Densities of qualifying species within Liverpool Bay/ Bae Lerpwl SPA: 2015 to 2020

First published June 2023

Natural England Commissioned Report NECR440

www.gov.uk/natural-england

NATURAL ENGLAND

About Natural England

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.

Further Information

This report can be downloaded from the Natural England Access to Evidence Catalogue. For information on Natural England publications or if you require an alternative format, please contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Copyright

Catalogue code: NECR440

ISBN: 978-1-78354-697-8

Report details

Author(s)

HiDef Aerial Surveying Limited

Natural England Project Manager

Aurelie Bohan-Rayson

Contractor

HiDef Aerial Surveying Limited

Keywords

Natural England Commissioned Report, Marine, Offshore Wind Farm, Conservation Advice, Special Protected Area.

Citation

HiDef Aerial Surveying Limited (2023). Densities of qualifying species within Liverpool Bay/ Bae Lerpwl SPA: 2015 to 2020. Natural England Commissioned Report 440, Natural England.

Contents

Figures

Tables

Executive summary

Extending from Morecambe Bay in northwest England to Anglesey in north Wales, the Liverpool Bay / Bae Lerpwl SPA was first designated in 2010 to protect non-breeding populations of red-throated diver (*Gavia stellata*), common scoter (*Melanitta nigra*) and a waterbird assemblage (Natural England, 2018). Red-throated diver is listed in Annex I of the European Union Birds Directive while common scoter is classed as a migratory species under the Directive (Stroud *et al.,* 2001). An extension in 2017 saw the seaward boundaries pushed north and west to include foraging areas for breeding little tern (*Sternula albifrons*), common tern (*Sterna hirundo*) and non-breeding little gulls (*Hydrocoloeus minutus*), with red-breasted merganser (*Mergus serrator*) and great cormorant (*Phalacrocorax carbo;* hereafter 'cormorant') added as the main components of the waterbird assemblage (Natural England, 2018).

Prior to designation and extension of the SPA, seabird data were collected within Liverpool Bay to assess the populations comprising the waterbird assemblage and red-throated diver, common scoter and little gull. Between 2001/02 and 2010/11, visual aerial survey data were collected by the Wildfowl and Wetland Trust (WWT) across eight winter seasons and analysed using distance sampling methods (Webb *et al.,* 2006; Lawson *et al.,* 2016; Natural England *et al.,* 2016).

Digital video aerial surveys were conducted between 2015 and 2020 by HiDef Aerial Surveying Ltd ('HiDef') and commissioned by DONG and Ørsted as part of their post-consent monitoring programme for Burbo Bank Extension offshore wind farm. In total, eight surveys were completed between January and March in 2015, 2018, 2019 and 2020, covering the original SPA boundary designated in 2010. The aim of this monitoring programme and report is to provide updated density and abundance estimates for red-throated diver, common scoter and the waterbird assemblage within the SPA. Estimates for other species, including little gull, red-breasted merganser, and cormorant were included in this report as components of the waterbird assemblage.

HiDef designed a survey that placed 2.75km-spaced transects across the SPA, which were undertaken using an aircraft equipped with four HiDef Gen II cameras with sensors set to a resolution of 2cm Ground Sample Distance (GSD). Each camera sampled a strip of 125m width, separated from the next camera by ~25m, to provide a combined sampled width of 500m within a 575m overall strip. Approximately 20% coverage of the SPA was achieved per survey.

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

Density and abundance estimates were calculated using strip transect analysis and kernel density estimation ('KDE') was used to create density surface maps.

The surveys recorded a total of 217,399 birds of 27 species within the Liverpool Bay SPA. A further 3,814 birds were recorded which were not assigned to a species. An identification rate to species level of 94.3% was achieved across the eight surveys.

The primary observations from the eight surveys of the SPA were:

- Over the survey period, population estimates calculated for the waterbird assemblage varied, ranging from 101,831 birds (95% CI 57,763 – 165,333) in March 2020 to 216,824 birds (95% CI 128,609 – 327,427) in February 2015, equating to densities of 59.99 birds/km^2 (95% CI 34.02 – 97.39) and 127.72 birds/km^2 (95% CI 75.76 – 192.87), respectively. Generally, most birds were observed across the SPA with higher densities tending to be recorded closer to the coast, especially in the north and southwest.
- Common scoters were the most abundant species recorded, with population estimates ranging between 78,797 birds (95% CI 35,298 – 142,596) in March 2020 and 202,224 birds (95% CI 116,262 – 309,045) in February 2015, equating to densities of 46.41 birds/km^2 (95% CI 20.79 – 84.00) and 119.12 birds/km^2 (95% CI 68.48 – 182.04), respectively.
- Population estimates of cormorants were variable, with peak estimates calculated in February 2015 at 3,180 birds (95% CI 416 – 8,068), equating to densities of 1.87 birds/km^2 (95% CI 0.25 – 4.75). The lowest abundances were recorded in March 2020 estimated at 234 birds (95% CI 146 – 337), equating to 0.14 birds/km2 (95%CI 0.09 – 0.20).
- Red-throated divers were one of the most abundant species recorded, with population estimates throughout the survey period ranging from 372 birds (95% CI 209 – 583) in January 2018 to 2,073 birds (95% CI 1,412 – 2,817) in March 2020, equating to densities of 0.22 birds/km^2 (95% CI 0.12 – 0.34) and 1.22 birds/km^2 (95% CI 0.83 – 1.66), respectively.
- Population estimates of little gull fluctuated, ranging from 0 birds (95% CI 0 – 0) in February 2015, January 2019 and February 2020, to 286 birds (95% CI 124 – 475) February 2019, equating to 0.17 birds/km^2 (95% CI 0.07 – 0.28).
- Red-breasted merganser population estimates ranged from 11 birds (95% CI 0 – 32) in February 2020 to 156 birds (95% CI 48 – 289) in February 2019, equating to densities of 0.01 birds/km^2 (95% CI 0.00 – 0.02) and 0.09 birds/km^2 (95% CI 0.03 – 0.17) respectively.

Updated abundance targets for the SPA, calculated from digital aerial surveys across four winter seasons between 2015 and 2020 will be used to inform Natural England, Natural Resources Wales and the Joint Nature Conservation Committee in adjusting the conservation objectives within the Joint Conservation Advice package.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Introduction

Bordering north Wales and northwest England, extending from Morecambe Bay to Anglesey, the Liverpool Bay / Bae Lerpwl SPA (hereafter 'Liverpool Bay SPA') was first designated in 2010 to protect non-breeding populations of red-throated diver (*Gavia stellata*), common scoter (*Melanitta nigra*) and a waterbird assemblage. The original waterbird assemblage included the non-breeding qualifying species as main components and several gull, auk and duck species, including, black-headed gull (*Chroicocephalus ridibundus*); common gull (*Larus canus*); great black-backed gull (*Larus marinus*); herring gull (*Larus argentatus*); lesser black-backed gull (*Larus fuscus*); kittiwake (*Rissa tridactyla*); guillemot (*Uria aalge*); razorbill (*Alca torda*); puffin (*Fratercula arctica*); common eider (*Somateria mollissima*); great crested grebe (*Podiceps cristatus*); fulmar (*Fulmarus glacialis*); gannet (*Morus bassanus*); great northern diver (*Gavia immer*); shag (*Phalacrocorax aristotelis*) and velvet scoter (*Melanitta fusca*; Natural England *et al.,* 2016).

An extension in 2017 saw the seaward boundaries pushed north and west to include areas used by non-breeding little gulls (*Hydrocoloeus minutus*), with red-breasted merganser (*Mergus serrator*) and great cormorant (*Phalacrocorax carbo;* hereafter 'cormorant') added as the main components of the waterbird assemblage, following recalculation of numbers of birds present.

Additional nearshore areas were also added to the west of The Dee Estuary SPA, along the north Wirral coast and in the Mersey Estuary to incorporate the foraging area of little terns (*Sternula albifrons*) and common terns (*Sterna hirundo*; Natural England *et al.,* 2016).

The Liverpool Bay SPA boundary is adjacent to multiple SPAs, including the Dee Estuary SPA (designated for multiple duck, wader and tern species), Mersey Narrows and North Wirral Foreshore SPA (designated for common tern, little gull, bar-tailed Godwit (*Limosa lapponica*) and knot (*Calidris canutus*)), and Ribble and Alt Estuaries SPA (designated for multiple duck, wader, gull, tern and waterfowl species; Natural England, 2014a; 2014b; 2014c, respectively).

Qualifying under Article 4.1 of the Birds Directive (2009/147/EC), the SPA supports over 1% of the Great British (GB) population of multiple Annex I species, including red-throated diver, little gull, little tern and common tern. It also qualifies under Article 4.2 of the Birds Directive (79/409/EC), supporting over 1% of the biogeographical population of migratory common scoter in addition to a waterbird assemblage of over 20,000 birds (Natural England, 2018). At the time of designation in 2010, red-throated diver and common scoter populations within the SPA were estimated at 922 individuals (5.4% of GB population) and 54,675 individuals (3.4% NW European population), respectively (Natural England, 2010; 2018). When the SPA was extended in 2017, the little gull population was estimated at 319 individuals (Natural England, 2017).

To assess population trends of species within the SPA, regular monitoring over the winter season was deemed necessary. Digital video aerial surveys were conducted by HiDef between January 2015 and March 2020 to assess the condition and management of the SPA, in addition to the effect of the Burbo Bank Offshore Wind Farm extension on the SPA.

This report only considers birds recorded within the *original* SPA boundary designated in 2010, with a focus on red-throated diver, common scoter, little gull, red-breasted merganser, cormorant and the waterbird assemblage. This report aims to provide up to date density estimates for red-throated diver, common scoter and the waterbird assemblage. Figures presented for additional species, in particular little gull, are not intended to be used to update current abundance figures, but are instead included as components of the waterbird assemblage. Since surveys cover only

the original SPA boundary, core areas for these species and key passage periods occurring outwith the winter survey season are likely to have been missed.

Prior to analysis, data collected between January 2015 and March 2020 were trimmed to the original SPA boundary, and observations and survey effort summarised. The overall survey area was calculated as 1,696km^2. Results are presented as density surface distribution maps and density and population estimates with 95% confidence intervals (CIs). A brief discussion is provided to discuss the representativeness of the results in relation to the SPA.

Methods

Survey flights

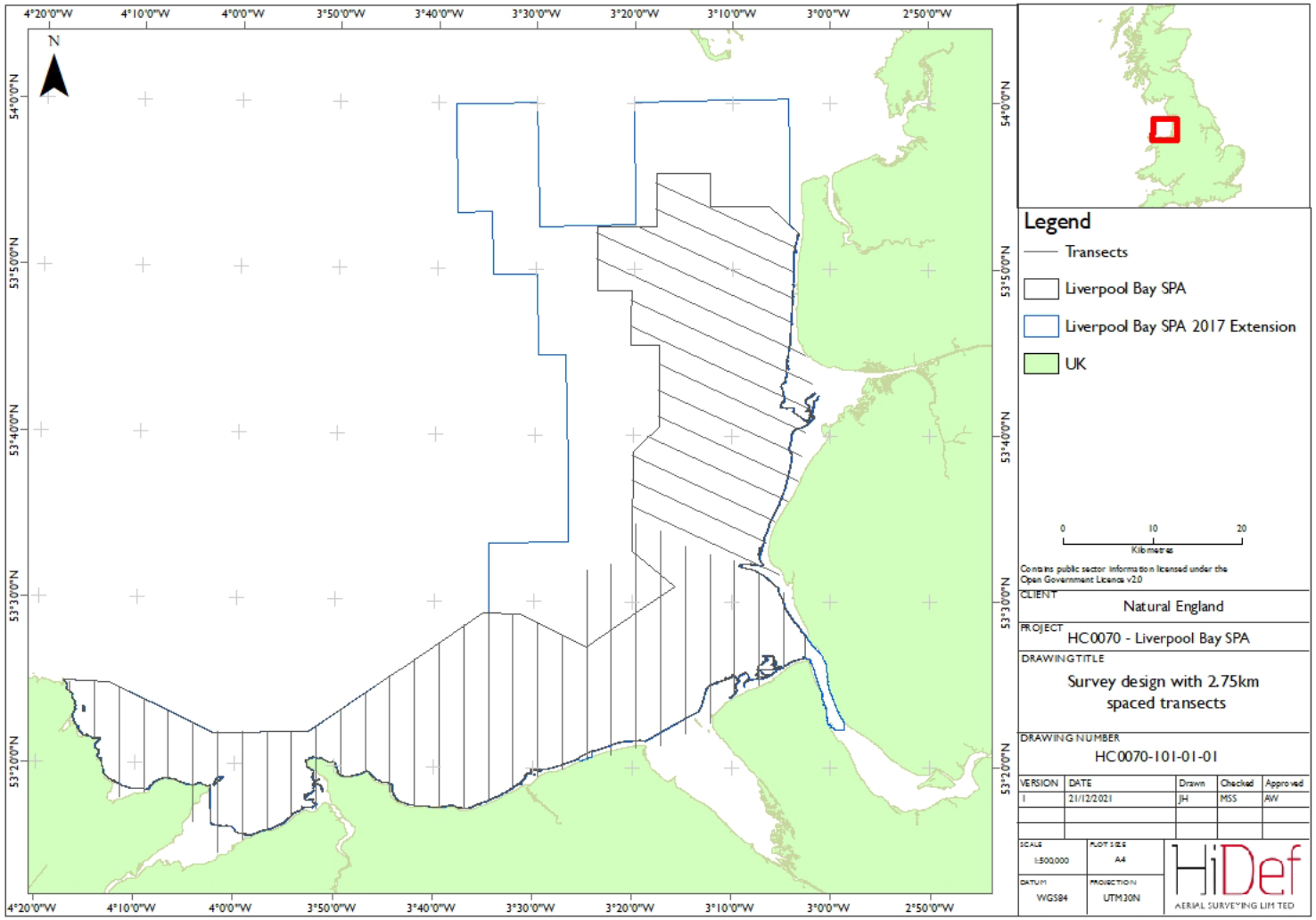
Digital video aerial surveys were carried out using HiDef's Gen II camera rig comprising four cameras with sensors set to a resolution of 2cm Ground Sample Distance ('GSD'), mounted in a low-emission Diamond Aviation DA42 Twinstar aircraft flying at a height of ~550m above sea level ('ASL') (1800 ft).

The chosen flight height is particularly important, as sensitive species are likely to exhibit responsive movement to aircraft flying at altitudes up to 365m ASL, which risks biasing abundance estimates. This flushing behaviour appears to be in response to visual and sound stimulus, with a key manner of determining flushing behaviour being where a high percentage of birds are observed to be taking off. Thaxter *et al.* (2016) recommends a flight altitude of 460-550m to ensure no risk of flushing species which have been proven to be easily disturbed by aircraft noise, such as red-throated diver and common scoter.

A series of strip transects were flown twice over each winter season between 2015 and 2020, with the amount of survey required determined by reworking analysis presented in Webb *et al.* (2014). A full explanation of the rationale for the survey is contained in the protocol. Transects were spaced 2.75 km apart and were aligned perpendicular to the coast, running north to south off the coast of Wales and Merseyside, and south-east to north-west off the coast of Lancashire (Figure 1).

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

Figure 1 Liverpool Bay SPA survey design with 2.75km spaced transects. Area flown for digital aerial surveys within original SPA boundary, 2017 extension in blue shown for reference



Data Review and Object Detection

Data were viewed by trained reviewers who marked any objects in the footage as requiring further analysis.

As part of HiDef's quality assurance (QA) process, an additional 'blind' review of 20% of the raw data was carried out and the results compared with those of the original review. If 90% agreement is not attained during the QA process, then corrective action is initiated: the remaining data set is reviewed and where appropriate, the failed reviewer's data discarded and all the data re-reviewed. In addition, additional training is then given to the reviewer to improve performance.

Objects are only recorded where they reach a reference line (known as 'the red line') which defines the true transect width of 125m for each camera. By excluding objects that do not cross the red line, biases to abundance estimates caused by flux (movement of objects in the video footage relative to the aircraft, such as where the survey craft is buffeted by airflow) are eliminated.

Object Identification

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

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

All objects were assigned to a species group and where possible, each of these then further identified to species level. The species identifications were given a confidence rating of 'possible', 'probable' or 'definite'[2].

It is important to note that these confidence ratings are not a standardised assessment. The likelihood of achieving a definite or probable identification is not consistent for all component members of a species group. For example, someone undertaking identification of a large auk species will find it easier to be confident of guillemot identification than razorbill. Confidence scores should not be used to filter or weight the probability of 'large auk' being one species or another in any analysis, as this will lead to biased results, particularly if the identification rate is low.

Any animals that could not be identified to species level were assigned to a category 'No ID'. If, on occasion, the unidentified bird is suspected of belonging to two possible genera, then a broader group category may be used. For example, a bird would usually be assigned to the group category 'Shearwater species' if identified as a Manx shearwater *Puffinus puffinus*, or to

---

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

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

‘Large Auk species’ if identified as a guillemot. However, if the bird has the potential to be either, then it would be assigned to a wider group category ‘Shearwater / Auk species’ and the species level recorded as ‘No ID’.

