Digital video aerial surveys of common scoter at Dundalk Bay: Final Report for January 2019

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Executive Summary

1 In winter 2018/19 Marine Institute Ireland commissioned HiDef Aerial Surveying Limited ('HiDef') to undertake a programme of high-resolution digital video aerial marine megafauna, ornithological and human activity surveys over four sites along the east Irish coast.

2 While the survey programme was commissioned to assess common scoter *Melanitta nigra* numbers and distribution, a single survey of Dundalk Bay was commissioned as part of the programme to assess the numbers of shorebirds at this site.

3 A single survey was commissioned for January 2019. HiDef designed a survey that placed transects at 750m apart across the survey site. (Figure 1).

4 The HiDef surveys were undertaken using an aircraft equipped with four (4) HiDef Gen II cameras with sensors set to a resolution of 1.7 cm Ground Sample Distance (GSD). Each camera sampled a strip of 115m width, separated from the next camera by ~20m, which provides a combined sampled width of 440m within a 500m overall strip. However, to ensure that sufficient footage is available to allow either a design-based or model-based analysis, footage from only two (2) of the four (4) cameras was analysed. The remaining footage is available for analysis at a later stage if required.

5 Surveys with the cameras set to this position allowed a sample size of ~25% coverage of the site.

6 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.

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

8 Surveys were successful in characterising the bird and mammal species present in the Dundalk Bay survey area. A total of 11,277 birds of 35 species and 23 marine mammals were counted and identified to species. Most of the birds observed were waders (oystercatcher, dunlin, knot) and differences in the spatial abundance between species were found. In general, the northern half of the site was used by more birds and more species, though the southern half of the site was commonly used by several species, often with high abundances.

9 Analyses of spatial abundances provided robust population size predictions (with confidence intervals) and generally showed that most of the SPA qualifying features that had apparently increased were waterfowl (particularly teal *Anas crecca* and wigeon *A. penelope*) and those that had apparently decreased were waders (particularly lapwing *Vanellus vanellus*, grey *Pluvialis squaterola* and golden plovers *P. apricaria*). It was noted that care needs to be applied in comparing citation population size with snapshot surveys, due to important differences between the datasets.

1 Introduction

10 HiDef Aerial Surveying Limited undertook a series of seabird surveys in four areas of shallow inshore waters off the east coast of Ireland between October 2018 and March 2019. These were commissioned by the Marine Institute, the state agency responsible for marine research, technology development and innovation in Ireland.

11 These surveys were designed to provide data on the abundance and distribution of seabirds, with an emphasis on common scoter, in waters off the east coast of Ireland from Dundalk to Malahide in the north and Carnsore to Wicklow in the south. In addition, population estimates of wading birds utilising intertidal habitats in Dundalk Bay was included. These data were acquired using digital aerial survey methods to provide raw data, imagery, GIS files and, where appropriate, population estimates for each species. Counts of marine mammals by species and of fishing vessels encountered opportunistically during the survey were also included.

12 HiDef designed the survey methodology to provide information suitable for robust estimation of the abundance and distribution of shorebirds within the surveyed areas.

13 This report provides results from a survey undertaken in January 2019. Counts of observed animals, maps of locations of counted animals, modelled density surface distribution maps and abundance estimates with confidence estimates are provided.

2 Methods

2.1 Survey flights

14 A series of strip transects were flown in January 2019, following the methodology agreed in November 2018 (document reference: HP00098-001).

