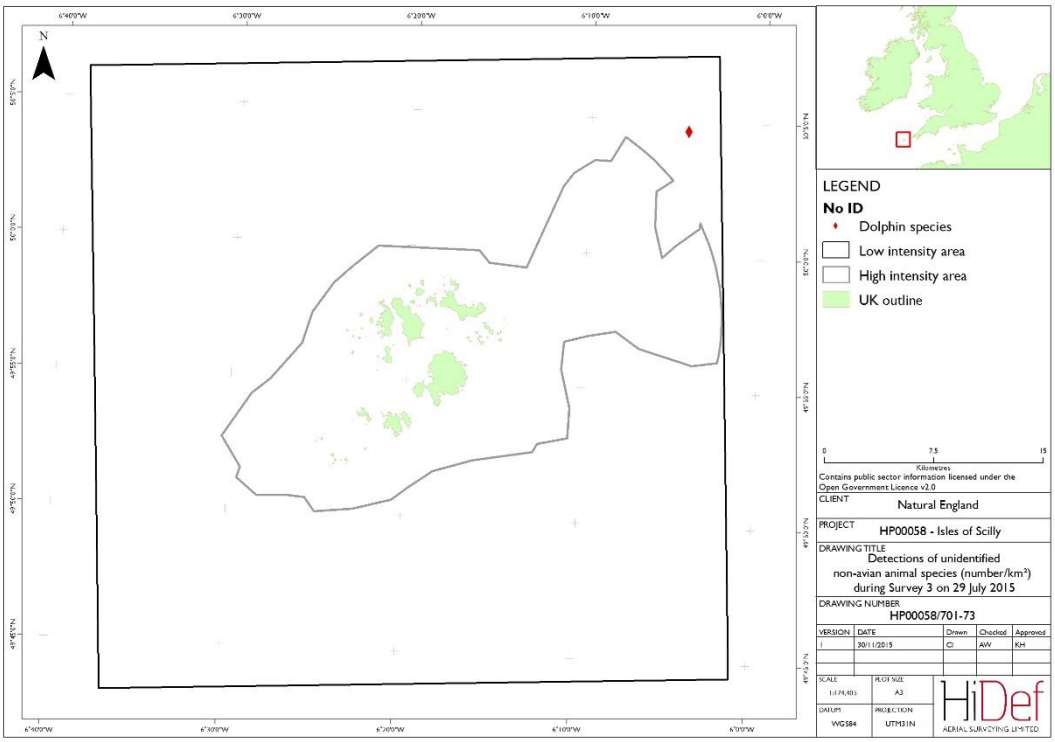


Figure 73 **Detections of unidentified non-avian animal species (number/km²) during Survey 3 on 29 July 2015**



3.5 Behaviours of seabirds and non-avian animals

90 The behaviour of seabirds has been categorised as follows: flying, loafing (on land), sitting and taking off. The number of each category observed is presented in Table 21 to Table 24.

91 Loafing has been included for information only and was not analysed in the results overall. In addition, the surfacing behaviour for all non-avian animals is presented in Table 25 to Table 28. Snapshot surfacing indicates where the head or dorsal fin of a seal or cetacean (respectively) are clear of the water surface at the red line (middle frame of the sequence where the animal was present) during the identification process (See Section 2.3).

92 Shag showed the most variation in behaviour between the three surveys. During May 2015, the majority of individuals were recorded as sitting on the sea surface, with only 13% recorded as flying and fewer than 10% loafing. In June and July 2015, only 3% of birds were recorded as flying.

93 In the June 2015 survey, 33 out of 143 observations were of loafing birds, while in July 2015 the number rose to 162 out of 176 observations. Foraging behaviour in the form of diving behaviour was only recorded in June, with seven individuals being recorded diving.

94 The percentage of flying lesser black-backed gull was 73% in May, decreasing to 56% in June and then increase to 87% in July 2015.

95 Great black-backed gull was recorded flying more often than other species, with 54% recorded in May, 69% in June and 63% in July 2015.

96 The majority of grey seal observed were surfacing, with 91% of those recorded during the June survey being surfacing or snapshot surfacing. Fewer grey seal were observed in both May and July than June 2015.

97 Harbour porpoise were more often observed as either submerged and surfacing, with 75% and 40% snapshot surfacing and surfacing in May and June respectively but only 25% recorded as snapshot surfacing in July 2015.

Table 21 **Summary of seabird behaviours between May and July 2015 (loafing figures only included in final column and excluded from overall analysis)**

Species	Number diving	Number flying	Number sitting	Number taking off	% flying	Total	Number loafing
Red-throated diver	0	0	2	0	0%	2	0
Fulmar	0	43	107	1	28%	151	0
Manx shearwater	0	165	144	97	41%	406	0
Gannet	0	147	156	1	48%	304	0
Shag	7	17	143	0	5%	366	199
Oystercatcher	0	13	0	0	100%	13	0
Curlew	0	3	0	0	100%	3	0
Great skua	0	1	0	0	100%	1	0
Kittiwake	0	9	11	0	45%	20	0
Black-headed gull	0	1	1	0	50%	2	0
Lesser black-backed gull	0	257	115	3	68%	379	4
Herring gull	0	140	120	4	51%	274	10
Great black-backed gull	0	171	100	0	63%	273	2
Common tern	0	16	2	0	89%	18	0
Guillemot	0	33	243	0	12%	276	0
Razorbill	0	2	4	0	33%	6	0
Puffin	0	3	39	0	7%	42	0
No ID							
Fulmar / gull species	0	3	31	0	9%	34	0
Cormorant / shag	0	0	1	0	0%	1	0
Wader species	0	5	0	0	100%	5	0
Small gull species	0	0	0	0	0%	1	1
Black-backed gull species	0	8	4	0	67%	12	0
Large gull species	0	17	13	0	57%	30	0
Gull species	0	4	24	0	14%	29	1
Arctic / common tern	0	1	0	0	100%	1	0
Tern species	0	4	0	0	100%	4	0
Large auk	0	3	1	0	75%	4	0
Auk species	0	5	22	1	18%	28	0
Auk / small gull	0	1	5	0	17%	6	0
Auk / shearwater species	0	7	13	1	33%	21	0
Total	**7**	**1079**	**1292**	**108**	**40%**	**2712**	**217**