Final processing

All data were geo-referenced, taking into account the offset from the transect line of the cameras, and compiled into a single output; Geographical Information System (GIS) files for the Observation and Track data are issued in ArcGIS shapefile format, using UTM30N projection, WGS84 datum.

Data analysis

1.1.1 Data treatment

Raw count data were trimmed to the original SPA boundary prior to presentation in this report. After basic presentation, data were processed to estimate density, abundance and distribution of key species and species groups.

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

1.1.2 Abundance estimates

Each strip transect was treated as a statistically independent random sample from the site. The length and breadth (i.e. the width of the field of view of the camera) of each transect were multiplied together to give the transect area; dividing the number of observations for each species on each transect by the transect area gives a point estimate of the density of that species for the transect. The density of animals at the site (and hence the population size by multiplying by the area of the site), the standard deviation, the 95% confidence intervals (CIs) and coefficient of variance (CV) were then estimated using a non-parametric block bootstrap method with replacement (Buckland *et al.,* 2001), to ensure equal transect effort was sampled across each bootstrap iteration. This was done by using transect ID as the sampling unit with replacement. A group of transects were randomly sampled until their total length equalled approximately the same length as the total survey length.

A total of 1,000 bootstrap iterations were performed from which we calculated the mean and standard deviation of the sampled means, as well as the relative standard error (or CV) as defined by the standard deviation divided by the mean. Data were processed in the R programming language (version 4.1.1) and code can be provided on request.

The density estimate is expressed as the average number of animals per square km in the whole survey area. The population estimate is expressed as the estimated number of animals within the whole survey area. The upper and lower CIs define the range that the population estimate falls within with 95% certainty. The CV is a measure of the precision of the population and density estimates.

1.1.3 Density mapping

Density maps were created to display the distribution of red-throated diver, common scoter, little gull and the waterbird assemblage. Maps were 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 within the SPA. 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.

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

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

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

It should be noted that some of the KDE maps are effectively flat (i.e., they appear the same colour throughout the study area). These correspond to distributions where the density surface as obtained from a small local kernel was not effective at predicting missing data; this can happen with evenly distributed birds, but mainly happens for very sparse distributions. In the case of sparse distributions, the ‘flat’ map does not necessarily mean that the true underlying distribution is ‘flat’; it could mean that the data doesn’t contain enough evidence to determine what the underlying distribution is. It is therefore useful to refer back to the population estimates for the corresponding map when looking at these ‘flat’ densities; we have also overlaid the relevant observations as dots to help with interpretation of the maps. In extreme cases, kernel density maps were not included in the results section, and the data were only presented as dot maps.

Results

Survey effort

The date, number of transects and survey effort (i.e., length of transects) undertaken between January 2015 and March 2020 are shown in Table 1. The number of transects and the total length of transects are those used in subsequent analyses (see Figure 2 and Figure 3 for the aircraft flight pattern). Variation in presentation of track data is due to differing GPS equipment used in some surveys.

Transect lines flown were the same for each survey; however, effort differed slightly due to slight differences in start and stop times and minor deviations of the aircraft from the transect line.

Table 1 Survey effort across the Liverpool Bay SPA between January 2015 and March 2020

Survey date	Survey Number	Number of transects analysed	Total length of transects analysed (km)	Area Covered (km^2)	Area Covered (%)
24 January 2015	1	44	702.44	351.22	20.7
04 February 2015	2	44	725.19	362.60	21.4
22 January 2018	3	44	705.14	352.57	20.8
23 February 2018	4	44	706.53	353.26	20.8
09 January 2019	5	44	718.93	359.46	21.2
22 February 2019	6	45	705.51	352.83	20.8
07 February 2020	7	45	719.70	359.85	21.2
05 March 2020	8	44	704.84	352.42	20.8

Figure 2 Flight pattern for surveys flown between January 2015 and February 2018

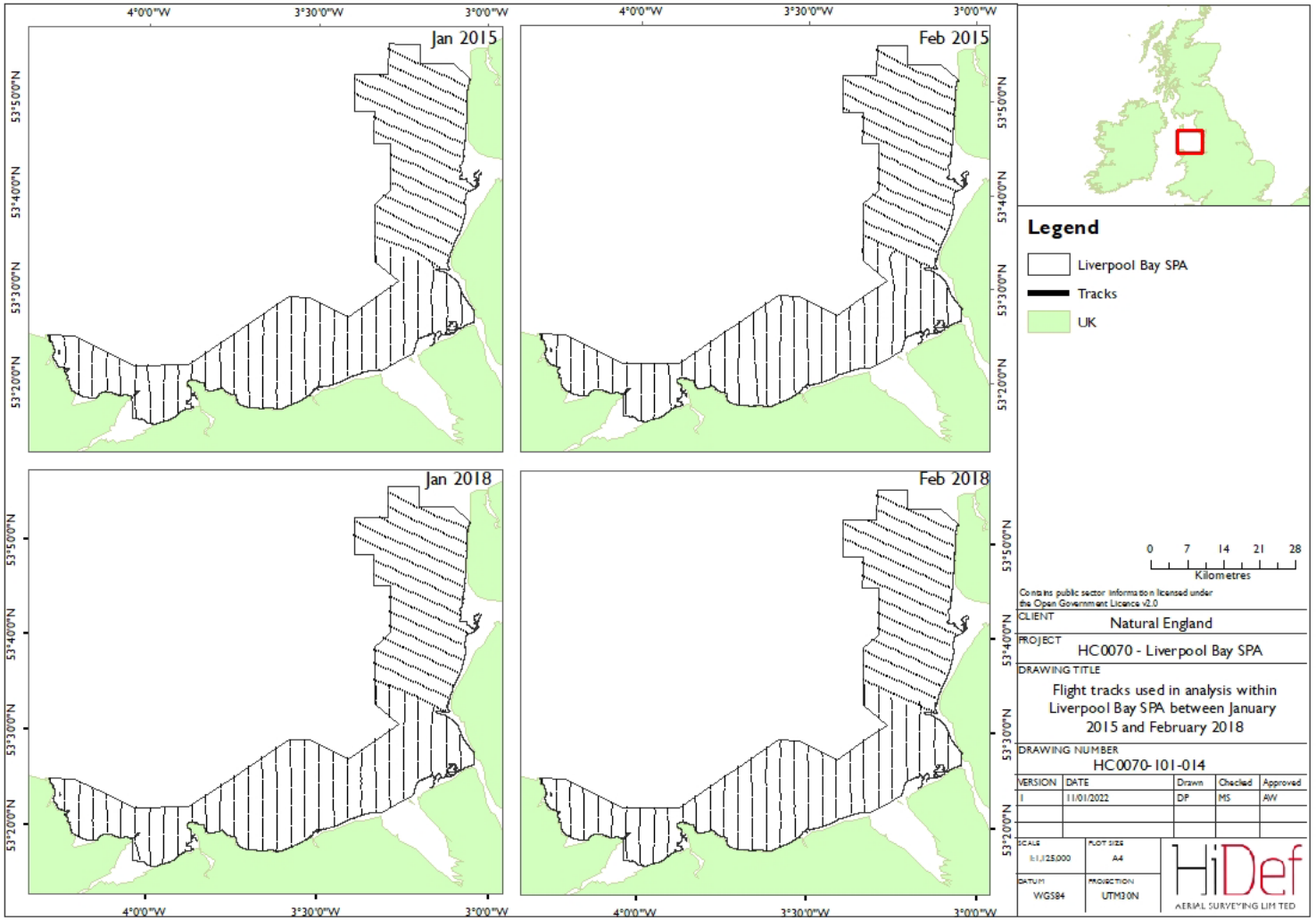
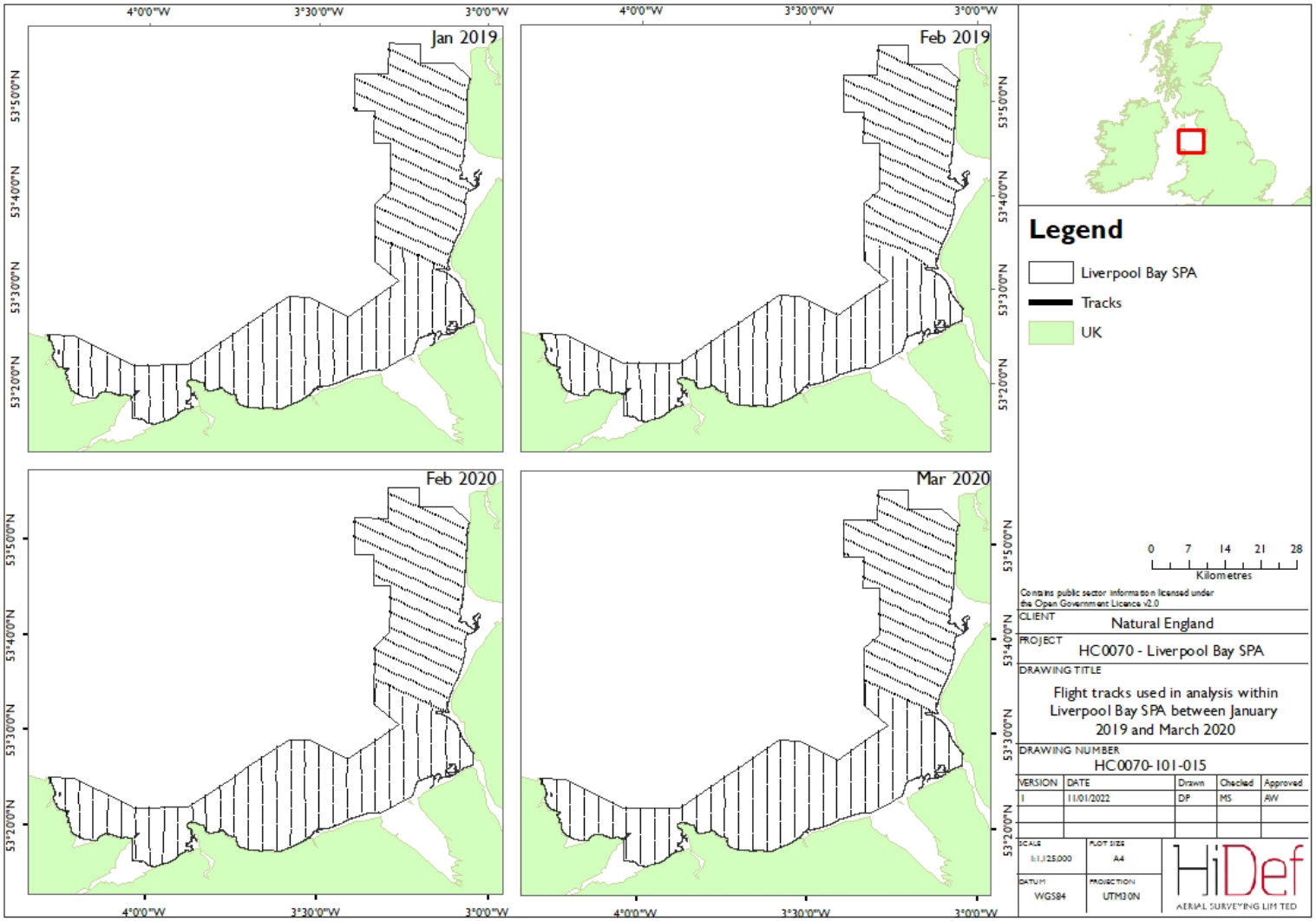


Figure 3 Flight pattern for surveys flown between January 2019 and March 2020



Survey results

Each bird 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 birds that could not be identified to species level were assigned to a category 'No ID' in the species column. The analysis of data to species level uses all levels of identification confidence. The overall identification rate of birds to species level (not including 'No ID's) for the eight surveys are given in Table 2.

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 Table 4.

Table 2 Liverpool Bay SPA identification rates between January 2015 and March 2020

Survey date	ID rate (%)
24 January 2015	98.8
04 February 2015	99.1
22 January 2018	97.8
23 February 2018	97.0
09 January 2019	80.9
22 February 2019	91.6
07 February 2020	94.8
05 March 2020	94.0
Average	**94.3**

Table 3 Number of objects detected per survey assigned to species level in the Liverpool Bay SPA between January 2015 and March 2020. Survey dates presented in Table 1.

Species	Scientific Name	Jan 2015	Feb 2015	Jan 2018	Feb 2018	Jan 2019	Feb 2019	Feb 2020	Mar 2020
Wigeon	*Mareca penelope*	0	0	0	0	0	202	0	0
Eider	*Somateria mollissima*	7	34	1	11	0	11	3	15
Velvet scoter	*Melanitta fusca*	1	1	0	0	0	1	0	2
Common scoter	*Melanitta nigra*	34873	38575	18840	27940	21400	21479	18098	14665
Long-tailed duck	*Clangula hyemalis*	0	0	0	0	0	0	0	2
Goldeneye	*Bucephala clangula*	1	2	0	0	0	0	0	0
Red-breasted merganser	*Mergus serrator*	15	13	3	9	5	29	2	18
Great crested grebe	*Podiceps cristatus*	12	77	0	45	68	253	62	44
Slavonian grebe	*Podiceps auritus*	0	0	0	0	0	0	0	5
Kittiwake	*Rissa tridactyla*	237	1	47	8	44	101	18	65
Black-headed gull	*Chroicocephalus ridibundus*	3	11	7	23	35	97	45	46
Little gull	*Hydrocoloeus minutus*	49	0	27	10	0	53	0	1
Common gull	*Larus canus*	246	762	145	68	805	554	248	445
Great black-backed gull	*Larus marinus*	54	83	50	44	88	32	35	44
Herring gull	*Larus argentatus*	159	101	53	280	174	527	629	763
Lesser black-backed gull	*Larus fuscus*	2	5	0	3	3	25	7	56

Species	Scientific Name	Jan 2015	Feb 2015	Jan 2018	Feb 2018	Jan 2019	Feb 2019	Feb 2020	Mar 2020
Guillemot	*Uria aalge*	1626	667	173	561	2018	966	980	1045
Razorbill	*Alca torda*	215	23	49	33	55	145	82	348
Black guillemot	*Cepphus grylle*	0	0	0	0	0	0	0	9
Puffin	*Fratercula arctica*	1	0	0	0	0	0	0	9
Red-throated diver	*Gavia stellata*	253	284	69	302	382	238	204	383
Black-throated diver	*Gavia arctica*	0	0	0	0	0	1	0	0
Great northern diver	*Gavia immer*	0	0	0	2	0	0	1	3
Fulmar	*Fulmarus glacialis*	15	2	7	0	3	4	7	7
Gannet	*Morus bassanus*	1	0	0	0	0	0	0	0
Shag	*Phalacrocorax aristotelis*	2	40	0	11	1	31	35	47
Cormorant	*Phalacrocorax carbo*	302	593	232	179	217	204	46	44
Total		**38074**	**41274**	**19703**	**29529**	**25298**	**24953**	**20502**	**18066**

Table 4 **Number of objects with no species ID detected per survey assigned to species groups in the Liverpool Bay SPA between January 2015 and March 2020. Survey dates presented in Table 1.**

Species group (No ID)	Jan 2015	Feb 2015	Jan 2018	Feb 2018	Jan 2019	Feb 2019	Feb 2020	Mar 2020
Duck species	2	4	15	1	7	12	3	3
Grebe species	0	0	0	0	1	22	0	1
Small gull species	19	17	19	14	100	97	172	39
Black-backed gull species	0	0	0	3	1	2	2	0
Large gull species	4	5	4	29	7	4	26	19
Gull species	63	14	32	120	167	90	307	75
Skua excluding great	0	0	0	0	0	0	0	1
Large auk	181	28	108	177	186	226	107	302
Small auk	0	0	0	0	0	0	2	3
Auk species	59	18	9	27	16	7	60	36
Auk / small gull	18	3	1	10	41	18	33	17
Large auk / diver species	57	10	3	25	20	24	20	8
Diver species	0	0	0	0	0	0	4	4
Fulmar / gull species	9	0	0	0	7	0	12	5
Cormorant / shag	9	6	10	18	11	11	11	8
Small bird	0	0	0	0	225	47	22	12
Total	**421**	**105**	**201**	**424**	**789**	**560**	**781**	**533**

Distribution patterns and seasonal abundance

Density estimates calculated for the Liverpool Bay SPA, as well as 95% confidence intervals, are presented for red-throated diver, common scoter, little gull, red-breasted merganser, cormorant and the waterbird assemblage. Density and population estimates for all species and species groups, as well as measures of standard deviation, confidence intervals (CIs) and CVs, are presented in Appendix 1. An explanation of these parameters is presented in Table 5.

Distribution patterns are presented as density maps, in which a density surface depicts the estimated number of individuals per km².