15 HiDef designed a survey that placed transects at 750m apart across the survey area at Dundalk Bay Figure 1.

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

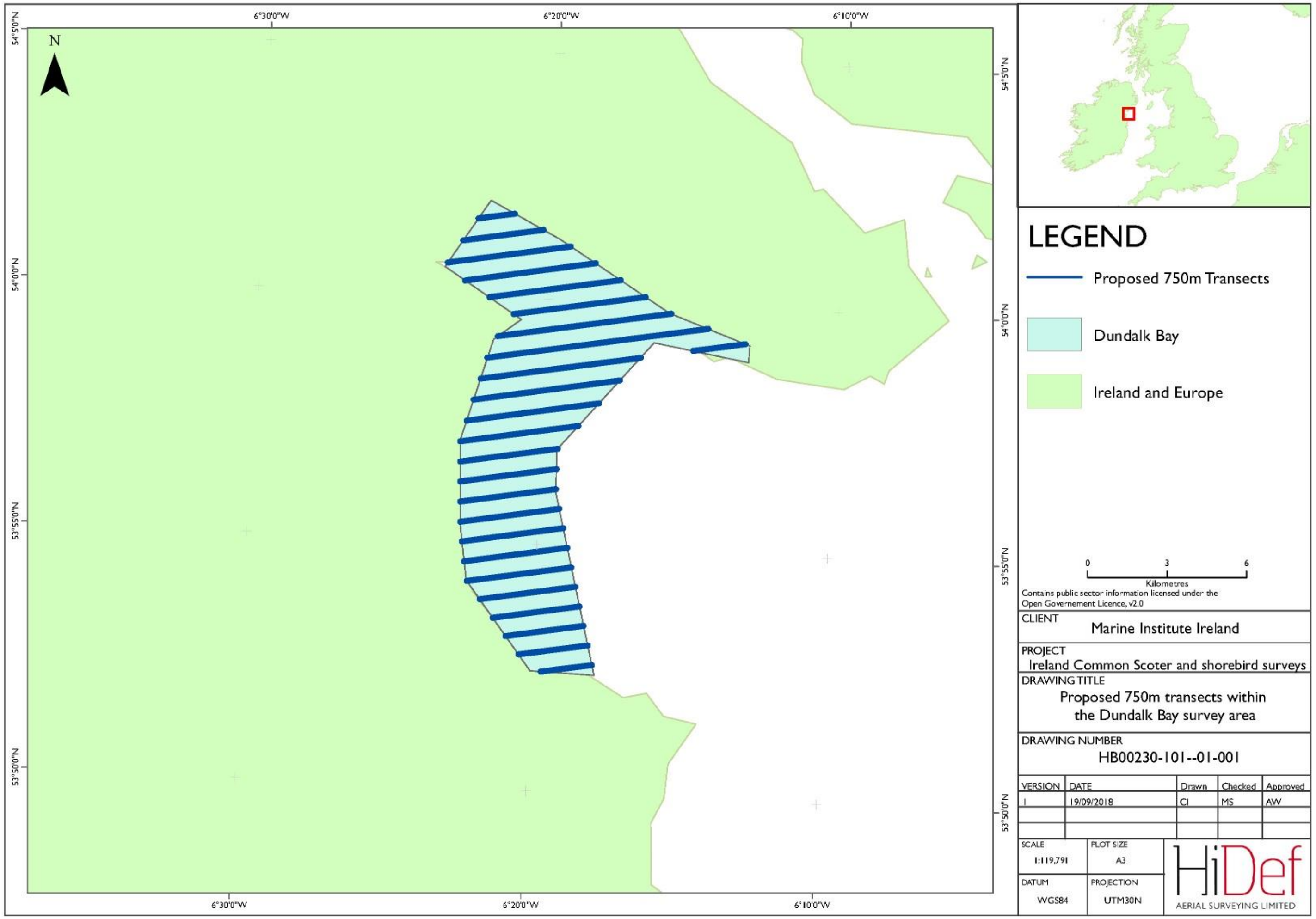
17 Surveys were undertaken using an aircraft equipped with four (4) HiDef Gen II cameras with sensors set to a resolution of 1.7cm Ground Sample Distance (GSD). Each camera sampled a strip of 110 m width, separated from the next camera by ~20 m, thus providing a combined sampled width of 440 m within a 500 m overall strip. Typically, a camera resolution of 2cm would be used for seabird surveys, but the resolution was increased to help improve species detection and identification of smaller wading bird species, resulting in a reduced transect width from typical offshore surveys.

18 To provide 25% coverage of the site, while ensuring an adequate number of transects, HiDef agreed with Marine Institute that data from two (2) cameras would be processed. Not only does this ensure that Marine Institute has a survey designed with sufficient coverage and number of transects, but it also offers the potential for the subsequent review and identification of additional data without undertaking additional survey flights, should unusual observations be made, or should additional counts be necessary.

19 The surveys were flown along the transect pattern shown in **Error! Reference source not found.** at a height of approximately 465m above sea level (ASL) (~1520'). Flying at this height ensures that there is low risk of flushing those species which have been proven to be easily disturbed by aircraft noise (Thaxter *et al.* (2016) recommended a minimum flight altitude of 500 m ASL).

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

Figure 1 **Survey design showing Dundalk Bay survey area with 750 m spaced transects**



2.2 Data Review and Object Detection

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

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

23 An object is only recorded where it reaches a reference line (known as 'the red line') which defines the true transect width of 110m for each camera. By excluding objects that do not cross the red line, biases to abundance estimates caused by flux (movement of objects in the video footage relative to the aircraft, such as 'wing wobble') are eliminated.

2.3 Object Identification

24 Images marked as requiring further analysis were reviewed by 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.

25 At least 20% of all objects were subjected to an external QA process. If less than 10% disagreement is not attained then corrective action is initiated: if appropriate, the failed reviewer's data is discarded and the data re-reviewed. Any disputed identifications are passed to a third-party expert ornithologist for a final decision[1].

26 All objects are assigned to a species group and where possible, each of these then further identified to species level. The species identifications are given a confidence rating of possible, probable or definite. Surfacing behaviour was defined as any surfacing behaviour that occurred while the non-avian animal was visible. However, for the purposes of calculating availability bias, harbour porpoise surfacing behaviour was also classified as if the animal's dorsal fin was above the water in the frame nearest to the 'red line'.

27 Additional information was recorded for each bird on their basic behaviour (whether the bird was sitting, loafing on land or other objects or flying; in the latter case the direction of travel was also recorded. More detail was recorded where possible on foraging behaviour, approximate age and sex and any other details of interest.

2.4 Final processing

28 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.