Table 22 Summary of seabird behaviours between May 2015 (loafing figures only included in final column and excluded from overall analysis)

Species	Number diving	Number flying	Number sitting	Number taking off	% flying	Total	Number loafing
Red-throated diver	0	0	2	0	0%	2	0
Fulmar	0	5	2	0	71%	7	0
Manx shearwater	0	162	86	96	47%	344	0
Gannet	0	28	10	0	74%	38	0
Shag	0	6	37	0	13%	47	4
Curlew	0	3	0	0	100%	3	0
Great skua	0	1	0	0	100%	1	0
Kittiwake	0	1	0	0	100%	1	0
Lesser black-backed gull	0	59	19	0	73%	81	3
Herring gull	0	72	55	0	53%	135	8
Great black-backed gull	0	28	23	0	54%	52	1
Guillemot	0	1	137	0	1%	138	0
Razorbill	0	0	3	0	0%	3	0
No ID							
Fulmar / gull species	0	0	4	0	0%	4	0
Small gull species	0	0	0	0	0%	1	1
Black-backed gull species	0	2	4	0	33%	6	0
Large gull species	0	1	2	0	33%	3	0
Gull species	0	0	7	0	0%	8	1
Tern species	0	2	0	0	100%	2	0
Auk species	0	1	1	0	50%	2	0
Auk / small gull	0	0	1	0	0%	1	0
Auk / shearwater species	0	0	3	0	0%	3	0
Total	**0**	**372**	**393**	**96**	**42%**	**882**	**18**

Table 23 Summary of seabird behaviours between June 2015 (loafing figures only included in final column and excluded from overall analysis)

Species	Number diving	Number flying	Number sitting	Number taking off	% flying	Total	Number loafing
Fulmar	0	5	17	1	22%	23	0
Manx shearwater	0	0	51	0	0%	51	0
Gannet	0	29	59	0	33%	88	0
Shag	7	5	98	0	3%	143	33
Oystercatcher	0	13	0	0	100%	13	0
Kittiwake	0	7	11	0	39%	18	0
Lesser black-backed gull	0	110	83	3	56%	197	1
Herring gull	0	35	38	4	44%	79	2
Great black-backed gull	0	47	20	0	69%	68	1
Common tern	0	16	2	0	89%	18	0
Guillemot	0	22	106	0	17%	128	0
Razorbill	0	2	1	0	67%	3	0
Puffin	0	3	39	0	7%	42	0
No ID							
Fulmar / gull species	0	2	12	0	14%	14	0
Cormorant / shag	0	0	1	0	0%	1	0
Black-backed gull species	0	4	0	0	100%	4	0
Large gull species	0	6	4	0	60%	10	0
Gull species	0	0	6	0	0%	6	0
Tern species	0	2	0	0	100%	2	0
Large auk	0	3	1	0	75%	4	0
Auk species	0	4	21	1	15%	26	0
Auk / small gull	0	1	3	0	25%	4	0
Auk / shearwater species	0	7	10	1	39%	18	0
Total	**7**	**323**	**583**	**10**	**34%**	**960**	**37**

Table 24 **Summary of seabird behaviours between July 2015 (loafing figures only included in final column and excluded from overall analysis)**

Species	Number diving	Number flying	Number sitting	Number taking off	% flying	Total	Number loafing
Fulmar	0	33	88	0	27%	121	0
Manx shearwater	0	3	7	1	27%	11	0
Gannet	0	90	87	1	51%	178	0
Shag	0	6	8	0	3%	176	162
Kittiwake	0	1	0	0	100%	1	0
Black-headed gull	0	1	1	0	50%	2	0
Lesser black-backed gull	0	88	13	0	87%	101	0
Herring gull	0	33	27	0	55%	60	0
Great black-backed gull	0	96	57	0	63%	153	0
Guillemot	0	10	0	0	100%	10	0
No ID							
Fulmar / gull species	0	1	15	0	6%	16	0
Wader species	0	5	0	0	100%	5	0
Black-backed gull species	0	2	0	0	100%	2	0
Large gull species	0	10	7	0	59%	17	0
Gull species	0	4	11	0	27%	15	0
Arctic / common tern	0	1	0	0	100%	1	0
Auk / small gull	0	0	1	0	0%	1	0
Total	**0**	**384**	**316**	**2**	**44%**	**870**	**162**

Table 25 Summary of surfacing behaviour for non-avian animals between May and July 2015