Table 5 Terms used in abundance analysis

Term	Definition
Density estimate *(animals/km^2)*	The average number of animals per square km surveyed over the survey area
Population estimate *(number)*	The mean number of animals estimated within the survey area
95% confidence intervals or 'limits' of population *(CI)*	A measure of uncertainty in the mean value. If the analysis was repeated, 95% of the time the mean population estimate would fall within this upper and lower boundary. The smaller the CI range the more confident we can be that the mean estimate is an accurate reflection of the true population size.
Standard deviation *(SD)* of population estimate	The amount of variation or dispersion of a set of values. A low SD indicates that the bootstrap values tend to be close to the mean of the set.
CV (%)	The coefficient of variation is a standard measure that describes the dispersion of data points around the mean. The lower the CV the more precise the estimate. It is calculated as the SD / mean.

1.1.4 Abundance estimates within the SPA

Table 6 Abundance and density estimates of the waterbird assemblage in the Liverpool Bay SPA between January 2015 and March 2020

Survey	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
24 January 2015	124.04	64.14	198.16	210571	108890	336403	58807	27.93
04 February 2015	127.72	75.76	192.87	216824	128609	327427	50283	23.19
22 January 2018	63.18	30.13	105.76	107255	51144	179524	33576	31.30
23 February 2018	96.00	47.94	153.22	162977	81375	260118	46464	28.51
09 January 2019	81.61	55.37	110.8	138478	94006	187891	24283	17.53
22 February 2019	81.45	50.71	118.29	138273	86088	200816	29913	21.63
07 February 2020	66.91	37.92	104.90	113527	64373	177890	29353	25.84
05 March 2020	59.99	34.02	97.39	101831	57763	165333	28148	27.64

Table 7 Abundance and density estimates of common scoter in the Liverpool Bay SPA between January 2015 and March 2020

Survey	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
24 January 2015	111.05	50.75	185.07	188527	86163	314186	58662	31.12
04 February 2015	119.12	68.48	182.04	202224	116262	309045	49899	24.68
22 January 2018	59.76	26.77	102.77	101454	45453	174476	33704	33.22
23 February 2018	89.79	40.09	149.57	152437	68060	253918	47327	31.05
09 January 2019	66.58	41.10	94.30	113028	69770	160097	22960	20.31
22 February 2019	68.69	38.22	104.93	116611	64893	178138	29431	25.24
07 February 2020	56.51	29.18	93.79	95931	49541	159232	28084	29.27
05 March 2020	46.41	20.79	84.00	78797	35298	142596	27742	35.21

Table 8 Abundance and density estimates of red-throated diver in the Liverpool Bay SPA between January 2015 and March 2020

Survey	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
24 January 2015	0.82	0.60	1.07	1394	1012	1815	205	14.69
04 February 2015	0.88	0.51	1.33	1500	865	2255	355	23.64
22 January 2018	0.22	0.12	0.34	372	209	583	97	26.01
23 February 2018	0.95	0.66	1.27	1612	1125	2157	267	16.52
09 January 2019	1.19	0.77	1.72	2016	1315	2914	417	20.66
22 February 2019	0.76	0.50	1.07	1295	851	1820	247	19.02
07 February 2020	0.64	0.37	0.95	1084	623	1612	258	23.81
05 March 2020	1.22	0.83	1.66	2073	1412	2817	360	17.36

Table 9 Abundance and density estimates of cormorant in the Liverpool Bay SPA between January 2015 and March 2020

Survey	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
24 January 2015	0.97	0.42	1.66	1647	715	2826	552	33.47
04 February 2015	1.87	0.25	4.75	3180	419	8068	2321	72.99
22 January 2018	0.74	0.29	1.31	1251	496	2222	456	36.41
23 February 2018	0.55	0.21	1.03	933	355	1757	385	41.28
09 January 2019	0.68	0.32	1.17	1147	537	1995	379	32.99
22 February 2019	0.65	0.32	1.05	1098	540	1791	330	30.04
07 February 2020	0.15	0.08	0.23	249	132	387	65	26.09
05 March 2020	0.14	0.09	0.20	234	146	337	49	20.89

Table 10 Abundance and density estimates of red-breasted merganser in the Liverpool Bay SPA between January 2015 and March 2020

Survey	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
24 January 2015	0.05	0.01	0.09	82	22	147	32	38.78
04 February 2015	0.04	0.01	0.08	69	21	129	28	39.66
22 January 2018	0.01	0.00	0.03	17	0	49	16	95.60
23 February 2018	0.03	0.00	0.06	49	6	106	27	53.86
09 January 2019	0.02	0.00	0.04	27	0	68	19	69.76
22 February 2019	0.09	0.03	0.17	156	48	289	63	40.14
07 February 2020	0.01	0.00	0.02	11	0	32	11	96.70
05 March 2020	0.06	0.02	0.12	98	27	207	49	50.12

Table 11 Abundance and density estimates of little gull in the Liverpool Bay SPA between January 2015 and March 2020

Survey	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
24 January 2015	0.16	0.03	0.35	265	53	596	147	55.53
04 February 2015	0.00	0.00	0.00	0	0	0	0	0.00
22 January 2018	0.12	0.04	0.23	212	64	399	88	41.20
23 February 2018	0.03	0.01	0.07	54	11	112	26	47.30
09 January 2019	0.00	0.00	0.00	0	0	0	0	0.00
22 February 2019	0.17	0.07	0.28	286	124	475	90	31.29
07 February 2020	0.00	0.00	0.00	0	0	0	0	0.00
05 March 2020	0.00	0.00	0.01	6	0	17	6	98.63

1.1.5 Four-year peak means

Table 12 **Four-year peak density and population estimates of the waterbird assemblage, red-throated diver and common scoter in the Liverpool Bay SPA**

Year	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Waterbird assemblage								
2015	127.72	75.76	192.87	216824	128609	327427	50283	23.19
2018	96.00	47.94	153.22	162977	81375	260118	46464	28.51
2019	81.61	55.37	110.8	138478	94006	187891	24283	17.53
2020	66.91	37.92	104.9	113527	64373	177890	29353	25.84
Red-throated diver								
2015	0.88	0.51	1.33	1500	865	2255	355	23.64
2018	0.95	0.66	1.27	1612	1125	2157	267	16.52
2019	1.19	0.77	1.72	2016	1315	2914	417	20.66
2020	1.22	0.83	1.66	2073	1412	2817	360	17.36
Common scoter								
2015	119.12	68.48	182.04	202224	116262	309045	49899	24.68
2018	89.79	40.09	149.57	152437	68060	253918	47327	31.05
2019	68.69	38.22	104.93	116611	64893	178138	29431	25.24
2020	56.51	29.18	93.79	95931	49541	159232	28084	29.27

Table 13 **Four-year peak mean density and population estimates of the waterbird assemblage, red-throated diver and common scoter in the Liverpool Bay SPA**

Species	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Standard deviation of density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Waterbird assemblage	93.06	51.72	134.40	25.98	157952	87721	228182	44136	27.92
Red-throated diver	1.06	0.79	1.33	0.17	1800	2256	1344	287	16.07
Common scoter	83.53	39.89	127.16	27.42	141801	67718	215883	46557	32.83

1.1.6 Distributions within the SPA

Figure 4 Density of the waterbird assemblage (number/km²) and number of detections per segment between January 2015 and February 2018

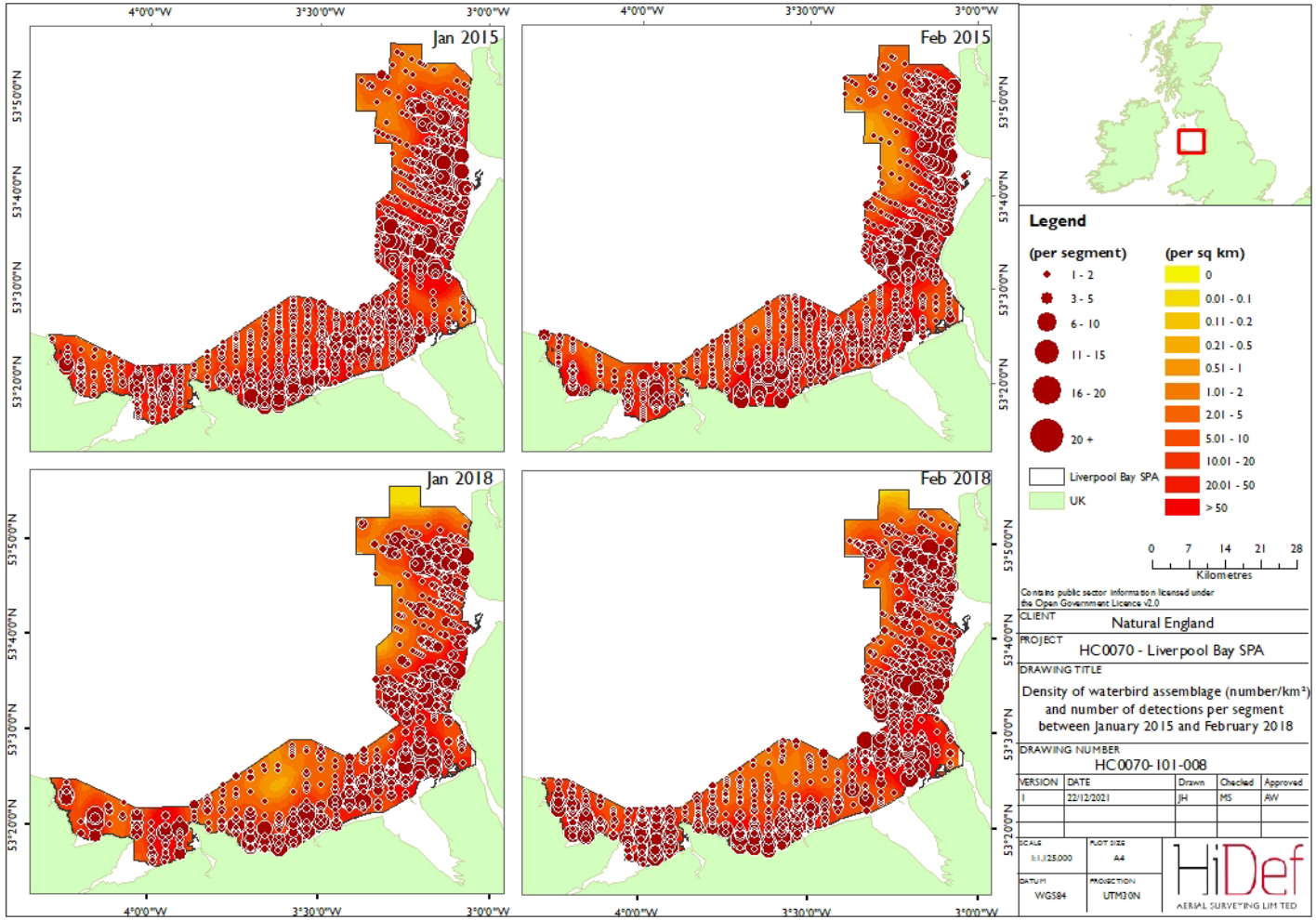


Figure 5 Density of the waterbird assemblage (number/km²) and number of detections per segment between January 2019 and March 2020

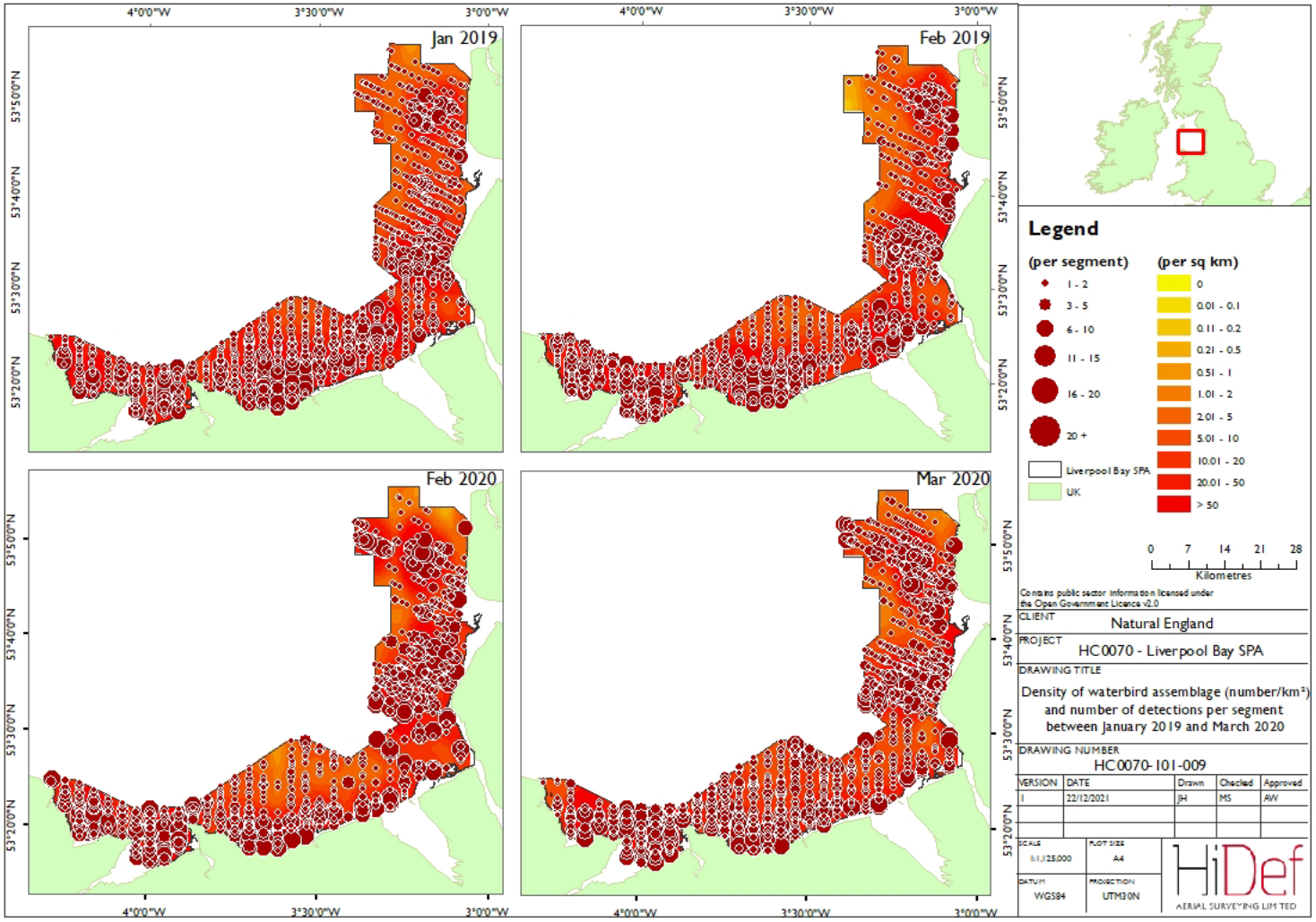


Figure 6 Density of common scoter (number/km²) and number of detections per segment between January 2015 and February 2018

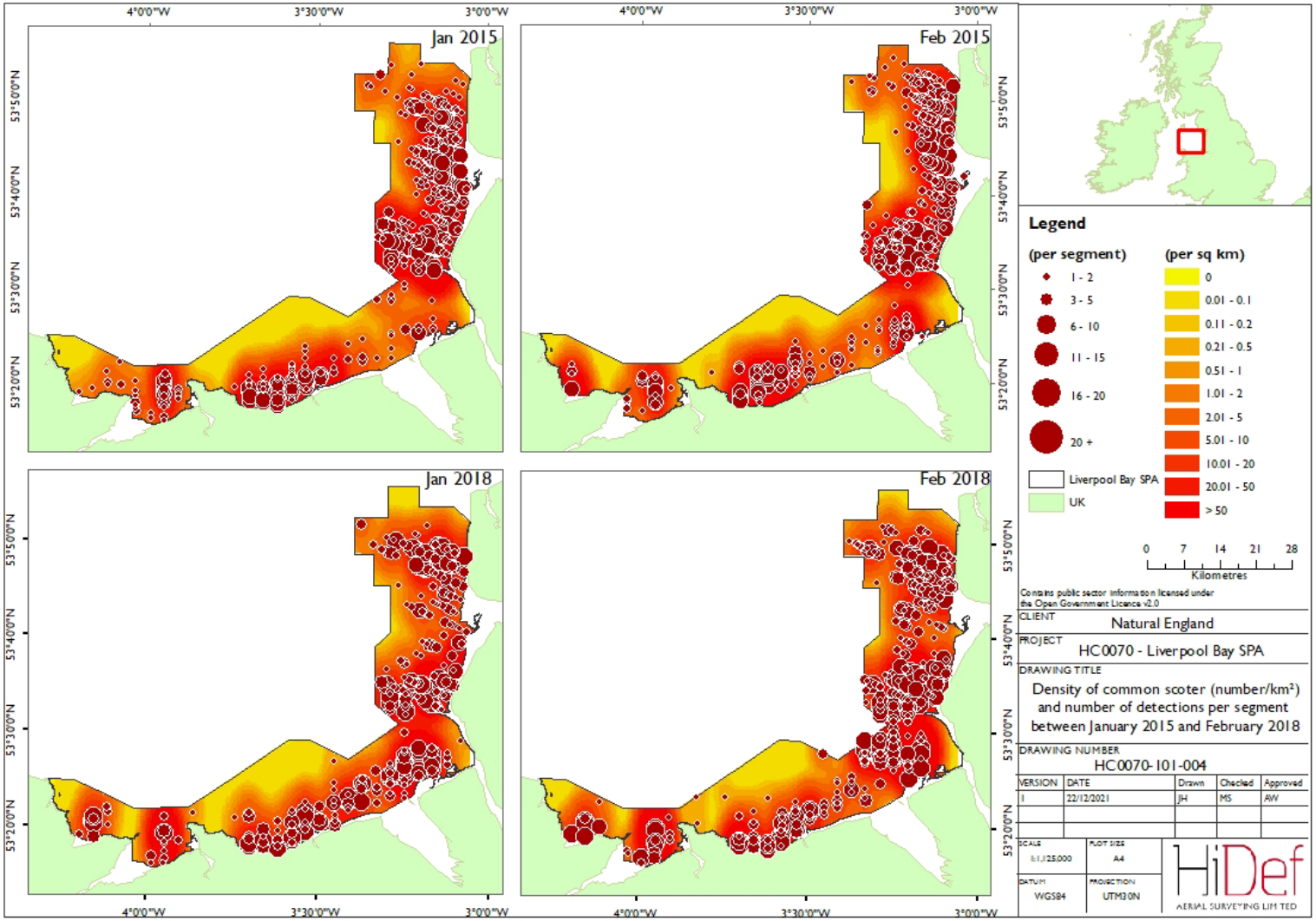


Figure 7 Density of common scoter (number/km²) and number of detections per segment between January 2019 and March 2020