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

2.5 Data analysis

2.5.1 Data treatment

29 After baseline numbers were established, data were processed for estimating abundance and distribution of the key species and species groups. Confidence levels, giving high and low extremes, were produced for each species as part of statistical working. 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. Where identification to species was not possible analysis was carried out at species group level.

30 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 or remain as 'Shearwater / auk species' if no species level identification was recorded. Where no identification was made this is presented as NO_ID in the result tables.

2.5.2 Abundance Estimates

31 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, all clipped to within the defined study area, gives a point estimate of the density of that species for the site. The density of animals at the site (and hence the population size), the standard deviation, 95% confidence intervals (CI) and coefficient of variance (CV) are then estimated using a non-parametric bootstrap method with replacement (Buckland *et al.*, 2001).

32 The upper and lower 95% confidence intervals were performed by way of a blocked bootstrapping technique in order to ensure equal transect effort was sampled across each iteration. This was done by using transect ID as the sampling unit with replacement, and then randomly sampling until the total length of the sampled transects equalled approximately the same length as the total survey length. A total of 10,000 bootstrap iterations were performed from which we calculated the mean and standard deviation of the sampled means, as well as the relative standard error as defined by the standard deviation divided by the mean. Data were processed in the R programming language (version 3.4.3) and code can be provided on request. For most species these abundance estimates relate to absolute abundance, but for diving species (auks and marine mammals) the abundance relates to relative abundance. In Section 2.6.4 we describe our method for taking account of availability, which provides a reasonable measure of absolute abundance.

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

2.5.3 Density Mapping

34 The density surface 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.

35 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.

36 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.

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

38 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 birds, but mainly happens for very sparse distributions. In the case of sparse distributions, the ‘flat’ map does not necessarily mean that the true underlying distribution is ‘flat’; it could mean that the data doesn’t contain enough evidence to determine what the underlying distribution is. It is therefore useful to refer back to the population estimates for the corresponding map when looking at these ‘flat’ densities; we have also overlaid the relevant observations as dots to help with interpretation of the maps. In extreme cases, the maps were not included in the results section, and the data presented as dot maps. This occurred where there were fewer than five observations of the species or species group in question.

3 Results

3.1 Survey effort

39 The date, number of transects and survey effort (as expressed by length of transects) undertaken in January 2019 are shown in Table 1. The number of transects and the total length of transects are those used in subsequent analysis.

40 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.

Table 1 Survey effort across Dundalk Bay in January 2019

Survey date	Survey Number	Number of transects analysed	Total length of transects analysed (km)	Area covered (km^2)
17 January 2019	1	24	101.13	25.28

3.2 Survey results

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

42 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. 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 five (5) surveys were:

Table 2 Survey identification rates at Dundalk Bay in January 2019

Survey date	ID rate (%)
17 January 2019	**95.5%**

Table 3 Number of objects detected during each survey assigned to species level January 2018. Survey number dates can be observed in Table 1.

Species	Scientific Name	Number of detections
Mute swan	*Cygnus olor*	4
Brent goose	*Branta bernicla*	217
Shelduck	*Tadorna tadorna*	138
Wigeon	*Anas penelope*	317
Teal	*Anas crecca*	822
Mallard	*Anas platyrhynchos*	169
Pintail	*Anas acuta*	61
Common scoter	*Melanitta nigra*	23
Goldeneye	*Bucephala clangula*	5
Red-breasted merganser	*Mergus serrator*	86
Red-throated diver	*Gavia stellata*	24
Cormorant	*Phalacrocorax carbo*	12
Little egret	*Egretta garzetta*	25
Grey heron	*Ardea cinerea*	1
Great crested grebe	*Podiceps cristatus*	28
Kestrel	*Falco tinnunculus*	1
Oystercatcher	*Haematopus ostralegus*	2,478
Ringed plover	*Charadrius hiaticula*	12
Golden plover	*Pluvialis apricaria*	411
Grey plover	*Pluvialis squatarola*	51
Lapwing	*Vanellus vanellus*	429
Knot	*Calidris canutus*	1,209
Sanderling	*Calidris alba*	3
Dunlin	*Calidris alpina*	1,834
Black-tailed godwit	*Limosa limosa*	283
Bar-tailed godwit	*Limosa lapponica*	1,044
Curlew	*Numenius arquata*	116
Greenshank	*Tringa nebularia*	4
Redshank	*Tringa totanus*	397
Black-headed gull	*Chroicocephalus ridibundus*	599
Common gull	*Larus canus*	390
Lesser black-backed gull	*Larus fuscus*	5
Herring gull	*Larus argentatus*	49
Great black-backed gull	*Laris marinus*	1

Species	Scientific Name	Number of detections
Hooded Crow	*Covus cornix*	8
Harbour seal	*Phoca vitulina*	21
Total		**11,277**

Table 4 Number of objects with no species ID detected during each survey assigned to species groups in January 2019. Survey number dates can be observed in Table 1.