Species	Submerged	Surfacing	Snapshot surfacing	Total
Barrel jellyfish	2	0	0	2
Ocean sunfish	52	1	1	54
Grey seal	3	2	32	37
Minke whale	1	0	0	1
Risso's Dolphin	2	1	3	6
Bottle-nosed dolphin	1	1	1	3
Harbour porpoise	27	11	13	51
Blue shark	3	0	0	3
No ID				
Jellyfish	1	0	0	1
Seal species	0	0	2	2
Dolphin species	1	0	0	1
Seal / small cetacean species	1	2	1	4
Total	**94**	**18**	**53**	**165**

Table 26 Summary of surfacing behaviour for non-avian animals in May 2015

Species	Submerged	Surfacing	Snapshot surfacing	Total
Barrel jellyfish	1	0	0	1
Grey seal	1	1	0	2
Risso's Dolphin	1	0	0	1
Harbour porpoise	3	5	4	12
No ID				
Seal species	0	0	2	2
Seal / small cetacean species	0	1	1	2
Total	**6**	**7**	**7**	**20**

Table 27 Summary of surfacing behaviour for non-avian animals in June 2015

Species	Submerged	Surfacing	Snapshot surfacing	Total
Barrel jellyfish	1	0	0	1
Ocean sunfish	38	0	0	38
Grey seal	2	1	31	34
Minke whale	1	0	0	1
Risso's Dolphin	1	1	3	5
Harbour porpoise	21	6	8	35
Blue shark	3	0	0	3
No ID				
Jellyfish	1	0	0	1
Seal / small cetacean species	1	1	0	2
Total	**69**	**9**	**42**	**120**

Table 28 Summary of surfacing behaviour for non-avian animals in July 2015

Species	Submerged	Surfacing	Snapshot surfacing	Total
Ocean sunfish	14	1	1	16
Grey seal	0	0	1	1
Bottle-nosed dolphin	1	1	1	3
Harbour porpoise	3	0	1	4
No ID				
Dolphin species	1	0	0	1
Total	**19**	**2**	**4**	**25**

3.6 Flying direction of seabirds

98 The flying directions of seabird species are presented in Figure 74 to Figure 79 as individual bird observations to show the total number of birds recorded flying in a particular direction. This is represented as an arrow pointing in the direction of flight.

3.6.1 Shag

Figure 74 Direction of movement of flying shag during Survey 1 on 12 May 2015 in relation to the location of breeding sites (breeding sites as per JNCC, 2014)

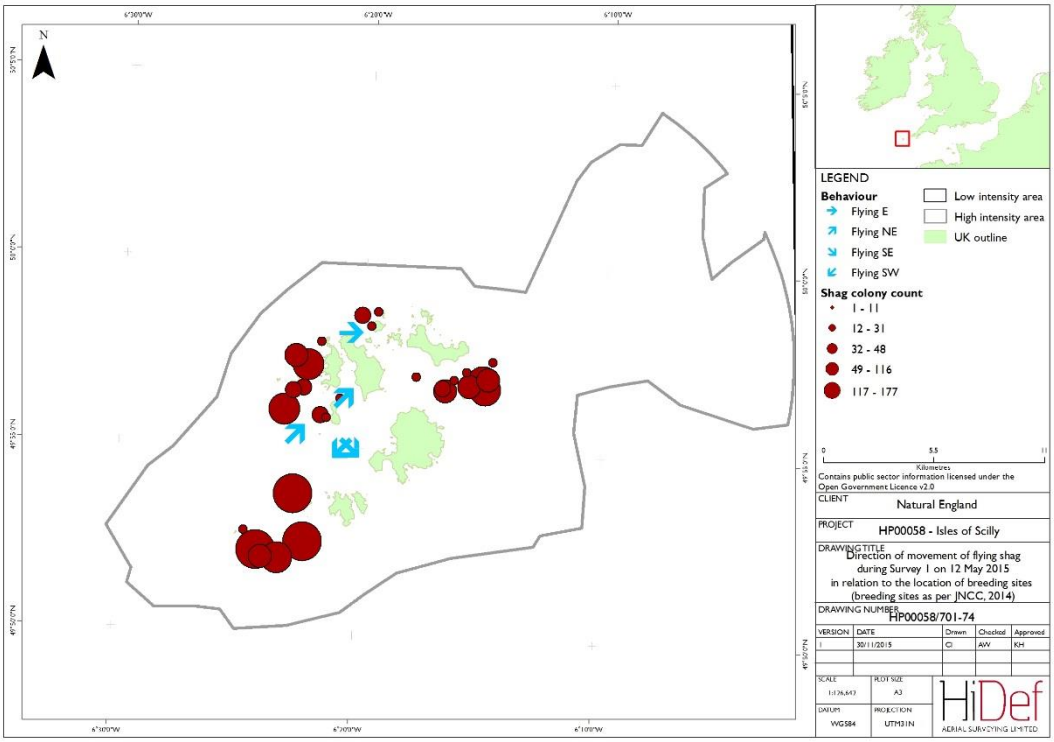


Figure 75 **Direction of movement of flying shag during Survey 2 on 16 June 2015 in relation to the location of breeding sites (breeding sites as per JNCC, 2014)**