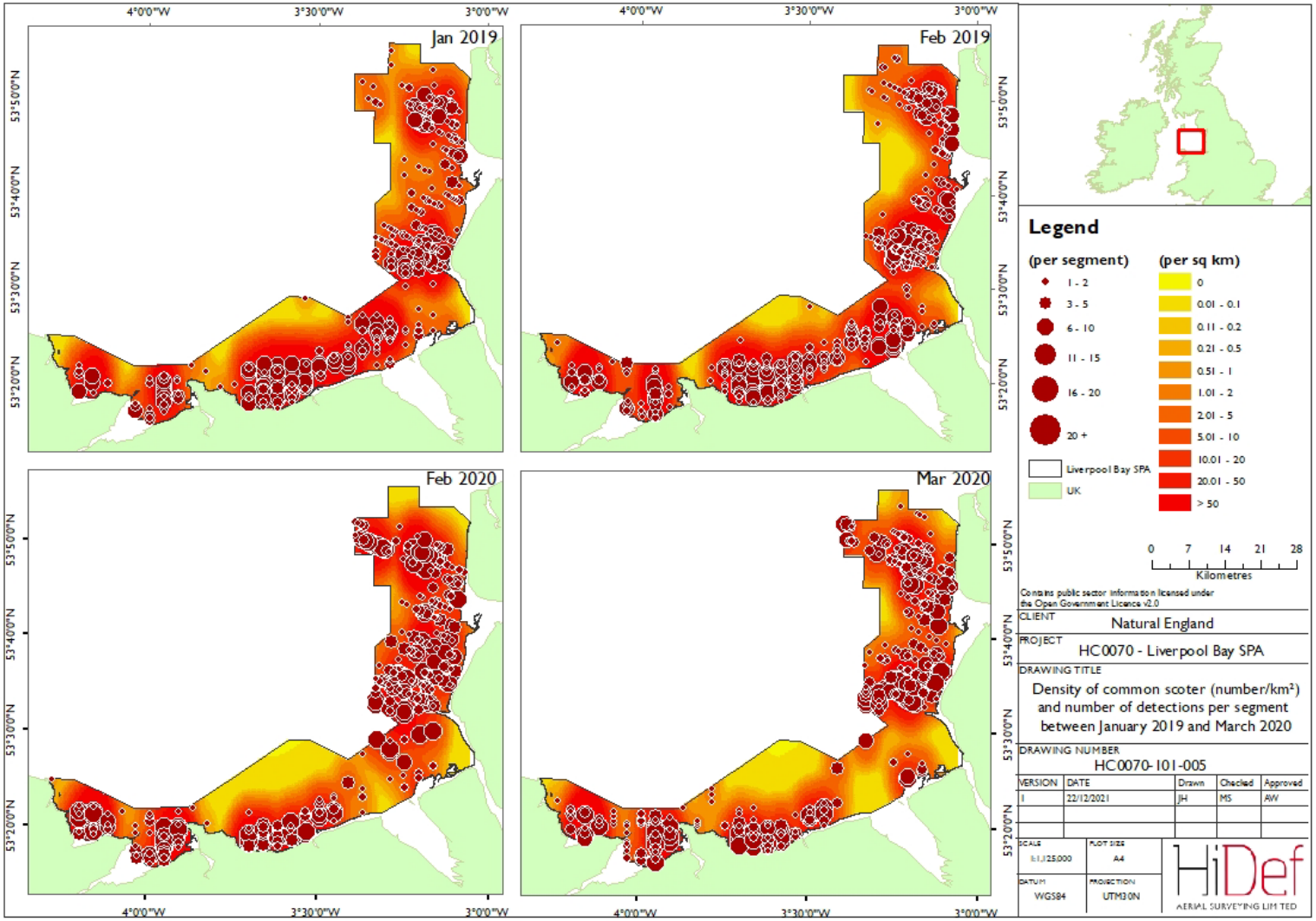


Figure 8 Density of red-throated diver (number/km²) and number of detections per segment between January 2015 and February 2018

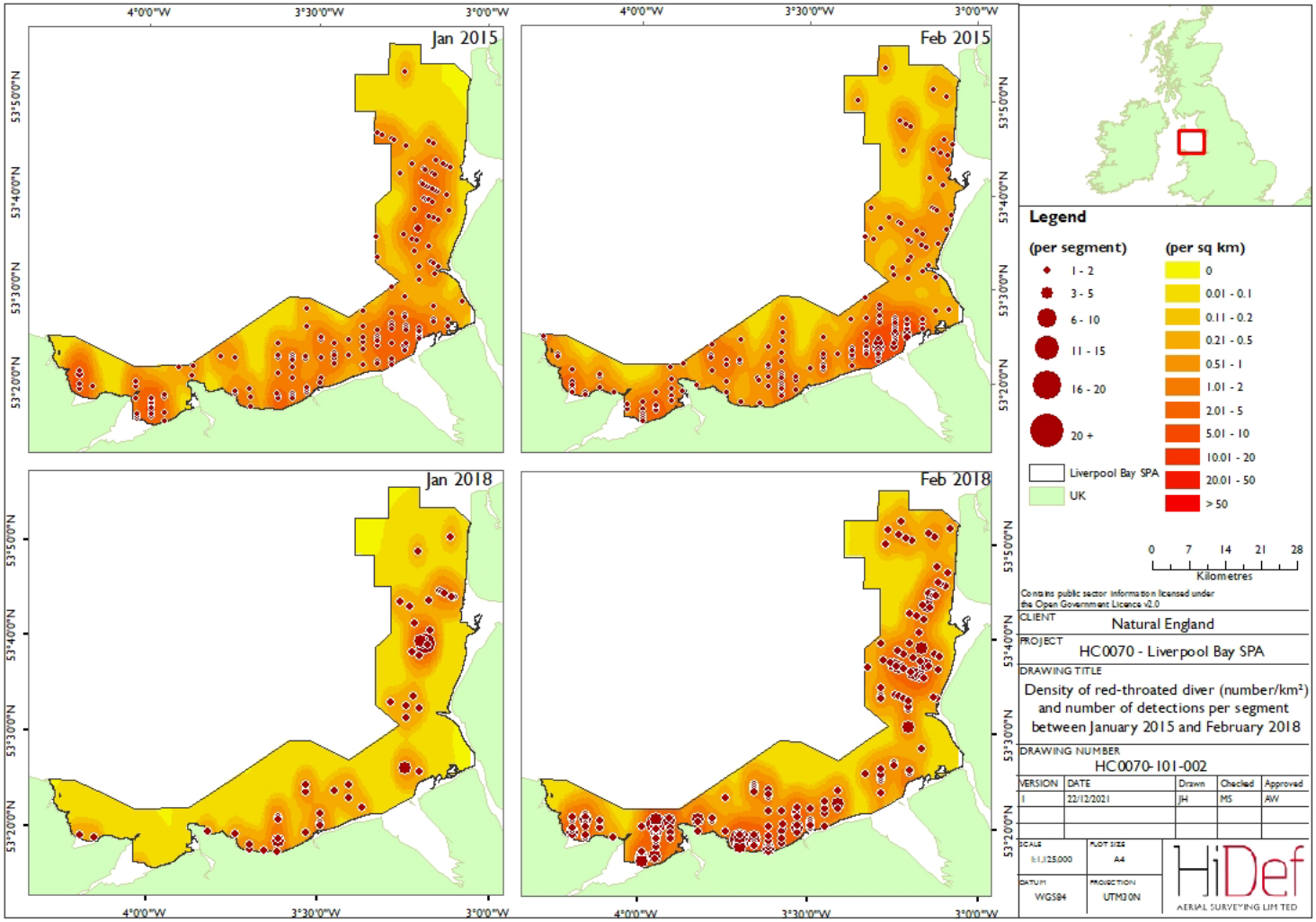


Figure 9 Density of red-throated diver (number/km²) and number of detections per segment between January 2019 and March 2020

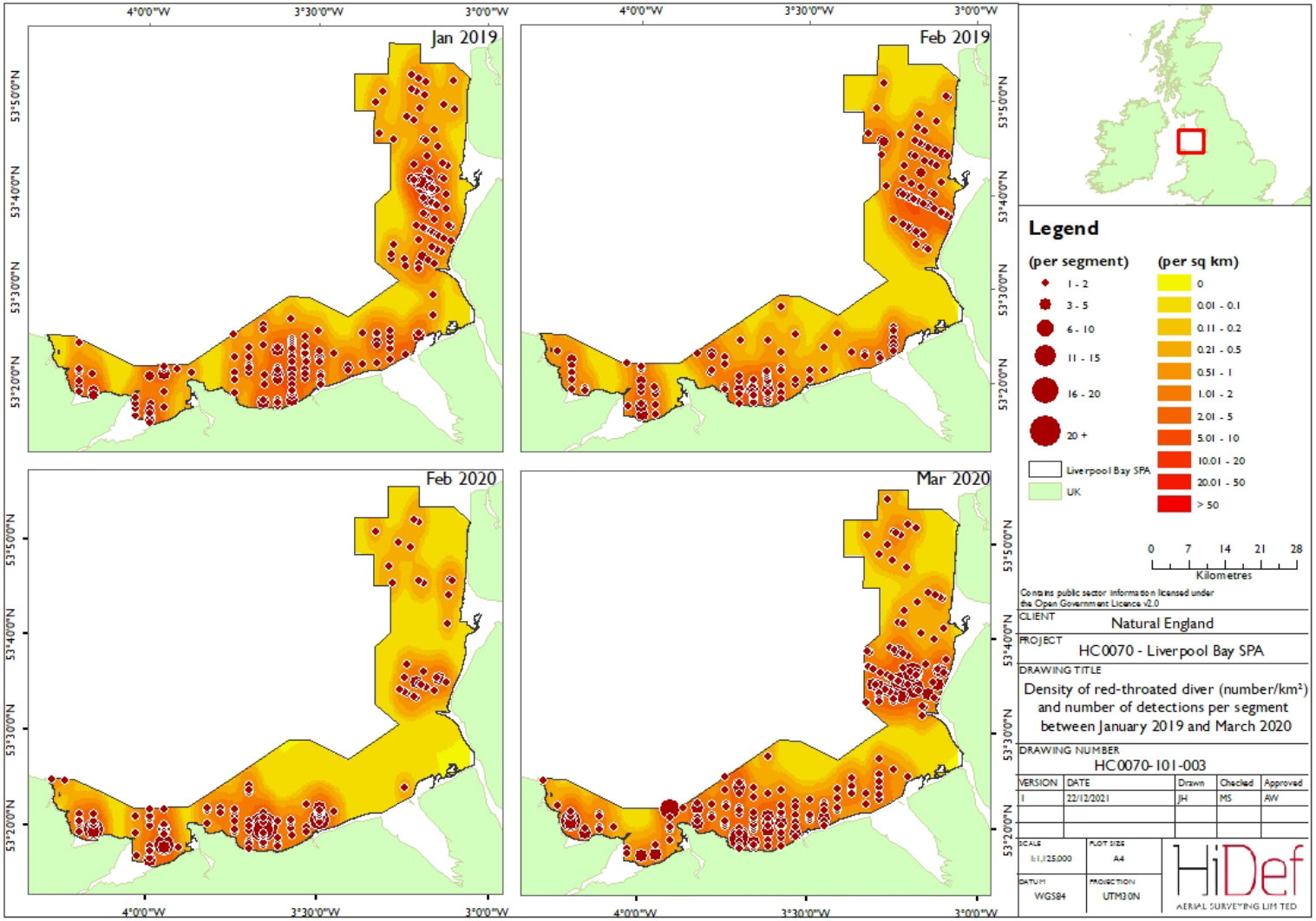


Figure 10 Density of cormorant (number/km²) and number of detections per segment between January 2015 and February 2018

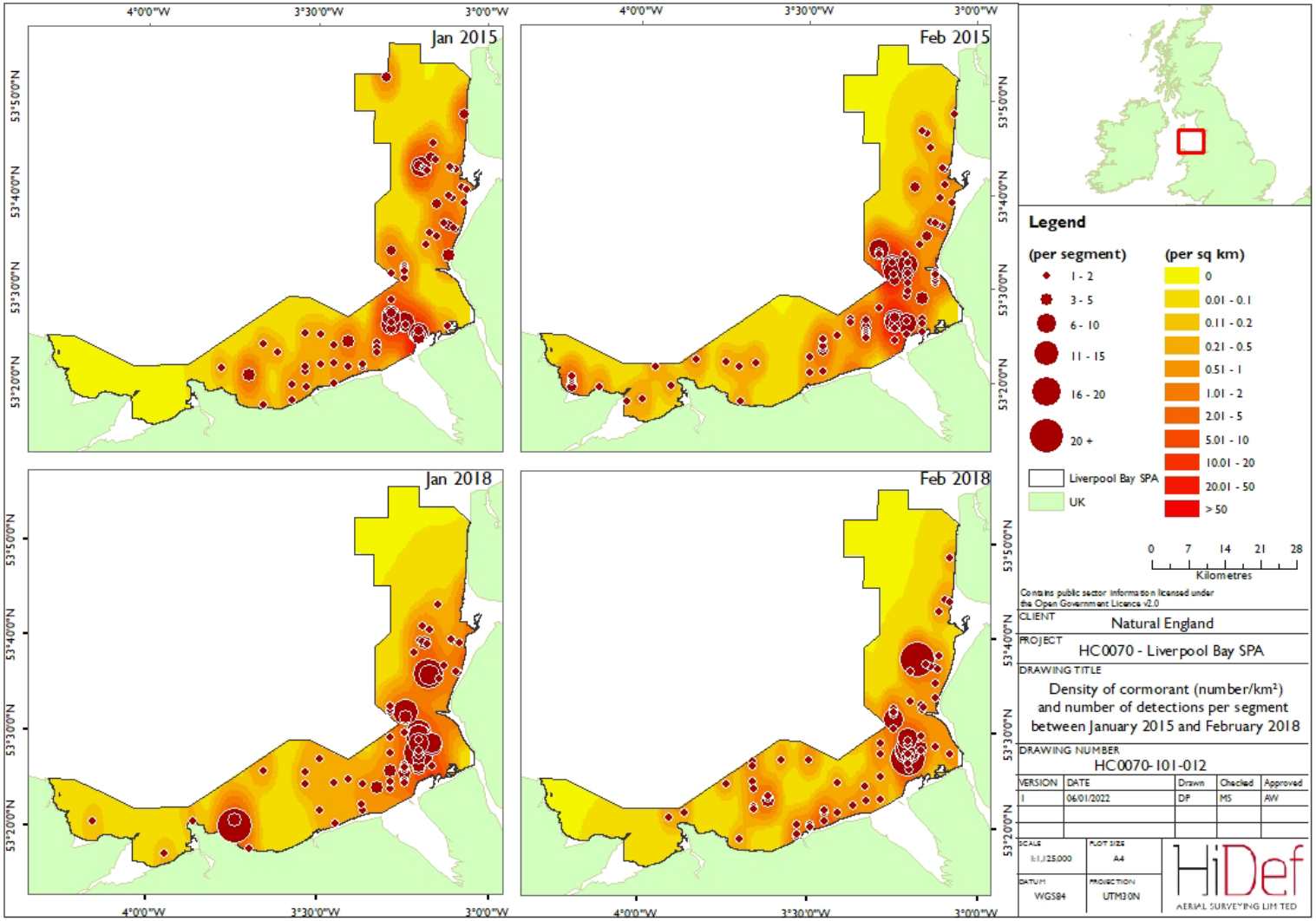


Figure 11 Density of cormorant (number/km²) and number of detections per segment between January 2019 and March 2020