Species group (No ID)	1
Duck species	14
Goose species	3
Grebe species	1
Gull species	10
Seal species	1
Small gull species	13
Wader species	488
Total	**530**

3.3 Abundance estimates

43 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 6. Highlights only, for the key species observed, are described in this section. Full details are provided in the tables and Figure 2 to Figure 13.

44 Low density estimates of common scoter were recorded at 0.12 birds/km^2 equating to 10 birds (±95% CI 0 – 27) in the survey.

Table 5 Abundance and density estimates of species groups in the survey area during Survey 1 on 17 January 2019

Category	Density estimate (birds/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	466.16	36056	23735	50643	8549	23.71%
All non-avian animals	0.89	70	0	191	62	88.72%
Species group						
Goose species	8.59	665	0	1937	641	96.37%
Swan species	0.16	13	0	36	12	98.22%
Duck species	63.76	4932	2592	7729	1586	32.16%
Diver species	0.56	44	12	85	23	51.54%
Cormorant species	0.48	37	15	62	15	40%
Heron species	1.02	79	51	110	19	23.67%
Grebe species	0.55	43	10	83	23	52.08%
Raptor species	0.04	4	0	9	3	93.68%
Wader species	343.63	26578	14435	41820	8364	31.47%
Small gull species	39.06	3021	2077	4292	679	22.47%
Black-backed gull species	0.04	3	0	9	3	101%
Large gull species	1.52	118	73	164	28	23.43%
Gull species	1.11	86	49	128	24	27.55%
Passerine species	0.31	25	12	39	9	35.98%

Category	**Density estimate (birds/km²)**	**Population estimate (number)**	**Lower 95% confidence limit of population (number)**	**Upper 95% confidence limit of population (number)**	**Standard deviation of population estimate (number)**	**CV (%)**
Seal species	0.87	68	0	190	61	89.87%

Table 6 Abundance and density estimates of species in the survey area during Survey 1 on 17 January 2019

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Mute swan	0.15	12	0	36	12	99.83%
Brent goose	8.66	671	0	1932	624	93.06%
Shelduck	5.35	415	121	761	189	45.54%
Wigeon	12.5	968	263	1863	495	51.12%
Teal	32.94	2548	1036	4464	1067	41.88%
Mallard	6.68	517	251	899	204	39.29%
Pintail	2.47	192	39	383	103	53.39%
Common scoter	0.12	10	0	27	10	97.01%
Goldeneye	0.2	16	0	34	11	70.06%
Red-breasted merganser	3.26	253	36	510	144	56.87%
Red-throated diver	0.55	43	10	88	24	55.17%
Cormorant	0.47	37	13	62	16	41.21%
Little egret	0.99	77	46	111	20	26.03%
Grey heron	0.04	4	0	9	4	101.01%
Great crested grebe	0.55	43	10	85	23	54.23%
Kestrel	0.04	4	0	9	3	92.61%
Oystercatcher	100.77	7794	3239	14029	3350	42.98%

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Ringed plover	0.47	37	3	82	26	70.15%
Golden plover	15.83	1225	13	3628	1191	97.24%
Grey plover	2.01	156	77	245	52	33.43%
Lapwing	16.85	1304	120	3167	1008	77.33%
Knot	50.17	3881	123	8534	2358	60.76%
Sanderling	0.12	10	0	28	9	96.72%
Dunlin	71.72	5548	2435	8989	2046	36.87%
Black-tailed godwit	11.15	863	295	1603	406	47.08%
Bar-tailed godwit	41.22	3188	1997	4506	775	24.28%
Curlew	4.48	347	146	588	137	39.36%
Greenshank	0.16	13	3	25	7	55.61%
Redshank	15.63	1210	840	1629	241	19.92%
Black-headed gull	23.48	1817	964	3092	685	37.70%
Common gull	15.11	1169	845	1505	201	17.15%
Lesser black-backed gull	0.16	13	0	31	10	78.51%
Herring gull	1.87	145	100	191	28	19.11%
Great black-backed gull	0.04	4	0	10	3	96.37%
Hooded crow	0.31	25	12	40	9	36.40%
Harbour seal	0.85	66	0	189	62	93.04%