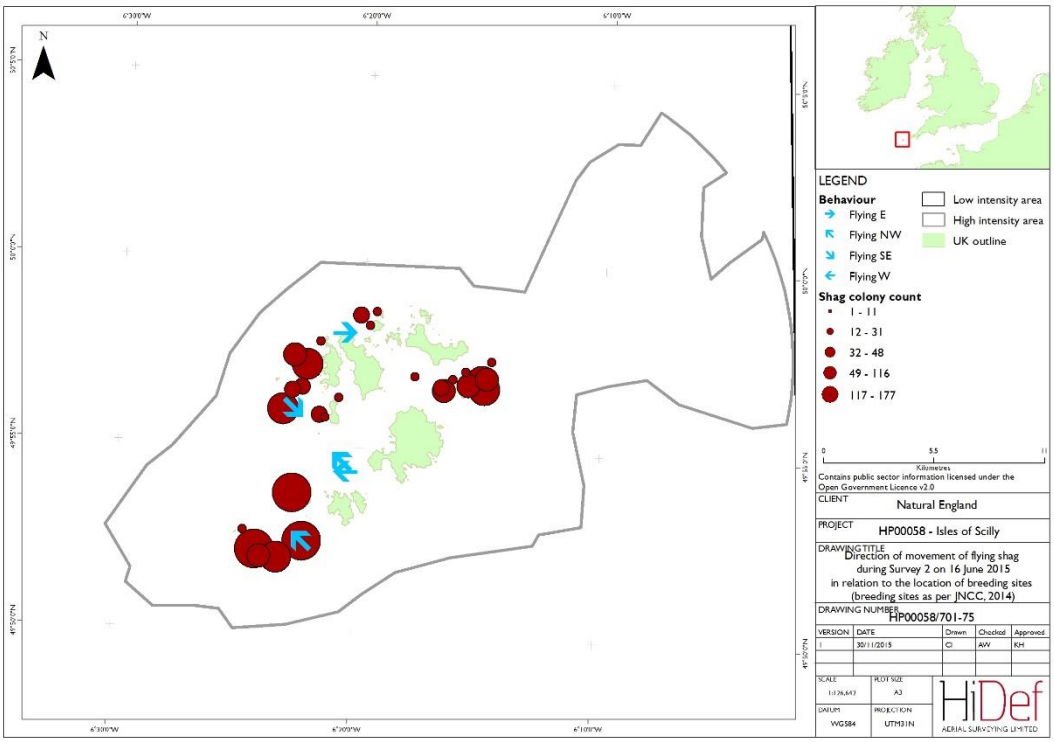
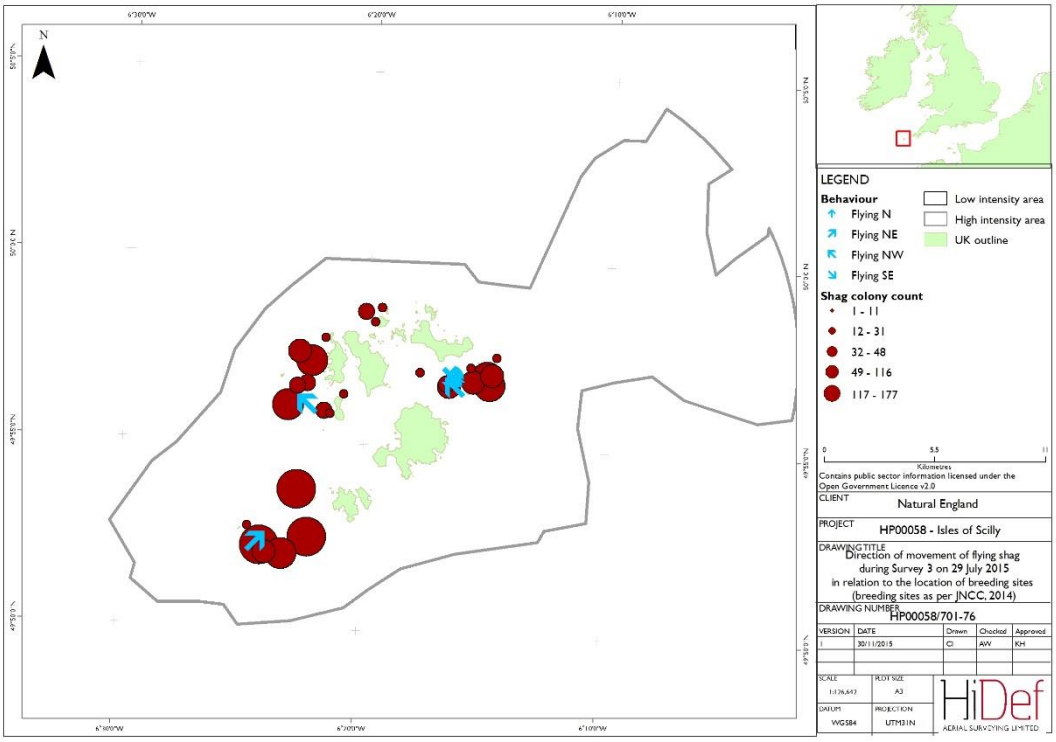


Figure 76 **Direction of movement of flying shag during Survey 3 on 29 July 2015 in relation to the location of breeding sites (breeding sites as per JNCC, 2014)**



3.6.2 Lesser black-backed gull

Figure 77 **Direction of movement of flying lesser black-backed gull during Survey 1 on 12 May 2015**