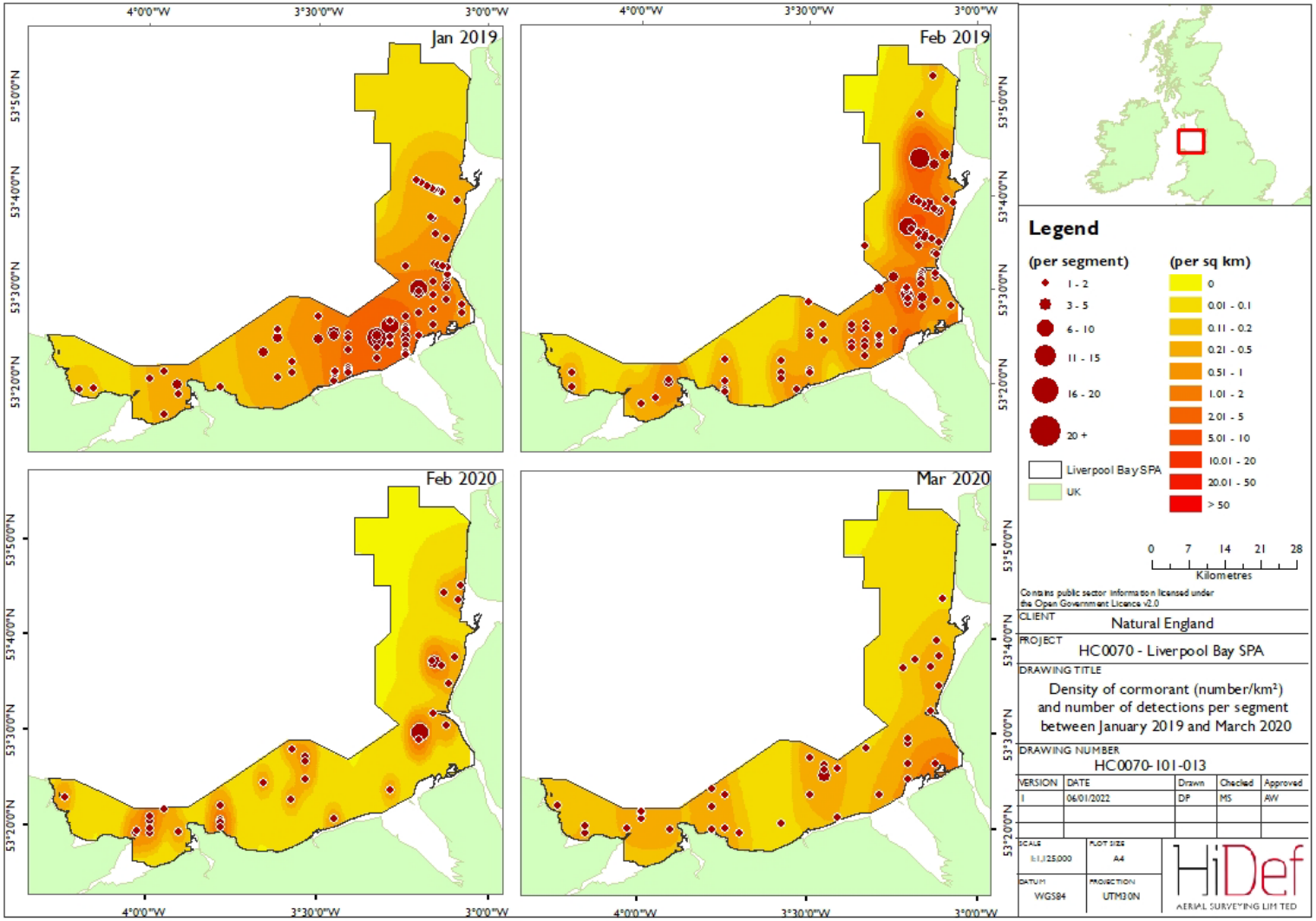


Figure 12 Density of red-breasted merganser (number/km²) and number of detections per segment between January 2015 and February 2018

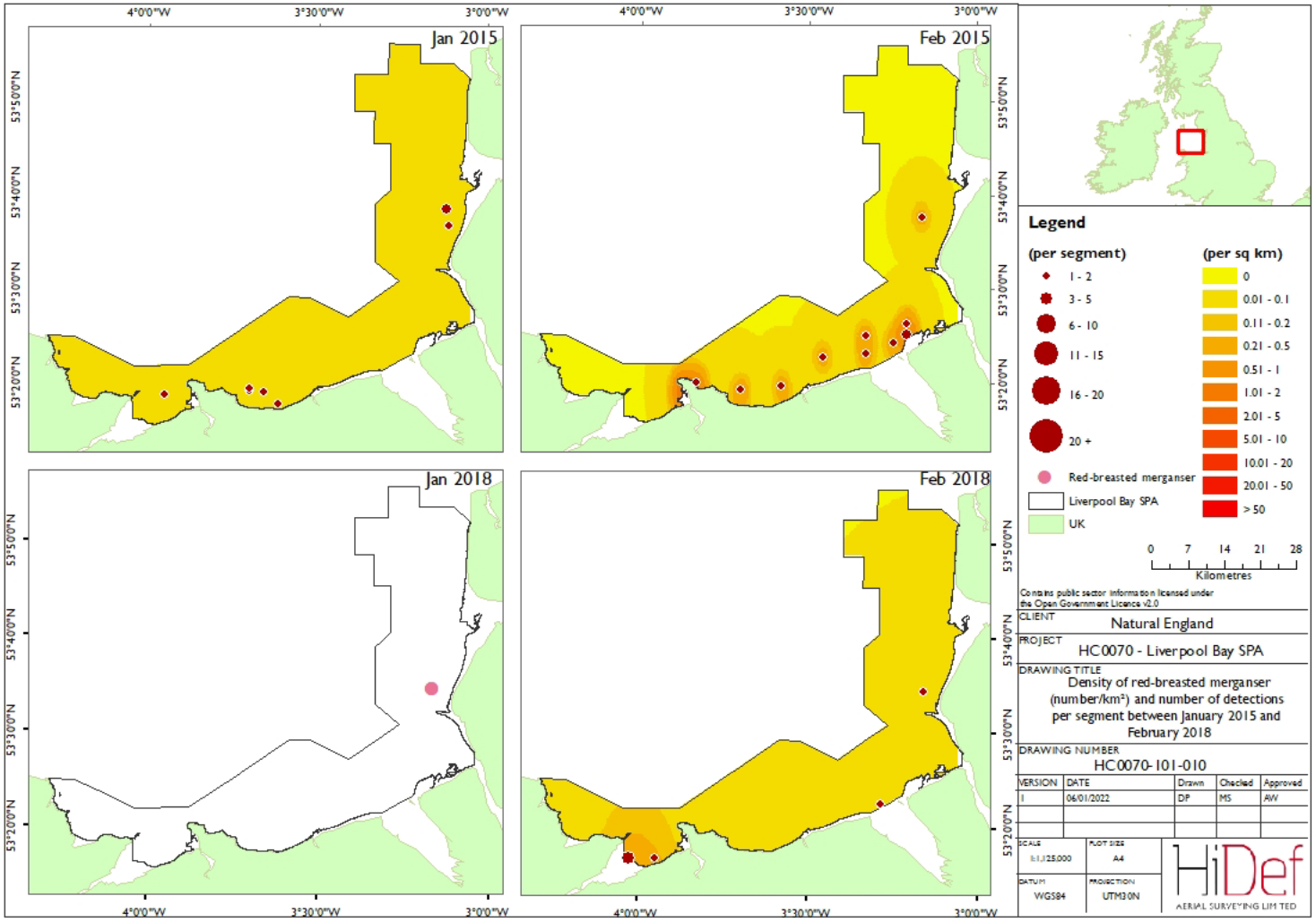


Figure 13 Density of red-breasted merganser (number/km²) and number of detections per segment between January 2019 and March 2020

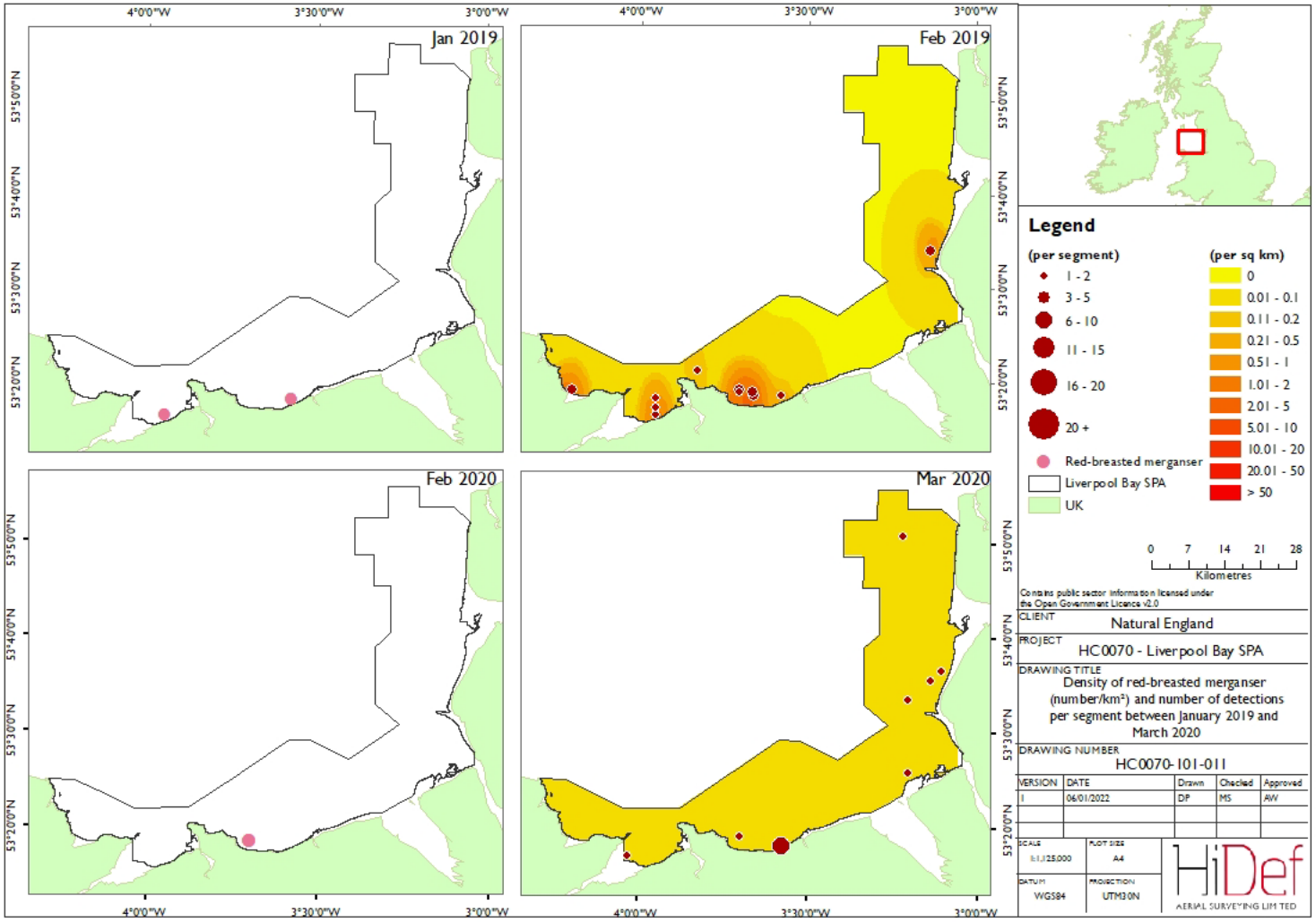


Figure 14 Density of little gull (number/km²) and number of detections per segment between January 2015 and February 2018

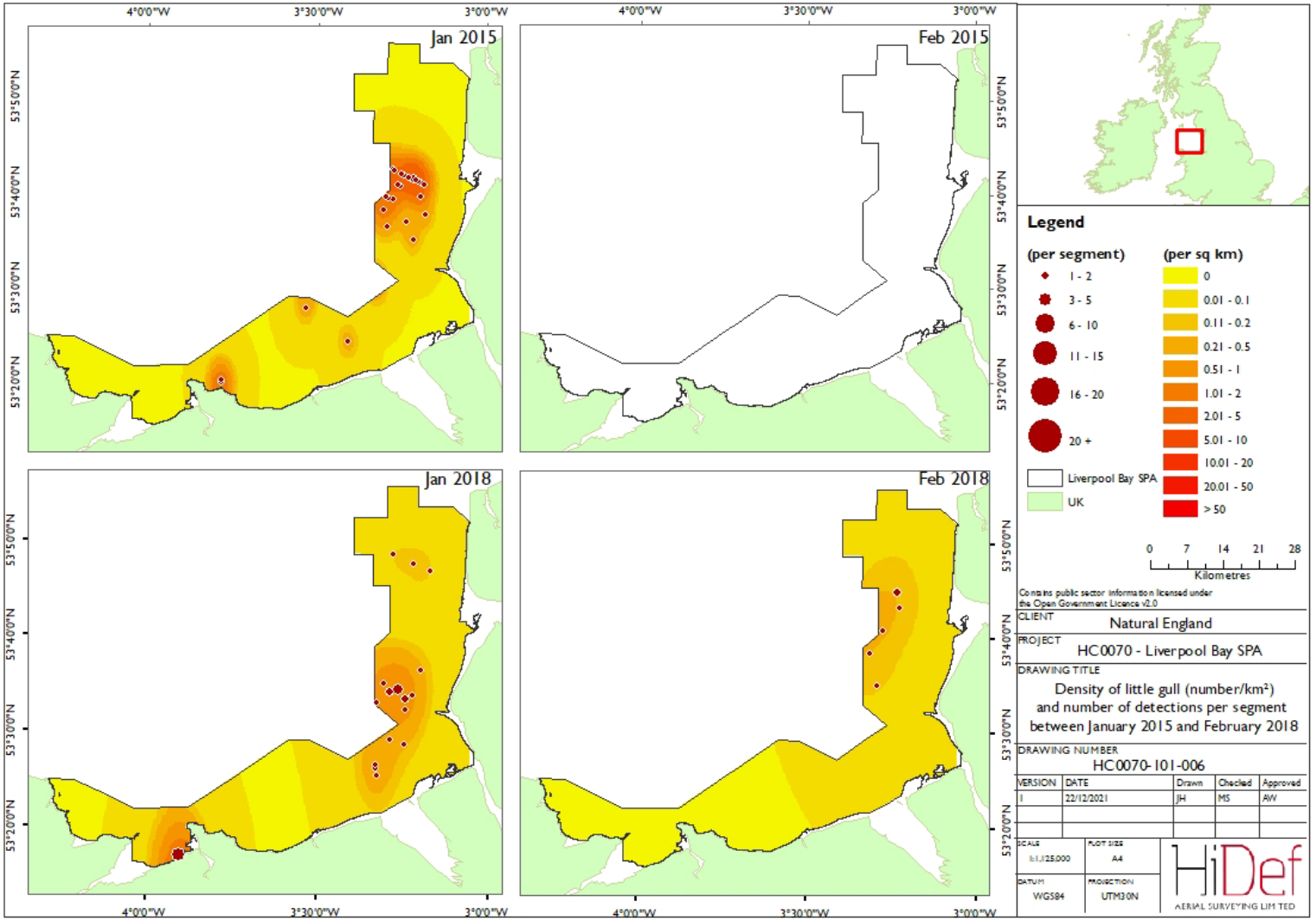
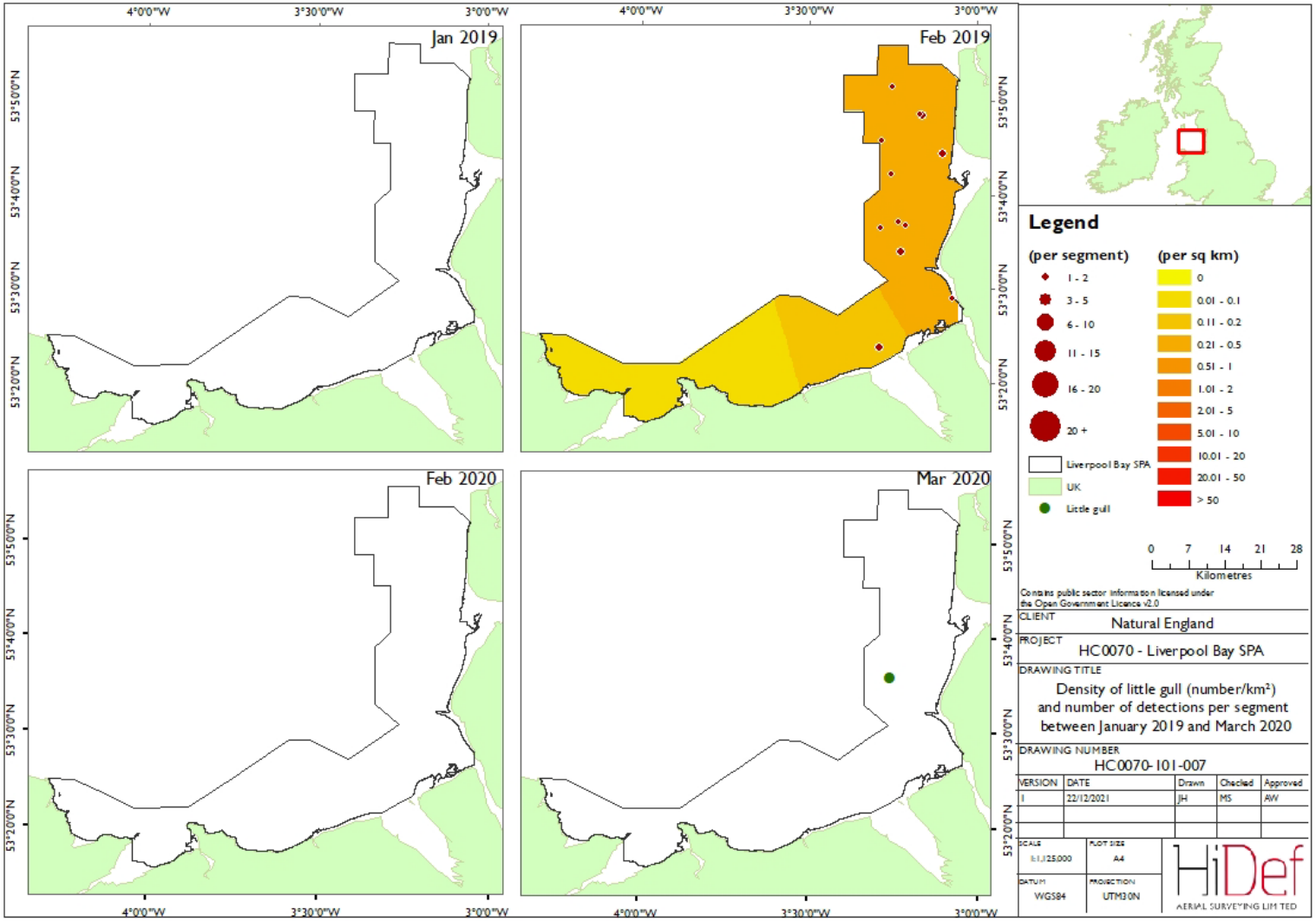