3.4 Distribution patterns and seasonal abundance

45 The distribution patterns 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 km^2 (**Figure 2** to **Figure 28**).

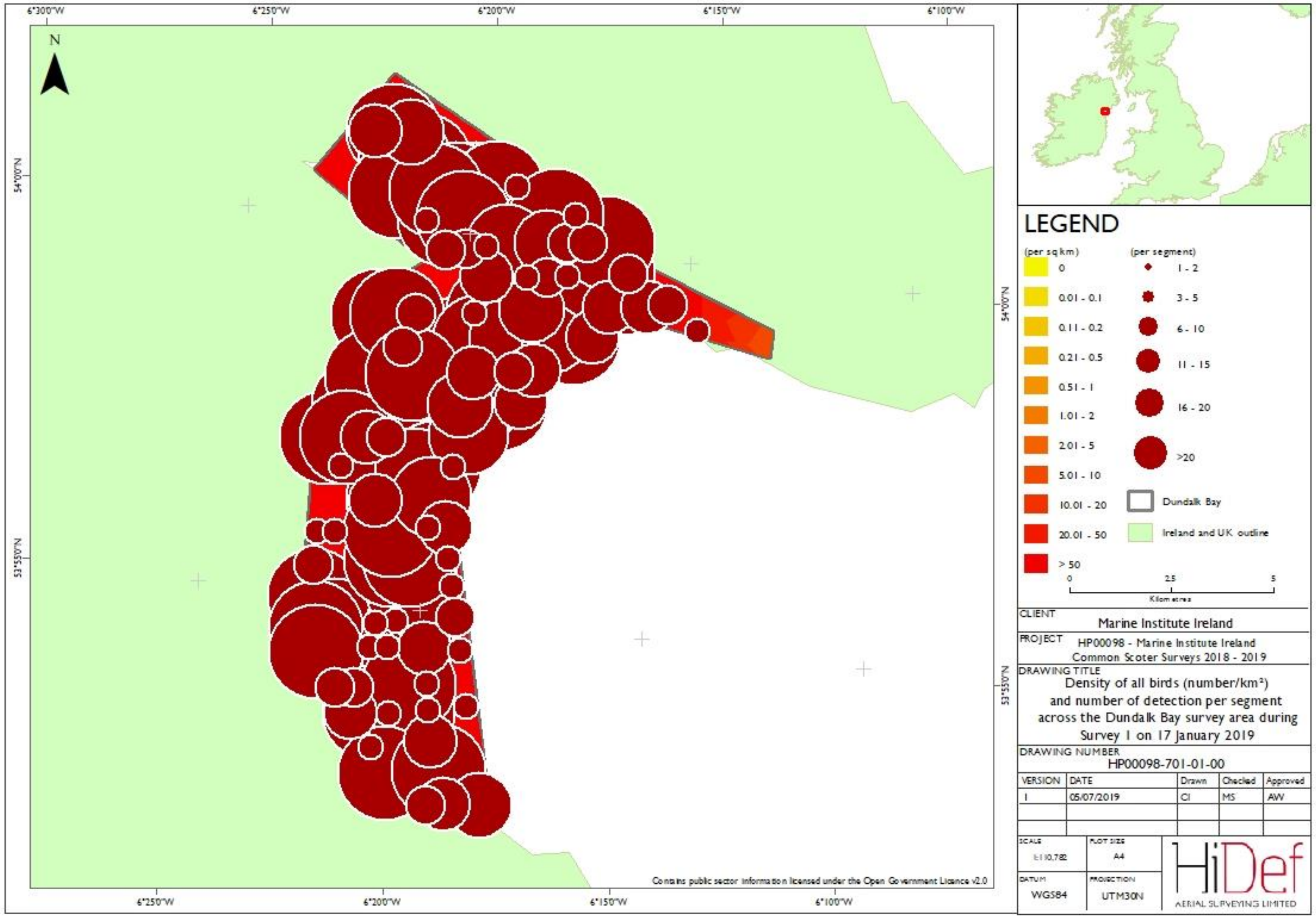
46 Species or species groups for which there were few observations are presented as dot maps only (**Figure 30** and **Figure 34**).