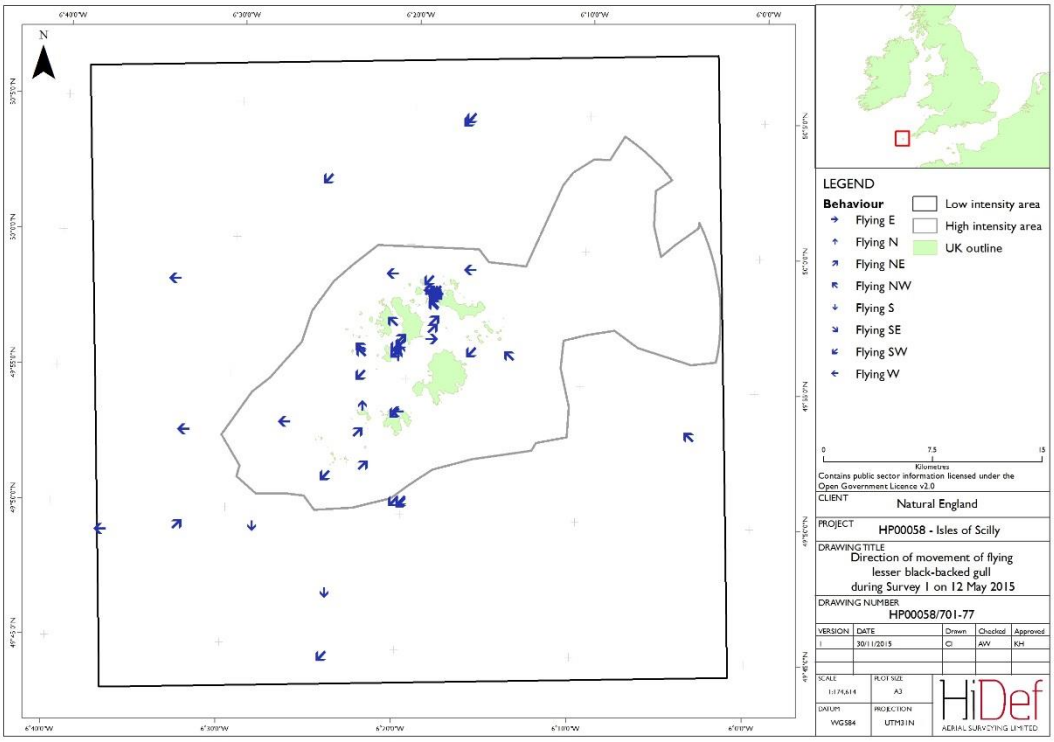


Figure 78 **Direction of movement of flying lesser black-backed gull during Survey 2 on 16 June 2015**

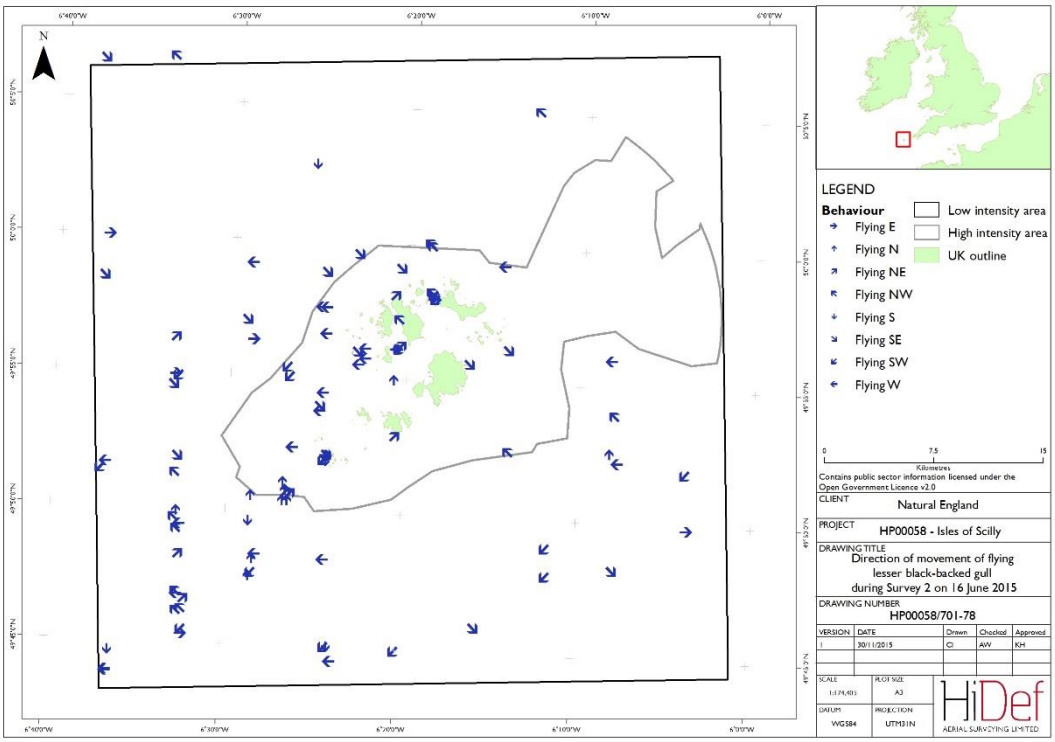
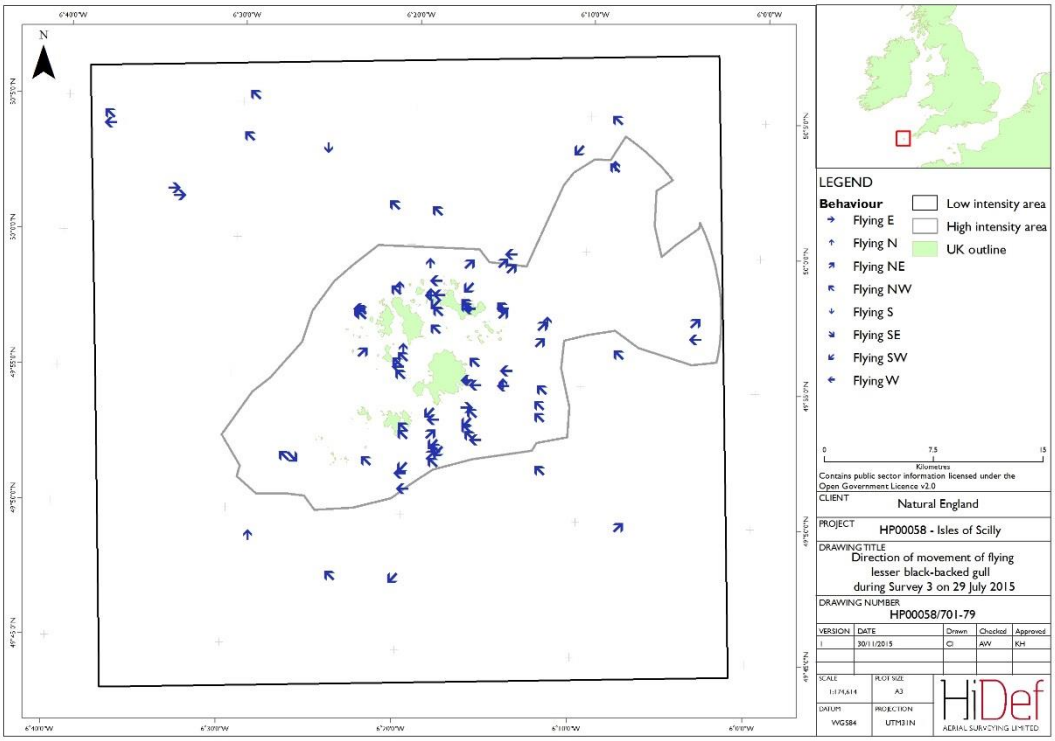