Figure 15 Density of little gull (number/km²) and number of detections per segment between January 2019 and March 2020



Discussion and conclusions

The surveys recorded a total of 217,399 birds of 27 species within the Liverpool Bay SPA. A further 3,814 birds were recorded which were not assigned to a species. An identification rate to species level of 94.3% was achieved throughout the eight surveys.

Between 2015 and 2020, population estimates calculated for the waterbird assemblage varied, ranging from 216,824 birds (95%CI 128,609 – 327,427) in February 2015 to 101,831 birds (95%CI 57,763 – 165,333) in March 2020, equating to densities of 59.99 birds/km^2 (95% CI 34.02 – 97.39) and 127.72 birds/km^2 (95% CI 75.76 – 192.87), respectively. Generally, birds were distributed throughout the SPA, with higher densities tending to be recorded closer to the coast, especially in the north and southwest.

Common scoters were the most abundant species recorded in the survey area, with population estimates ranging between 78,797 birds (95%CI 35,298 – 142,596) in March 2020 and 202,224 birds (95%CI 116,262 – 309,045) in February 2015. Peak population estimates recorded in February 2015 equated to densities of 119.12 birds/km^2 (95%CI 68.48 – 182.04). Relatively high abundance within the SPA may be attributed to the presence of a suitable foraging habitat, with the shallow, sandy substrate supporting large populations of bivalves and molluscs, a key food source for common scoter (Kaiser, 2002; Natural England, 2010; Schwemmer *et al.,* 2019).

Red-throated divers were one of the most abundant species recorded, with population estimates ranging from 372 birds (95%CI 209 – 583) in January 2018 to 2,073 birds (95%CI 1,412 – 2,817) in March 2020. Peak densities in March 2020 were calculated at 1.22 birds/km^2 (95%CI 0.83 – 1.66). Along the west coast of the UK, the wintering population of red-throated divers is patchily distributed, primarily consisting of breeding birds from the UK, Greenland, Iceland and Scandinavia (Natural England, 2010; Furness, 2015; Allen *et al.,* 2020).

Population estimates of cormorants were variable, with peak estimates calculated in February 2015 at 3,180 birds (95%CI 416 – 8,068), equating to densities of 1.87 birds/km^2 (95%CI 0.25 – 4.75). The lowest abundance was recorded in March 2020 estimated at 234 birds (95%CI 146 – 337), equating to 0.14 birds/km^2 (95%CI 0.09 – 0.20). Large coefficients of variation associated with some population and density estimates for the species should be noted. The species is generally found in coastal areas, although their breeding range has expanded to inland areas in recent decades (Cook and Robinson, 2010; Newton *et al.,* 2013). Despite some colonies remaining in the same area year-on-year, sudden changes in location have been recorded, leading to uncertainty when assessing population trends (Mitchell *et al.,* 2004). It is important to highlight digital aerial surveys did not include birds not roosting on the water, which may account for observed variability.

Red-breasted merganser population estimates ranged from 11 birds (95%CI 0 – 32) in February 2020 to 156 birds (95%CI 48 – 289) in February 2019, equating to densities of 0.01 birds/km^2 (95%CI 0.00 – 0.02) and 0.09 birds/km^2 (95%CI 0.03 – 0.17) respectively. Large coefficients of variation associated with some population and density estimates for the species should be noted. In the UK, wintering flocks of red-breasted merganser are usually small, primarily concentrated in estuarine environments, such as those within the Liverpool Bay SPA, although it is likely some movement between the SPA and adjoining estuaries will occur (Kirby *et al.*, 1993; Musgrove *et al.,* 2011).

Population estimates of little gull fluctuated, ranging from 0 birds (95%CI 0 – 0) in February 2015, January 2019 and February 2020, to 286 birds (95% CI 124 – 475) in February 2019, equating to 0.17 birds/km^2 (95%CI 0.07 – 0.28). Large coefficients of variation associated with

some population and density estimates for the species should be noted. Over the winter season, Liverpool Bay and the wider Irish Sea is known to of be importance for the species, however, the relatively low abundance recorded intermittently between 2015 and 2020 corresponds to data from All Wales Common Scoter surveys in 2002/03 (Cranswick *et al.,* 2004). Following extension of the SPA in 2017 to encompass known little gull foraging areas, it is likely that higher densities of little gull will be present outwith the original SPA boundary.

References

Allen, S., Banks, A.N., Caldow, R.W.G., Frayling, T., Kershaw, M. and Rowell, H. (2020). Chapter 29 – developments I understanding of red-throated diver responses to offshore wind farms in marine Spatial Protection Areas. *Marine Protected Areas,* 573-586.

Buckland, S.T., Anderson, D.R., Burnham, K. P., Laake, J.L., Borchers, D.L. and Thomas, L. (2001). *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford.

Cranswick, P.A., Hall, C. and Smith, L. (2004). *All Wales Common Scoter survey: report on 2002/03 work programme*. Countryside Council for Wales.

Cook, A.S.C.P. and Robinson, R.A. (2010). *How Representative is the Current Monitoring of Breeding Seabirds in the UK?.* British Trust for Ornithology.

Joint Nature Conservation Committee. (2017). *Natura 2000 – Standard data form, UK9020294, Liverpool Bay / Bae Lerpwl.* [Online]. https://jncc.gov.uk/jncc-assets/SPA-N2K/UK9020294.pdf. Accessed 10/01/2022.

Kaiser, M.J. (2002). *Predicting the displacement of common scoter Melanitta nigra from benthic feeding areas due to offshore windfarms*. COWRIE Research Report COWRIE-BEN-03-2002.

Kirby, J.S., Evans, R.J. and Fox, A.D. (1993). Wintering seaducks in Britian and Ireland: populations, threats, conservation and research priorities. *Aquatic conservation: marine and freshwater ecosystems*, 3(2), 105-137.

Lawson, J., Kober, K., Win, I., Allcock, Z., Black, J. Reid, J.B., Way, L. and O'Brien, S.H. (2016). *An assessment of the numbers and distribution of wintering waterbirds and seabirds in Liverpool Bay/Bae Lerpwl area of search*. JNCC Report No 576. JNCC, Peterborough.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. and Dunn, T.E. (2004). *Seabird populations of Britain and Ireland.* T. and AD Poyser, London.

Musgrove, A.J., Austin, G.E., Hearn, R.D., Holt, C.A., Stroud, D.A. and Wotton, S.R. (2011). Overwinter population estimates of British waterbirds. *British Birds*, 104, 364-397.

Natural England. (2010). *Departmental brief: Liverpool Bay / Bae Lerpwl Special Protection Area*. Natural England Report.

Natural England. (2014a). *European Site Conservation Objectives for Dee Estuary SPA Citation (UK9013011).* [Online]. publications.naturalengland.org.uk/publication/6557770283220992. Accessed 10/01/2022.

Natural England. (2014b). *European Site Conservation Objectives for Mersey Narrows and North Wirral Foreshore SPA Citation (UK9020287).* [Online]. publications.naturalengland.org.uk/publication/6521906232557568. Accessed 10/01/2022.

Natural England. (2014c). *European Site Conservation Objectives for Ribble and Alt Estuary SPA Citation (UK9005103).* [Online].

publications.naturalengland.org.uk/publication/4868920422957056. Accessed 10/01/2022.

Natural England, Natural Resources Wales and Joint Nature Conservation Committee. (2016). *Departmental brief: Liverpool Bay / Bae Lerpwl potential Special Protection Area (pSPA), Proposal for extension to existing site and adding new features, Advice to the Welsh Government and UK Government*. Natural England Report.

Natural England. (2017). *Liverpool Bay / Bae Lerpwl SPA Classification Citation (UK9020294).* [Online]. publications.naturalengland.org.uk/publication/5089733892898816. Accessed 10/01/2022.

Natural England. (2018). *European Site Conservation Objectives for Liverpool Bay SPA Citation (UK9020294).* [Online]. publications.naturalengland.org.uk/publication/5089733892898816. Accessed 10/01/2022.

Newson, S., Marchant, J., Sellers, R., Ekins, G., Hearn, R. and Burton, N. (2013). Colonisation and range expansion of inland-breeding cormorants in England. *British Birds*, 106, 737–743.

Schwemmer, P., Volmer, H., Enners, L., Reimers, H-C., Binder, K., Horn, S., Adler, S., Fox, A. and Garthe, S. (2019). Modelling distribution of common scoter (*Melanitta nigra*) by its predominant prey, the American razor clam (*Ensis leei*) and hydrodynamic parameters. *Estuarine, Coastal and Shelf Science*, 225, 106260.

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

Stroud, D.A., Chambers, D., Cook, S., Buxton, N., Fraser, B., Clement, P., Lewis, I., McLean, I., Baker, H. and Whitehead, S. (2001). *The UK SPA Network: Its Scope and Content, vols. 1–3*. JNCC.

Thaxter, C.B., Ross-Smith, V.H. and Cook, A.S.C.P. (2016). *How high do birds fly? A review of current datasets and an appraisal of current methodologies for collecting flight height data: Literature review.* BTO Research Report No. 666.

Webb, A., Bradbury, G., Burt, L. and Hexter, R. (2014). *Digital aerial surveillance of inshore waterbirds in Liverpool Bay Special Protection Area.* JNCC Report No. 559.

Webb, A., McSorley, C.A., Dean, B.J., Reid, J.B., Cranswick, P.A., Smith, L. and Hall, C. (2006). *An assessment of the numbers and distributions of inshore aggregations of waterbirds using Liverpool Bay during the non-breeding season in support of possible SPA identification*. JNCC Report No. 373, JNCC, Peterborough.

Appendix I: Density and population estimates

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 for each of the eight surveys undertaken.

Table 14 Density and population estimates of species groups in the Liverpool Bay SPA during Survey 1 on 24 January 2015

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	124.04	64.14	198.16	210571	108890	336403	58807	27.93
Species group								
Duck species	112.01	52.49	184.64	190163	89111	313449	58178	30.59
Diver species	0.75	0.54	0.98	1281	925	1667	191	14.90
Fulmar / gull species	0.08	0.02	0.15	135	38	261	58	42.47
Gannet species	0	0	0.01	6	0	17	6	95.51
Cormorant species	1.01	0.44	1.72	1715	752	2924	558	32.50
Grebe species	0.05	0.02	0.1	88	27	172	38	42.31
Small gull species	1.66	1.17	2.26	2818	1985	3836	475	16.85
Black-backed gull species	0.07	0.04	0.1	114	60	174	29	24.83
Large gull species	0.53	0.25	0.92	893	419	1560	297	33.24
Gull species	0.49	0.22	0.88	841	374	1488	295	35.10
Large auk	6.32	4.09	8.76	10728	6949	14878	2041	19.03
Auk species	0.3	0.16	0.51	512	267	868	155	30.23
Auk / small gull	0.07	0.04	0.12	126	64	201	36	28.36
Large auk / diver species	0.29	0.19	0.41	496	321	693	96	19.20

Table 15 Density and population estimates of species in the Liverpool Bay SPA during Survey 1 on 24 January 2015

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Eider	0.02	0.01	0.04	39	11	76	18	44.26
Common scoter	111.05	50.75	185.07	188527	86163	314186	58662	31.12
Velvet scoter	0	0	0.01	6	0	17	6	96.01
Goldeneye	0	0	0.01	6	0	17	6	98.40
Red-breasted merganser	0.05	0.01	0.09	82	22	147	32	38.78
Red-throated diver	0.82	0.6	1.07	1394	1012	1815	205	14.69
Fulmar	0.05	0.01	0.1	83	22	166	39	46.07
Gannet	0	0	0.01	6	0	17	6	97.41
Cormorant	0.97	0.42	1.66	1647	715	2826	552	33.47
Shag	0.01	0	0.02	11	0	28	8	68.57
Great crested grebe	0.05	0.02	0.1	88	27	169	37	41.69
Kittiwake	0.76	0.47	1.08	1286	796	1835	268	20.77
Little gull	0.16	0.03	0.35	265	53	596	147	55.53
Black-headed gull	0.01	0	0.03	17	0	44	13	73.56
Common gull	0.8	0.54	1.12	1352	913	1895	256	18.92
Lesser black-backed gull	0.01	0	0.02	11	0	27	8	67.16
Herring gull	0.6	0.21	1.13	1019	361	1915	400	39.25

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Great black-backed gull	0.17	0.11	0.23	284	189	383	50	17.43
Guillemot	5.21	3.35	7.31	8839	5683	12414	1740	19.68
Razorbill	0.71	0.46	1	1202	780	1693	236	19.62
Puffin	0	0	0.01	6	0	17	6	99.47

Table 16 Density and population estimates of species groups in Liverpool Bay SPA during Survey 2 on 04 February 2015

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	127.72	75.76	192.87	216824	128609	327427	50283	23.19
Species group								
Duck species	118.88	66.27	182	201815	112501	308969	50144	24.85
Diver species	0.87	0.51	1.31	1477	863	2227	352	23.78
Fulmar / gull species	0.01	0	0.02	16	0	37	10	57.04
Cormorant species	1.98	0.36	4.87	3362	618	8274	2294	68.23
Grebe species	0.24	0.05	0.54	401	84	917	240	59.87
Small gull species	2.25	1.33	3.31	3826	2261	5613	868	22.67
Black-backed gull species	0.05	0.03	0.08	90	48	136	23	25.07
Large gull species	0.55	0.31	0.83	937	534	1406	228	24.32
Gull species	0.14	0.08	0.22	246	136	378	62	25.09
Large auk	2.17	1.4	3.1	3677	2373	5259	747	20.31
Auk species	0.12	0.08	0.17	206	134	286	39	18.90

Table 17 Density and population estimates of species in Liverpool Bay SPA during Survey 2 on 04 February 2015