47 Anthropogenic activity is presented as a dot map for reference only (**Figure 35**).

3.4.1 Distribution and seasonal abundance for all bird species

48 Bird distribution varied across the survey area in Dundalk Bay with 11,256 bird observations recorded (**Figure 2**).

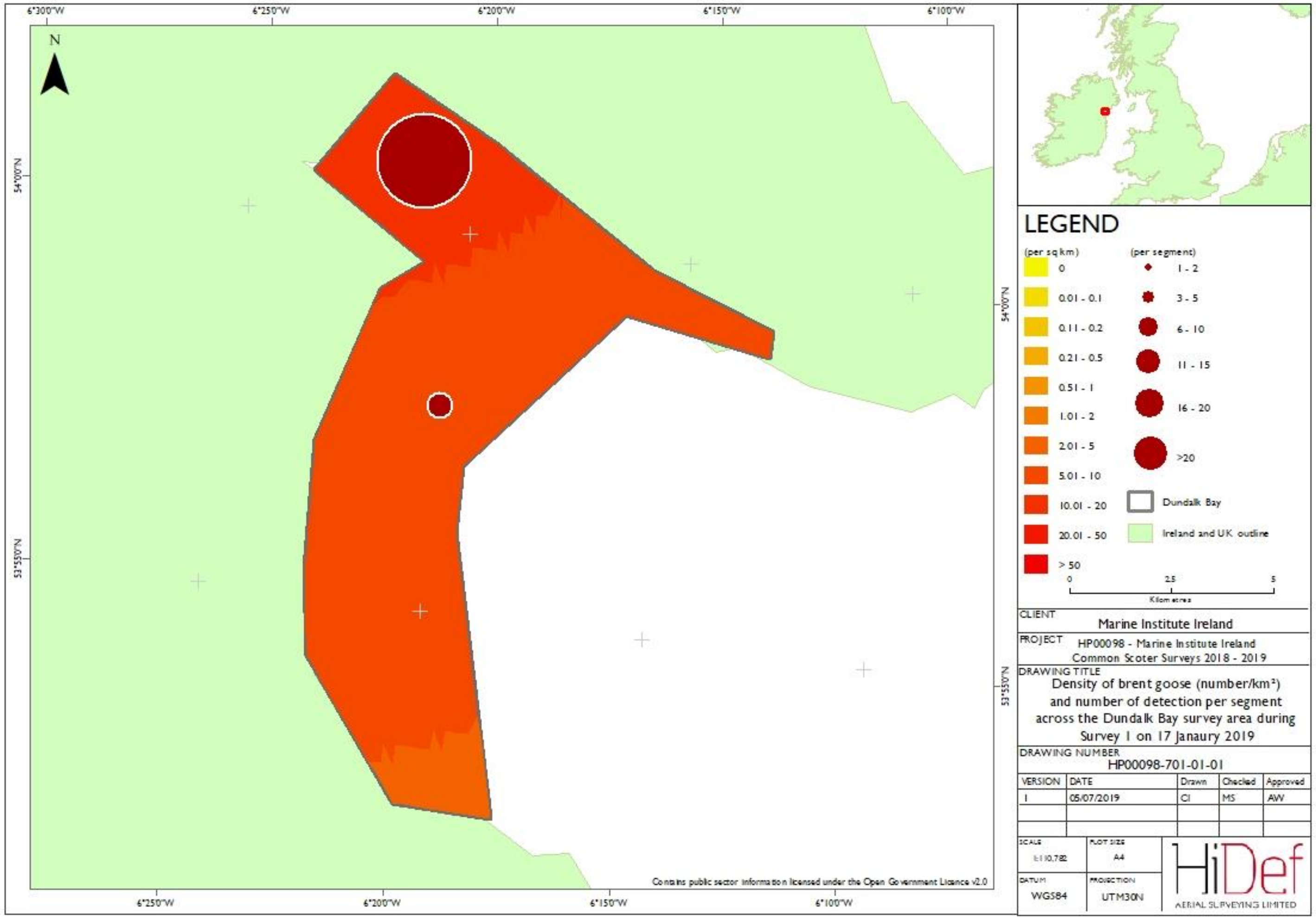
Figure 2 **Density of all birds (number/km²) and number of detections per segment during Survey 1 on 17 January 2019**



3.4.2 Distribution and seasonal abundance for Brent goose

49 Brent geese were concentrated in the very north of the survey area (**Figure 3**) and 217 observations were recorded during the surveys. It was not possible to determine the race of individuals from the angle of view in this survey.

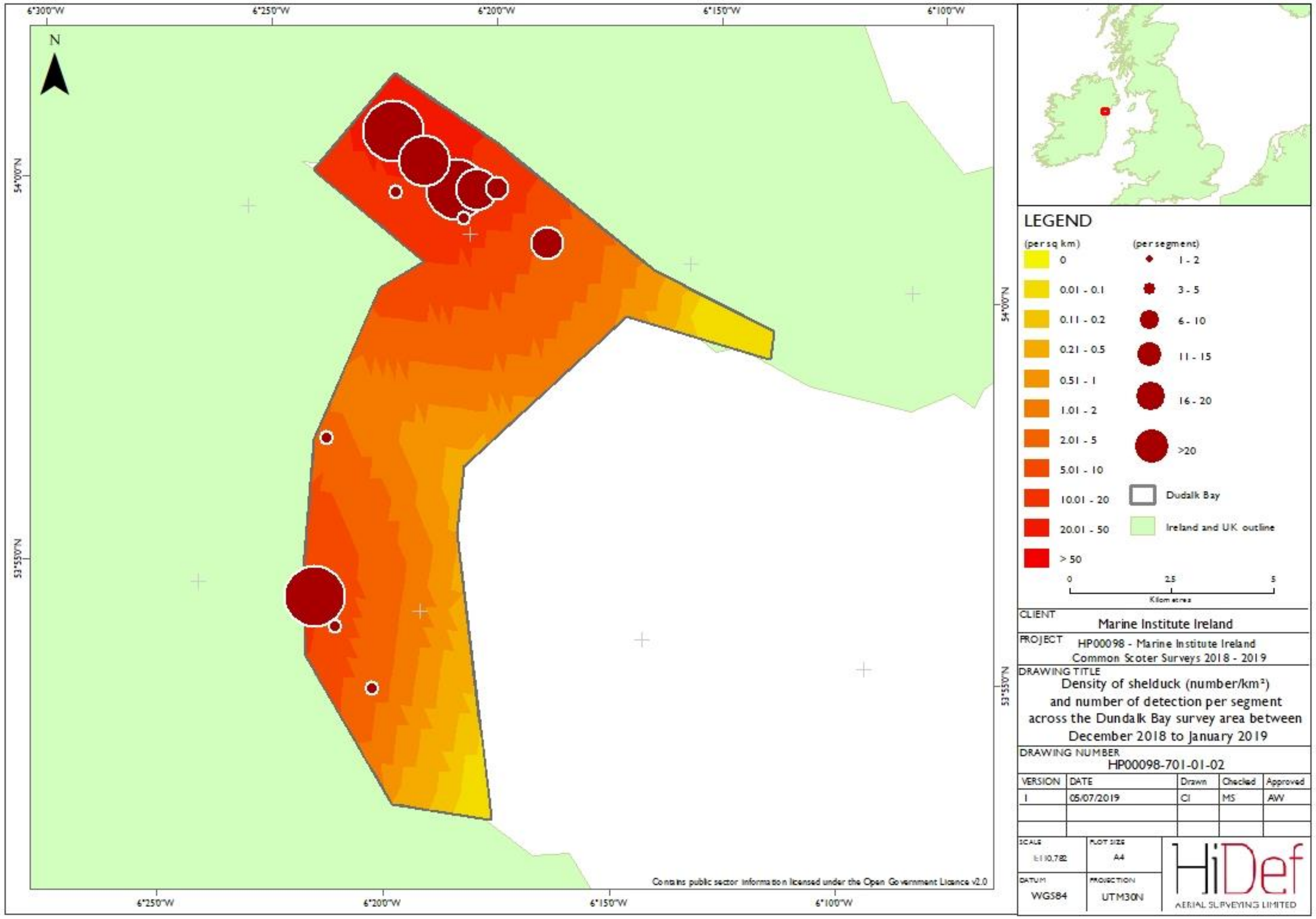
Figure 3 Density of Brent goose (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.3 Distribution and seasonal abundance for shelduck