Figure 79 **Direction of movement of flying lesser black-backed gull during Survey 3 on 29 July 2015**



3.7 Availability bias

99 The estimated density and numbers of shag in Table 5 to Table 18 were multiplied by a scaling factor as outlined in section 3.6.5 in order to take account of availability bias in the detection of these species.

100 These figures are presented in Table 29 to Table 32. To calculate the availability bias for shag, the density estimates were divided by the percentage time spent underwater.

Table 29 **Adjusted density and population estimates for shags in the Isles of Scilly survey area between May and July 2015 taking into account the estimated number of birds that are estimated as being unavailable for detection**

Species	Non-adjusted abundance estimates						Adjusted abundance estimates for availability bias				
	Density estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance	CV	Density Estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance
Shag	0.70	295	86	648	161	54.38%	1.35	571	139	1299	333
Sitting shag	0.60	254	60	584	151	59.21%	1.28	541	129	1242	320
Flying shag	0.07	30	10	57	12	40.45%	0.07	30	10	57	12

Table 30 **Adjusted monthly density and population estimates for shags in the Isles of Scilly survey area during Survey 1 on 12 May 2015 taking into account the estimated number of birds that are estimated as being unavailable for detection**

Species	Non-adjusted abundance estimates						Adjusted abundance estimates for availability bias				
	Density estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance	CV	Density Estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance
Shag	0.54	230	96	377	73	31.63%	1.07	453	160	802	166
Sitting shag	0.47	198	75	337	67	33.69%	1.00	421	160	717	142
Flying shag	0.08	32	0	85	25	76.39%	0.08	32	0	85	25

Table 31 **Adjusted monthly density and population estimates for shags in the Isles of Scilly survey area during Survey 2 on 16 June 2015 taking into account the potential number of birds that are estimated as being unavailable for detection**

Species	Non-adjusted abundance estimates						Adjusted abundance estimates for availability bias				
	Density estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance	CV	Density Estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance
Shag	1.41	594	10	1561	456	76.78%	2.92	1234	21	3246	956
Sitting shag	1.34	567	10	1495	441	77.78%	2.86	1207	21	3181	939
Flying shag	0.06	27	0	66	17	62.78%	0.06	27	0	66	17

Table 32 **Adjusted monthly density and population estimates for shags in the Isles of Scilly survey area during Survey 3 on 29 July 2015 taking into account the potential number of birds that are estimated as being unavailable for detection**

Species	Non-adjusted abundance estimates						Adjusted abundance estimates for availability bias				
	Density estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance	CV	Density Estimate	Abundance estimate	Lower 95% confidence limit of abundance	Upper 95% confidence limit of abundance	Standard deviation of population abundance
Shag	0.18	76	15	151	34	45.46%	0.13	55	0	124	31
Sitting shag	0.03	11	0	25	7	61.97%	0.05	23	0	53	14
Flying shag	0.08	32	0	70	17	53.24%	0.08	32	0	70	17

4 Discussion

101 Three ultra-high resolution digital video aerial surveys were undertaken across the Isles of Scilly study area during May, June and July 2015.

102 These surveys were highly successful in detecting large numbers of birds and non-avian animals, with the majority of observations being within the high intensity study area, where the transect spacing was closest.