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Eider	0.09	0	0.27	155	0	452	148	95.61
Common scoter	119.12	68.48	182.04	202224	116262	309045	49899	24.68
Velvet scoter	0	0	0.01	6	0	16	6	98.65
Goldeneye	0.01	0	0.02	11	0	32	11	99.58
Red-breasted merganser	0.04	0.01	0.08	69	21	129	28	39.66
Red-throated diver	0.88	0.51	1.33	1500	865	2255	355	23.64
Fulmar	0.01	0	0.02	11	0	27	8	69.95
Cormorant	1.87	0.25	4.75	3180	419	8068	2321	72.99
Shag	0.12	0.05	0.22	210	84	372	75	35.50
Great crested grebe	0.23	0.05	0.55	399	84	927	241	60.35
Kittiwake	0	0	0.01	6	0	16	6	98.10
Black-headed gull	0.03	0.01	0.06	58	21	104	22	37.55
Common gull	2.28	1.31	3.42	3869	2221	5808	912	23.56
Lesser black-backed gull	0.02	0.01	0.03	32	11	53	11	34.65
Herring gull	0.33	0.17	0.53	565	294	906	157	27.65
Great black-backed gull	0.26	0.14	0.43	445	242	728	130	29.07
Guillemot	2.06	1.3	3.03	3496	2203	5150	757	21.63

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Razorbill	0.08	0.03	0.14	138	53	238	48	34.40

Table 18 Density and population estimates of species groups in Liverpool Bay SPA during Survey 3 on 22 January 2018

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	63.18	30.13	105.76	107255	51144	179524	33576	31.30
Species group								
Duck species	59.81	26.72	102.56	101533	45361	174104	32839	32.34
Diver species	0.22	0.12	0.35	375	211	594	99	26.31
Fulmar / gull species	0.03	0	0.06	43	6	96	24	54.53
Cormorant species	0.77	0.33	1.37	1314	560	2327	458	34.80
Small gull species	0.8	0.51	1.14	1352	864	1928	276	20.36
Black-backed gull species	0.06	0.03	0.1	104	49	164	30	28.23
Large gull species	0.29	0.19	0.39	487	328	668	88	17.93
Gull species	0.13	0.08	0.18	217	134	311	45	20.72
Large auk	1.06	0.57	1.65	1800	968	2808	468	25.98
Auk species	0.03	0	0.09	55	0	146	40	72.10
Auk / small gull	0.01	0	0.02	11	0	27	8	69.28
Large auk / diver species	0.01	0	0.03	22	0	49	13	59.71

Table 19 Density and population estimates of species in Liverpool Bay SPA during Survey 3 on 22 January 2018

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Eider	0	0	0.01	6	0	17	6	96.78
Common scoter	59.76	26.77	102.77	101454	45453	174476	33704	33.22
Red-breasted merganser	0.01	0	0.03	17	0	49	16	95.60
Red-throated diver	0.22	0.12	0.34	372	209	583	97	26.01
Fulmar	0.02	0	0.05	38	6	87	24	61.66
Cormorant	0.74	0.29	1.31	1251	496	2222	456	36.41
Kittiwake	0.15	0.1	0.21	255	165	361	50	19.56
Little gull	0.12	0.04	0.23	212	64	399	88	41.20
Black-headed gull	0.02	0.01	0.04	38	11	75	18	45.14
Common gull	0.46	0.24	0.71	779	409	1207	207	26.53
Herring gull	0.18	0.1	0.28	309	176	470	77	24.63
Great black-backed gull	0.16	0.09	0.23	271	159	394	61	22.33
Guillemot	0.56	0.29	0.91	952	496	1552	265	27.79
Razorbill	0.16	0.07	0.26	267	112	446	87	32.51

Table 20 Density and population estimates of species groups in Liverpool Bay SPA during Survey 4 on 23 February 2018

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	96	47.94	153.22	162977	81375	260118	46464	28.51
Species group								
Duck species	87.69	41.11	146.44	148865	69795	248600	46557	31.27
Grebe species	0.14	0.02	0.35	236	43	601	145	61.33
Small gull species	0.38	0.26	0.53	642	444	897	117	18.19
Black-backed gull species	0.07	0.04	0.1	124	76	175	26	20.42
Large gull species	0.98	0.59	1.45	1656	997	2454	371	22.40
Gull species	0.41	0.24	0.62	695	411	1046	162	23.26
Large auk	2.47	1.29	3.86	4200	2195	6553	1137	27.06
Auk species	0.09	0.04	0.15	146	64	254	52	35.32
Auk / small gull	0.03	0.01	0.07	56	16	114	26	46.71
Large auk / diver species	0.08	0.04	0.13	141	76	214	36	25.53
Diver species	0.95	0.66	1.27	1616	1123	2156	269	16.61
Cormorant species	0.65	0.3	1.22	1106	508	2067	413	37.30

Table 21 Density and population estimates of species in Liverpool Bay SPA during Survey 4 on 23 February 2018

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Eider	0.03	0	0.09	59	0	157	42	71.15
Common scoter	89.79	40.09	149.57	152437	68060	253918	47327	31.05
Red-breasted merganser	0.03	0	0.06	49	6	106	27	53.86
Great crested grebe	0.14	0.03	0.33	235	44	564	142	60.30
Oystercatcher	0.03	0	0.08	54	0	128	34	62.37
Curlew	0.01	0	0.03	22	0	49	13	59.34
Kittiwake	0.03	0.01	0.05	44	11	80	18	39.89
Black-headed gull	0.07	0.02	0.16	126	27	279	68	53.59
Little gull	0.03	0.01	0.07	54	11	112	26	47.30
Common gull	0.22	0.15	0.32	378	250	550	80	21
Great black-backed gull	0.13	0.09	0.17	221	148	297	39	17.37
Herring gull	0.81	0.49	1.2	1379	829	2043	323	23.43
Lesser black-backed gull	0.01	0	0.03	23	6	43	11	46.47
Guillemot	1.77	0.84	2.95	3003	1423	5016	912	30.37
Razorbill	0.11	0.04	0.18	182	76	313	62	33.66
Red-throated diver	0.95	0.66	1.27	1612	1125	2157	267	16.52
Great northern diver	0.01	0	0.02	11	0	27	8	68.99

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Shag	0.04	0.02	0.07	65	27	112	22	34.29
Cormorant	0.55	0.21	1.03	933	355	1757	385	41.28
Chough	0	0	0.01	6	0	22	6	105.69

Table 22 Density and population estimates of species groups in Liverpool Bay SPA during Survey 5 on 09 January 2019

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	81.61	55.37	110.8	138478	94006	187891	24283	17.53
Species group								
Duck species	66.66	41.19	94.18	113161	69922	159884	22706	20.06
Diver species	1.18	0.76	1.72	2009	1296	2922	425	21.12
Fulmar / gull species	0.03	0.01	0.07	59	16	115	25	42.73
Cormorant species	0.71	0.35	1.23	1205	595	2092	394	32.67
Grebe species	0.21	0.13	0.29	350	213	500	73	20.63
Small gull species	2.98	1.77	4.42	5063	3011	7507	1152	22.74
Black-backed gull species	0.22	0.14	0.29	366	246	498	66	17.89
Large gull species	0.66	0.38	1.02	1124	652	1731	276	24.55
Gull species	0.66	0.45	0.91	1129	771	1538	199	17.54
Large auk	6.97	3.9	10.85	11839	6624	18413	3058	25.82
Auk species	0.06	0.03	0.1	106	47	178	34	31.24
Auk / small gull	0.14	0.08	0.21	239	144	349	54	22.26
Large auk / diver species	0.1	0.06	0.15	165	95	247	40	24.02

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Small bird species	0.7	0.5	0.95	1192	849	1610	196	16.38

Table 23 Density and population estimates of species in Liverpool Bay SPA during Survey 5 on 09 January 2019

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Common scoter	66.58	41.1	94.3	113028	69770	160097	22960	20.31
Red-breasted merganser	0.02	0	0.04	27	0	68	19	69.76
Red-throated diver	1.19	0.77	1.72	2016	1315	2914	417	20.66
Fulmar	0.01	0	0.03	21	0	48	13	60.93
Cormorant	0.68	0.32	1.17	1147	537	1995	379	32.99
Shag	0	0	0.01	6	0	16	6	99.86
Great crested grebe	0.2	0.12	0.29	346	209	498	74	21.36
Curlew	0.04	0	0.11	64	0	191	63	97.52
Kittiwake	0.14	0.05	0.26	239	84	449	95	39.71
Black-headed gull	0.18	0.02	0.39	301	27	668	166	54.99
Common gull	2.5	1.45	3.73	4239	2465	6341	991	23.36
Lesser black-backed gull	0.01	0	0.02	11	0	27	8	67.63
Herring gull	0.62	0.32	1	1046	551	1692	292	27.86
Great black-backed gull	0.26	0.18	0.36	448	298	618	82	18.13
Guillemot	6.25	3.32	10.14	10603	5643	17208	2936	27.68
Razorbill	0.17	0.09	0.26	291	157	442	74	25.38
Magpie	0	0	0.01	6	0	16	6	100.43

Table 24 Density and population estimates of species groups in Liverpool Bay SPA during Survey 6 on 22 February 2019

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	81.45	50.71	118.29	138273	86088	200816	29913	21.63
Species group								
Duck species	68.98	39.25	105.91	117101	66641	179797	29309	25.03
Diver species	0.76	0.51	1.04	1295	861	1767	237	18.24
Fulmar / gull species	0.01	0	0.02	17	0	38	10	57.10
Cormorant species	0.79	0.41	1.23	1340	702	2092	357	26.62
Grebe species	0.87	0.3	1.75	1472	508	2970	663	45.03
Small gull species	2.52	1.72	3.52	4270	2913	5983	792	18.54
Black-backed gull species	0.09	0.04	0.15	152	75	248	45	29.33
Large gull species	1.67	0.9	2.73	2836	1522	4636	799	28.14
Gull species	0.83	0.56	1.14	1411	958	1939	253	17.90
Large auk	4.27	2.3	6.82	7245	3903	11582	1958	27.02
Auk species	0.04	0.02	0.07	71	28	124	25	34.72
Auk / small gull	0.07	0.03	0.11	115	59	182	32	27.44
Large auk / diver species	0.08	0.03	0.16	141	53	280	62	43.87

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Small bird species	0.15	0.03	0.35	250	54	594	153	61.17

Table 25 Density and population estimates of species in Liverpool Bay SPA during Survey 6 on 22 February 2019

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Wigeon	0.65	0	1.87	1103	0	3171	993	90.04
Eider	0.04	0	0.09	60	0	155	43	70.61
Common scoter	68.69	38.22	104.93	116611	64893	178138	29431	25.24
Velvet scoter	0	0	0.01	6	0	17	6	98.33
Red-breasted merganser	0.09	0.03	0.17	156	48	289	63	40.14
Red-throated diver	0.76	0.5	1.07	1295	851	1820	247	19.02
Black-throated diver	0	0	0.01	6	0	17	6	99.18
Fulmar	0.01	0	0.02	17	0	38	10	56.37
Cormorant	0.65	0.32	1.05	1098	540	1791	330	30.04
Shag	0.11	0.01	0.29	180	16	486	145	80.49
Great crested grebe	0.79	0.27	1.61	1341	465	2727	608	45.35
Curlew	0	0	0.01	6	0	17	6	99.11
Kittiwake	0.32	0.14	0.57	542	233	963	189	34.84
Little gull	0.17	0.07	0.28	286	124	475	90	31.29
Black-headed gull	0.31	0.05	0.69	533	92	1165	289	54.18
Common gull	1.75	1.31	2.24	2974	2229	3797	396	13.29
Lesser black-backed gull	0.08	0.04	0.12	136	70	212	37	26.64

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Herring gull	1.77	0.95	2.82	3009	1621	4786	817	27.13
Great black-backed gull	0.11	0.06	0.16	189	108	276	43	22.65
Guillemot	3.13	1.72	4.86	5311	2921	8255	1357	25.54
Razorbill	0.47	0.24	0.74	792	413	1256	214	27.01

Table 26 Density and population estimates of species groups in Liverpool Bay SPA during Survey 7 on 07 February 2020

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	66.91	37.92	104.9	113527	64373	177890	29353	25.84
Species group								
Duck species	56.48	28.3	94.76	95881	48052	160876	28994	30.24
Diver species	0.64	0.37	0.96	1084	635	1629	259	23.83
Fulmar / gull species	0.06	0.02	0.11	101	32	194	42	41.63
Cormorant species	0.29	0.19	0.41	497	316	701	98	19.58
Grebe species	0.19	0.03	0.43	329	58	739	180	54.73
Small gull species	1.19	0.55	1.98	2017	935	3368	625	30.97
Black-backed gull species	0.09	0.05	0.15	159	83	253	45	27.99
Large gull species	1.62	0.9	2.55	2746	1521	4327	717	26.09
Gull species	1.71	0.79	2.88	2908	1340	4891	907	31.16
Large auk	3.51	2.04	5.18	5953	3458	8800	1359	22.81
Small auk	0.01	0	0.02	11	0	32	11	95.19
Auk species	0.3	0.18	0.43	515	314	734	107	20.69
Auk / small gull	0.11	0.04	0.21	184	68	360	78	42.04
Large auk / diver species	0.1	0.04	0.18	164	63	302	62	37.79

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Small bird species	0.07	0.01	0.16	118	21	268	65	55.01

Table 27 Density and population estimates of species in Liverpool Bay SPA during Survey 7 on 07 February 2020

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Eider	0.01	0	0.03	17	0	48	17	99.88
Common scoter	56.51	29.18	93.79	95931	49541	159232	28084	29.27
Red-breasted merganser	0.01	0	0.02	11	0	32	11	96.70
Red-throated diver	0.64	0.37	0.95	1084	623	1612	258	23.81
Great northern diver	0	0	0.01	6	0	16	6	98.22
Fulmar	0.02	0	0.05	38	6	80	20	50.85
Cormorant	0.15	0.08	0.23	249	132	387	65	26.09
Shag	0.11	0.07	0.17	193	114	288	45	23.05
Great crested grebe	0.19	0.04	0.43	329	62	729	176	53.47
Oystercatcher	0.01	0	0.02	11	0	27	8	69.46
Bar-tailed godwit	0.04	0	0.1	61	0	175	59	96.24
Kittiwake	0.05	0.02	0.09	92	43	146	27	29.30
Black-headed gull	0.14	0.05	0.26	240	83	440	93	38.61
Common gull	0.75	0.38	1.26	1281	647	2141	379	29.57
Lesser black-backed gull	0.02	0.01	0.04	38	11	69	16	40.54
Herring gull	1.73	0.99	2.7	2945	1684	4583	743	25.22
Great black-backed gull	0.11	0.07	0.17	192	111	285	45	23.15

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Guillemot	3.04	1.76	4.49	5155	2991	7625	1207	23.40
Razorbill	0.26	0.12	0.41	434	211	696	125	28.67

Table 28 Density and population estimates of species groups in Liverpool Bay SPA during Survey 8 on 05 March 2020

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category								
All birds	59.99	34.02	97.39	101831	57763	165333	28148	27.64
Species group								
Duck species	47.35	21.08	84.94	80376	35787	144193	28556	35.53
Diver species	1.2	0.81	1.63	2033	1380	2767	356	17.49
Fulmar / gull species	0.05	0.02	0.09	82	32	148	31	36.89
Cormorant species	0.29	0.19	0.41	499	324	699	96	19.13
Grebe species	0.16	0.09	0.23	270	161	392	60	21.91
Skua species excluding great	0	0	0.01	6	0	17	6	99.23
Small gull species	1.89	1.34	2.55	3207	2283	4338	534	16.62
Black-backed gull species	0.1	0.06	0.15	173	108	247	36	20.47
Large gull species	2.55	1.39	4.09	4324	2365	6941	1200	27.74
Gull species	0.87	0.46	1.38	1475	780	2338	395	26.73
Large auk	5.32	3.35	7.76	9025	5693	13179	1938	21.46
Small auk	0.01	0	0.03	17	0	43	12	73.12
Auk species	0.21	0.1	0.34	355	172	578	105	29.37
Auk / small gull	0.06	0.03	0.09	98	49	155	28	27.73

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Large auk / diver species	0.08	0.04	0.12	131	71	201	34	25.90
Small bird species	0.04	0.01	0.07	60	16	119	27	45.03

Table 29 Density and population estimates of species in Liverpool Bay SPA during Survey 8 on 05 March 2020

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species								
Eider	0.05	0	0.12	82	0	201	54	65.27
Long-tailed duck	0.01	0	0.02	11	0	27	8	68.83
Common scoter	46.41	20.79	84	78797	35298	142596	27742	35.21
Velvet scoter	0.01	0	0.02	11	0	27	8	68.32
Red-breasted merganser	0.06	0.02	0.12	98	27	207	49	50.12
Red-throated diver	1.22	0.83	1.66	2073	1412	2817	360	17.36
Great northern diver	0.01	0	0.02	17	0	38	10	56.22
Fulmar	0.02	0.01	0.03	33	11	60	13	39.84
Cormorant	0.14	0.09	0.2	234	146	337	49	20.89
Shag	0.13	0.06	0.21	222	108	360	65	29.07
Great crested grebe	0.14	0.08	0.2	238	144	343	52	21.48
Slavonian grebe	0.02	0	0.03	28	6	59	14	50.47
Oystercatcher	0.02	0	0.04	28	0	70	20	70.69
Curlew	0	0	0.01	6	0	17	6	98.55
Kittiwake	0.21	0.11	0.33	353	184	557	97	27.41
Little gull	0	0	0.01	6	0	17	6	98.63
Black-headed gull	0.17	0.03	0.41	287	49	701	173	60.22

Category	Density estimate (n/km²)	Lower 95% confidence limit of density (n/km²)	Upper 95% confidence limit of density (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Common gull	1.6	1.16	2.1	2711	1965	3561	410	15.11
Lesser black-backed gull	0.22	0.13	0.36	366	216	605	102	27.85
Herring gull	2.61	1.35	4.26	4434	2290	7229	1281	28.89
Great black-backed gull	0.14	0.09	0.21	244	150	351	52	21.01
Guillemot	3.29	1.96	5.02	5587	3335	8525	1316	23.55
Razorbill	1.11	0.69	1.6	1881	1173	2721	400	21.24
Black guillemot	0.03	0.01	0.06	48	11	96	22	45.75
Puffin	0.03	0	0.06	44	6	101	25	57.08

Appendix II: Quantile maps for abundant species

To allow clear presentation of those species/groups with relatively high abundances compared to other species included in this report, the quantiles of number of detections per segment have additionally been presented. These are presented for common scoter and the waterbird assemblage.