50 Shelduck distributions were mainly concentrated in the north and west of the Dundalk Bay survey area (**Figure 4**).

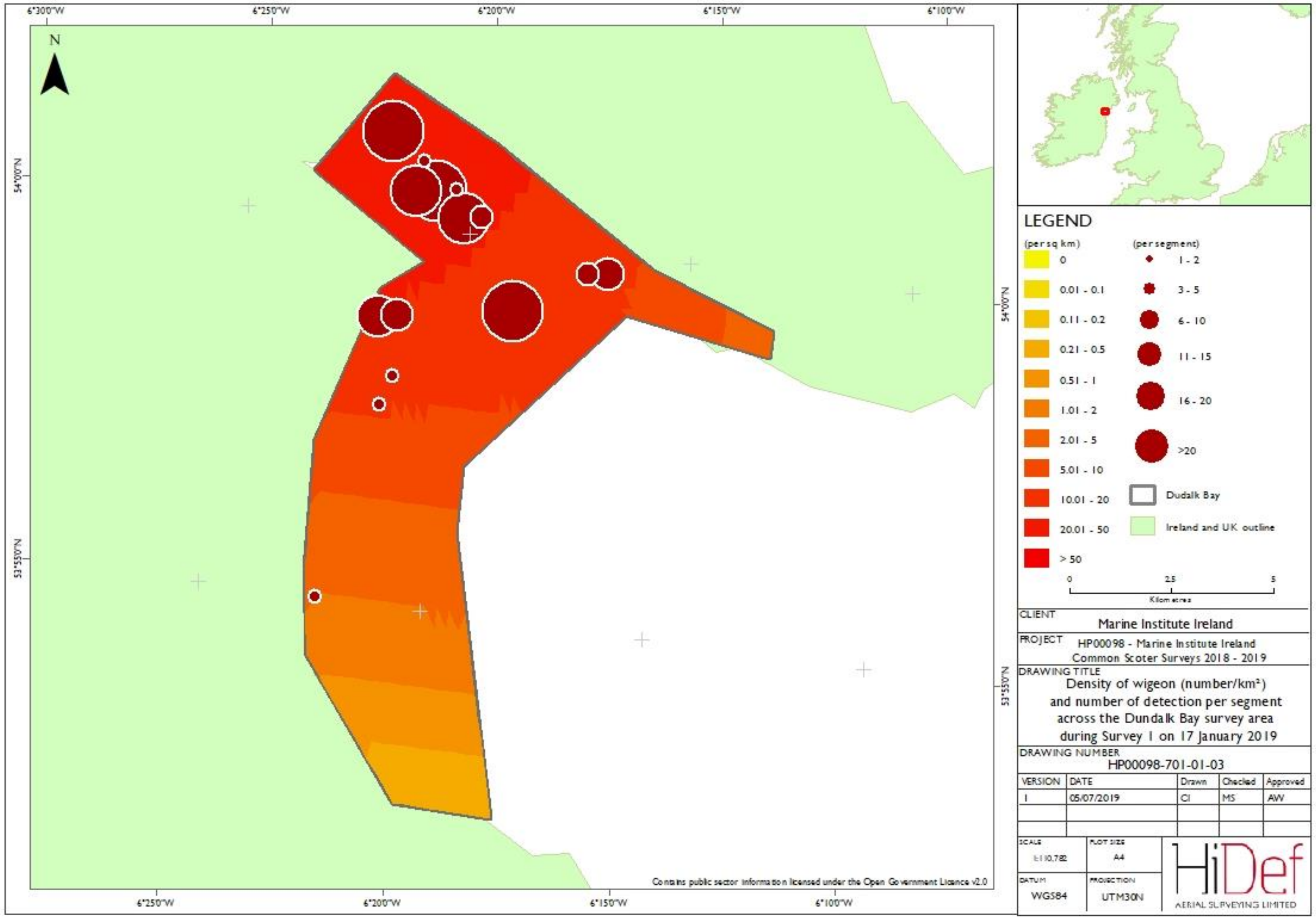
Figure 4 Density of shelduck (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.4 Distribution and seasonal abundance for wigeon