103 The two most abundant species recorded form part of the Isles of Scilly SPA assemblage: shag and lesser black-backed gull. Great black-backed gull, also a named feature of the SPA assemblage, was reasonably abundant.

104 One species not observed and which is a cited feature of the SPA, was European storm-petrel. This species would be expected to be present in offshore waters around the Isles of Scilly at low densities (e.g. Stone *et al.* 1996). It would therefore seem likely that, although the encounter rate should have been low in offshore waters, European storm-petrels were missed during these surveys. European storm-petrel is small and dark-plumaged and would therefore be difficult to detect, even when using cameras set to 2cm GSD. If considered important for future surveys, consideration should be given to using some or all cameras set to a higher resolution (e.g. 1 cm GSD) to improve the chances of detection. This can be achieved using HiDef's bespoke ultra high-resoltion camera rig, but would require a change in the survey design to ensure coverage of the same amount of sea area.

105 The estimated abundance of shag around the Isles of Scilly averaged 422 in all months (± 95% CI of 65 – 893) or 848 (± 95% CI of 123 – 1812) when corrected for availability bias. The estimated adjusted abundance varied widely between 667 in May to 1819 and 81 in June and July respectively, all with wide CI. The estimates should be compared to the most recent breeding population estimate for this species in the Isles of Scilly of 1296 apparently occupied sites (Heaney *et al.*, 2008) from a census in 2006. This should suggest a total population of approximately 4000, including both adults of the pair and non-breeding birds likely to be using feeding areas on the island. However, the majority of these birds would be on land at any one time, either at their nest site, or roosting.

106 The adjusted abundance estimates were lower overall in 2015 than in 2014 (Irwin, 2015) with 848 in all months in 2015 compared to 3290 for the same period in 2014. Abundance estimates for the study area were also lower in May 2015 (667) compared to May 2014 (7351) and again in July 2015 (81) compared to July 2014 (1361), but the reverse was true in June 2015 (1819) compared to June 2014 (1625). None of these differences were significant on account of the wide confidence intervals around these abundance estimates.

107 The wide CIs (and high CVs) makes it difficult to compare numbers observed at sea with expected numbers based upon the breeding population, and also the changes in abundance between the surveys. The main issue therefore is the very dense but infrequent aggregations recorded at sea, which makes it difficult to improve the precision of these abundance estimates other than by increasing the amount of sampling in the highest density areas.

108 One potential solution to the high CVs might be to use density surface modelling to build a model of shag distribution around the Isle of Scilly. Two co-variates could be used in the model: bathymetry and distance from the coast.

109 The prediction that shag would be found only in waters within 15km of their nest sites and in water depths of less than 70m held true in 2015, as it did in 2014; all records were within the high intensity study area. These limits were defined in the survey design based upon known maximum foraging depths (Wanless *et al.* 1991b) and likely maximum foraging range (Wanless *et al.* 1991a). On inspection, their foraging range and depth would appear to be even more restricted than the conservative limits set for the high intensity study area. As there is an energetic cost to nesting shags of flying further to feed and to diving deeper to find food (Wanless *et al.* 1997), it would seem logical that a feeding shag would not fly a long distance to find food in deep water, but would either fly far to feed in shallow water or feed close to the nest site in deeper water.

110 Shag sitting on the sea were found to occur mainly either singly or in a few very dense aggregations (mainly during the June survey). Only seven birds were recorded feeding, but it is likely that all birds sitting on the sea were feeding; shag was found to spend relatively little time when on the sea engaged in maintenance behaviour, the only likely alternative class of behaviours carried out at sea (McSorley *et al.* 2003) and this is likely to be because of the poor water-repellence properties of body and flight feathers in common with other members of the cormorant family (Rijke and Jesser, 2011). This limits the amount of time that can be spent on the sea, which instead is spent on land either at the nest or roosting on rocks. Consequently, flying shags are likely to be travelling only between feeding sites and roost or nest sites; individual observations might provide an insight to the location of feeding areas not detected by the aerial surveys.

111 The distribution maps using KDE for shag presented in this report showed a fairly coarse smoothing pattern which may not be sufficient by itself to use for determining the limits of foraging areas used by shags. The relationship between the feeding areas selected by shags and their habitats is likely to be more complex than that presented, which is based upon the simple relationship between neighbouring observations. A density surface model which used habitat parameters, such as distance from breeding site and sea depth would certainly provide a more accurate representation of shag feeding distribution. Similarly, more sampling between transects flown would also provide more detailed information.

112 The preferred method for finding a density threshold from density surface models such as this would be to find the point of maximum curvature in a plot of the population size captured compared to the size of area (O'Brien *et al.*, 2012).

113 Lesser black-backed gull tended to occur in highest densities close to likely nest sites. However, densities were also high further offshore, mainly to the south and west of the islands (as opposed to north and west in 2014). This pattern is consistent with the observations of Stone *et al.* (1992) who found that lesser black-backed gulls travelled long distances to the southwest of Skomer in Pembrokeshire, presumably to scavenge around trawlers. Camphuysen (2013) has also observed that this species is one of the most pelagic in the habitats it selects during the nesting season. The overall density of lesser black-backed gulls increased in 2015 compared to the density in 2014.