Figure 16 Density of the waterbird assemblage (number/km²) and quantiles of detections per segment between January 2015 and February 2018

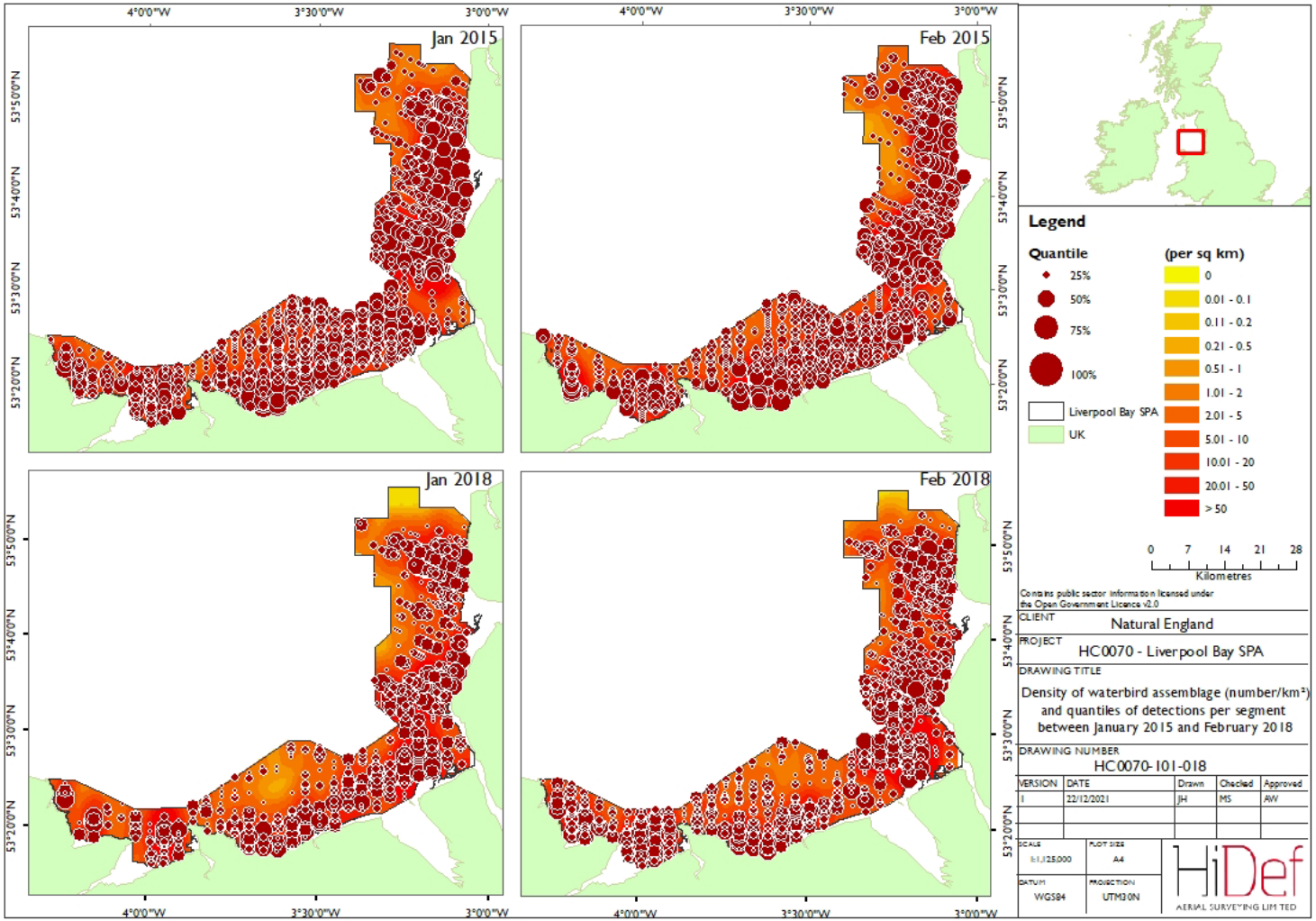


Figure 17 Density of the waterbird assemblage (number/km²) and quantiles of detections per segment between January 2019 and March 2020

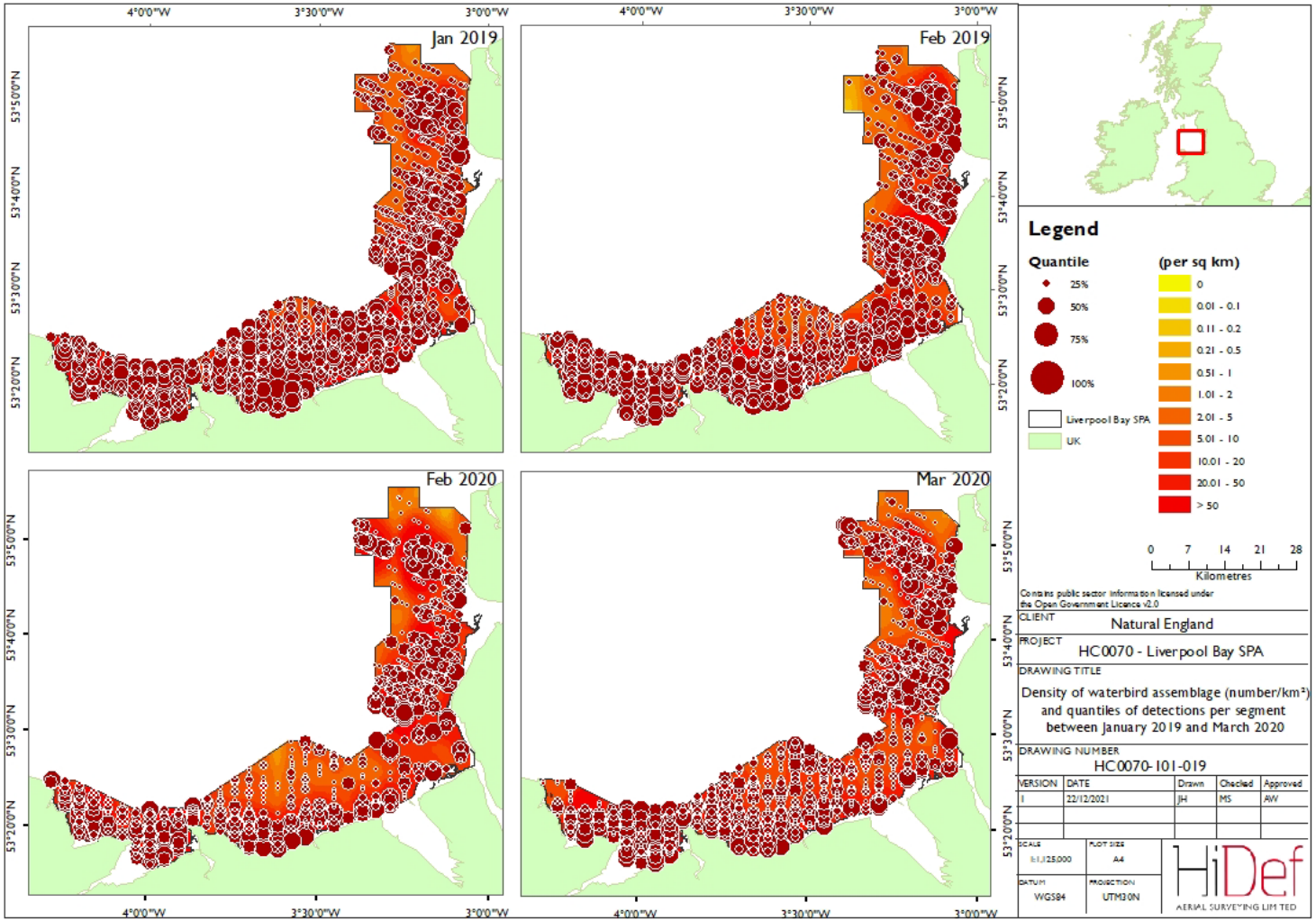


Figure 18 Density of common scoter (number/km²) and quantiles of detections per segment between January 2015 and February 2018

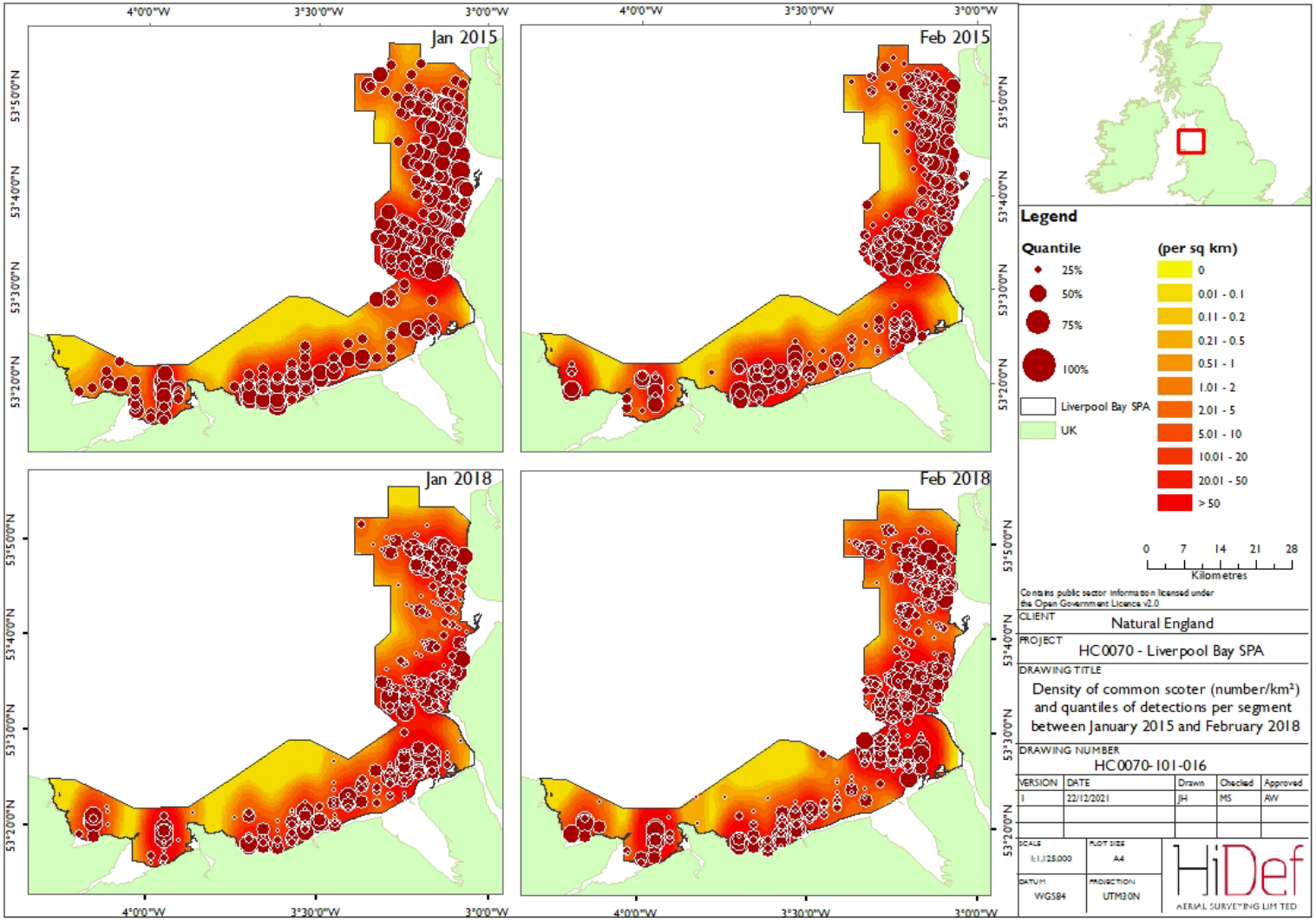
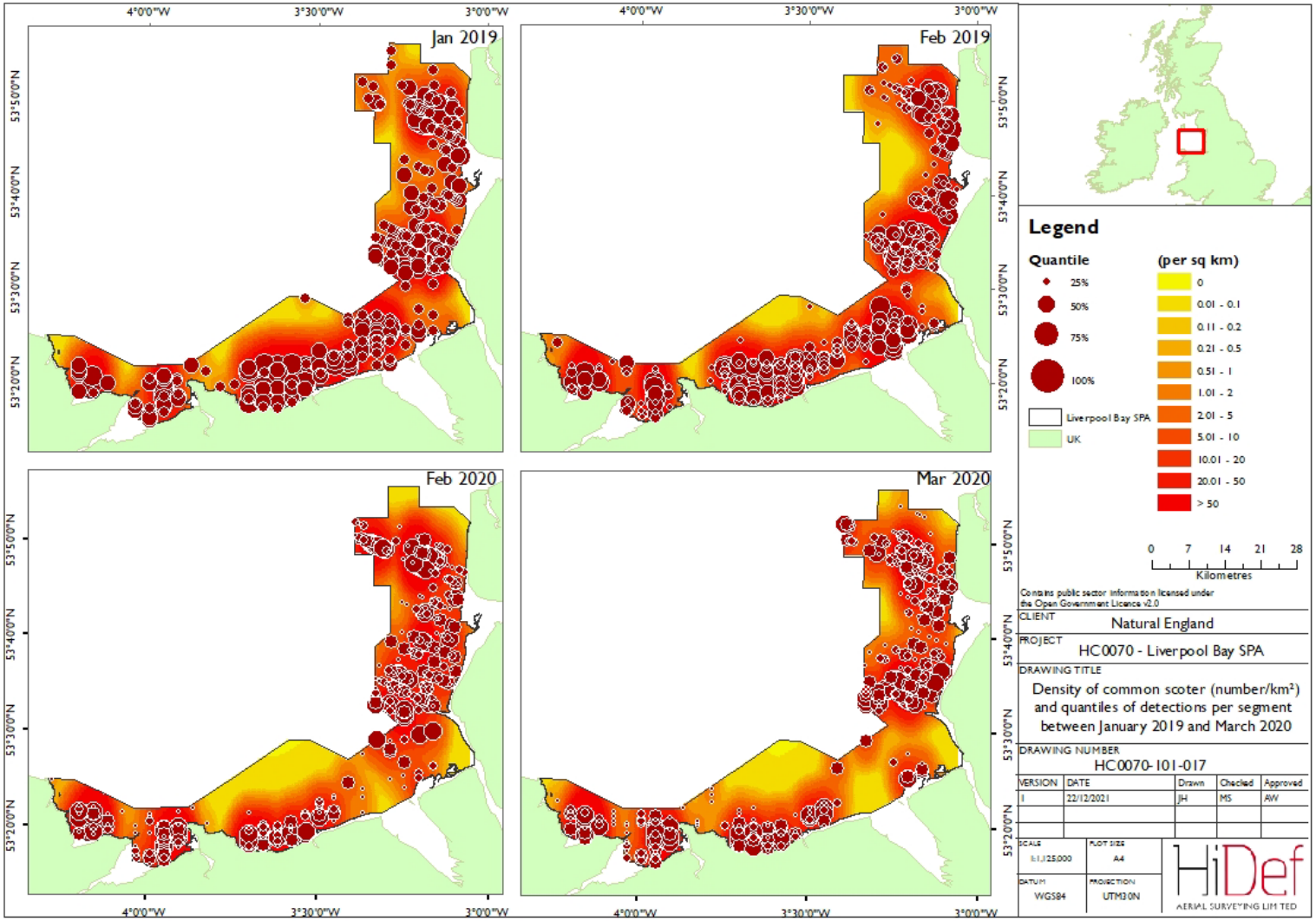


Figure 19 Density of common scoter (number/km²) and quantiles of detections per segment between January 2019 and March 2020



www.gov.uk/natural-england

NATURAL ENGLAND