114 Great black-backed gull was recorded in highest densities close to the islands during May and June 2015, with some concentrations further offshore, but were virtually absent from around the islands in July, when many juvenile and adult birds were likely to have begun dispersal from the nesting areas. This pattern was also observed in 2014.

5 Recommendations for further surveys

115 While this survey has been highly successful in locating some of the main feeding areas used by shag around the Isles of Scilly, modifications to the design are recommended for future surveys.

116 The precision of abundance estimates for shag was poor and are largely a result of the very dense feeding concentrations that were encountered. The precision could be improved by increasing the number of transects in the highest density areas, perhaps at the expense of the large amount of sampling that was carried out further offshore in low density areas. At the least, sampling should be stratified between the high and low density areas.

117 In addition, the use of density surface modelling, with the use of co-variates, to provide a better depiction of the distribution of shags around the islands and potentially to reduce the CV values for the abundance estimates.

118 The main benefit of surveying the large box around the Isles of Scilly was that it highlighted that during the survey period in 2015 (as was the case in 2014), shag were not travelling large distances offshore to forage. A further benefit of the large survey area was that additional information was obtained for other component species for the SPA and also for blue shark, a species for which there is very little empirical data on relative distribution around the UK.

119 The survey transects in 2015 were identical to those flown in 2014. An alternative design suggested might be to offset transects between years or between months by a short distance for each survey so that a wider range of different habitats could be sampled. This approach has some merit for a species like shag which feeds at the sea bed, and thus its distribution is likely to relate well to different static habitat variables. To obtain maximum benefit from such an approach would also require that habitat co-variates were built into a density surface model for this species.

6 References

Borchers, D. L., Buckland, S. T., & Zucchini W. 2002. *Estimating Animal Abundance: Closed Populations.* Springer, Berlin.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. & Thomas, L. 2001. *Introduction to Distance Sampling*. OUP, Oxford

Buckland, S. T., Burt L. M., Rexstad E. A., Mellor M., Williams A. E. and Woodward R. 2012. Aerial surveys of seabirds: the advent of digital methods. *Journal of Applied Ecology* 49: 960–967.

Camphuysen, C. J., 2013. *A historical ecology of two closely related gull species (Laridae): multiple adaptations to a man-made environment.* Ph.D.-thesis, Univ. Groningen, Groningen.

Heaney, V., Lock, L., St Pierre, P. and Brown, A., 2008. Important Bird Areas: Breeding seabirds on the Isles of Scilly. *British Birds* 101: 418–438.

JNCC, 2014. Seabird Online Database (http://jncc.defra.gov.uk/smp/). Joint Nature Conservation Committee, Peterborough. Accessed 10 April 2014.

McSorley, C. A., Dean, B. J., Webb, A & Reid, J. B. (2003) Seabird use of waters adjacent to colonies Implications for seaward extensions to existing breeding seabird colony Special Protection Areas. JNCC Report No. 329

Mitchell, P. I., Newton, S. F., Ratcliffe, N. and Dunn, T. E., 2004. *Seabird populations of Britain and Ireland, results of the Seabird 2000 Census (1998–2002).* T & A D Poyser, London.

O'Brien, S. H., Webb, A., Brewer, M. J. & Reid, J. B. 2012. Use of kernel density estimation and maximum curvature to set Marine Protected Area boundaries: Identifying a Special Protection Area for wintering red-throated divers in the UK. *Biological Conservation* 156: 15–21.

Rijke, A. M. and Jesser, W. A., 2011. The Water Penetration and Repellency of Feathers Revisited. *The Condor* 113: 245-254. http://dx.doi.org/10.1525/cond.2011.100113

Simonoff J. S. 1996. *Smoothing Methods in Statistics*. Springer, London.

Stone, C. J., Webb, A. & Carter, I. C. 1992. Lesser black-backed gull distribution and food availability around trawlers in the Celtic Sea, 1991. Joint Nature Conservation Committee Report No. 106.

Stone C. J., Webb A., Barton C., Ratcliffe N., Reed T. C., Tasker M. L., Camphuysen C. J. & Pienkowski M. W. 1995. *An atlas of seabird distribution in north-west European waters.* JNCC, Peterborough.

Wanless, S., Bacon, P. J., Harris, M. P., Webb, A. D., Greenstreet, S. P. R., and Webb, A. 1997. Modelling environmental and energetic effects on feeding performance and distribution of shags (*Phalacrocorax aristotelis*): integrating telemetry, geographical information systems, and modelling techniques. *ICES Journal of Marine Science*, 54: 524–544.

Wanless S., Burger A. E. and Harris M. P. (1991b). Diving depths of Shags *Phalacrocorax aristotelis* breeding on the Isle of May. *Ibis* 133:37-42.

Wanless, S., Corfield, T., Harris, M. P., Buckland, S. T. and Morris, J. A. (1993) Diving behaviour of the shag *Phalacrocorax aristotelis* (Aves: Pelecaniformes) in relation to water depth and prey size. *Journal of Zoology* 231:11-25.

Wanless, S., Harris M. P., and Morris J. A. (1991a). Foraging range and feeding locations of shags *Phalacrocorax aristotelis* during chick rearing. *Ibis* 133:30-36.

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

Natural England publications are available as accessible pdfs from www.gov.uk/natural-england.

Should an alternative format of this publication be required, please contact our enquiries line for more information: 0300 060 3900 or email enquiries@naturalengland.org.uk.

ISBN 978-1-78354-750-0

Catalogue code: NECR356

NATURAL ENGLAND