51 There was a total of 317 wigeon observed. These were strongly concentrated in the northern half of the survey area (**Figure 5**).

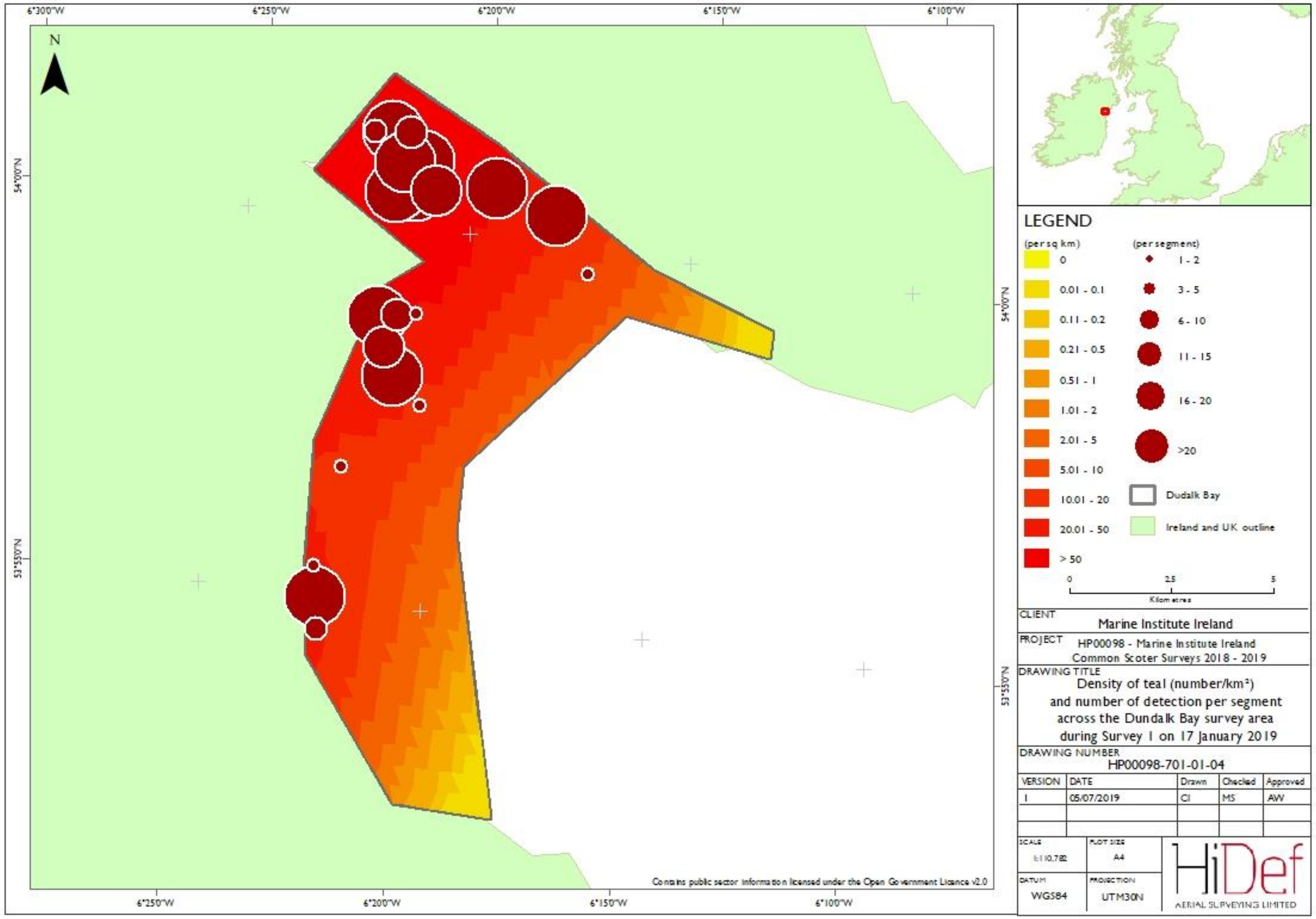
Figure 5 **Density of wigeon (number/km²) and number of detections per segment during Survey 1 on 17 January 2019**



3.4.5 Distribution and seasonal abundance for teal

52 A high number of teal was recorded, with 822 birds counted. Birds were mainly concentrated on the landward sides of the bay, with more birds in the north than the south (**Figure 6**).

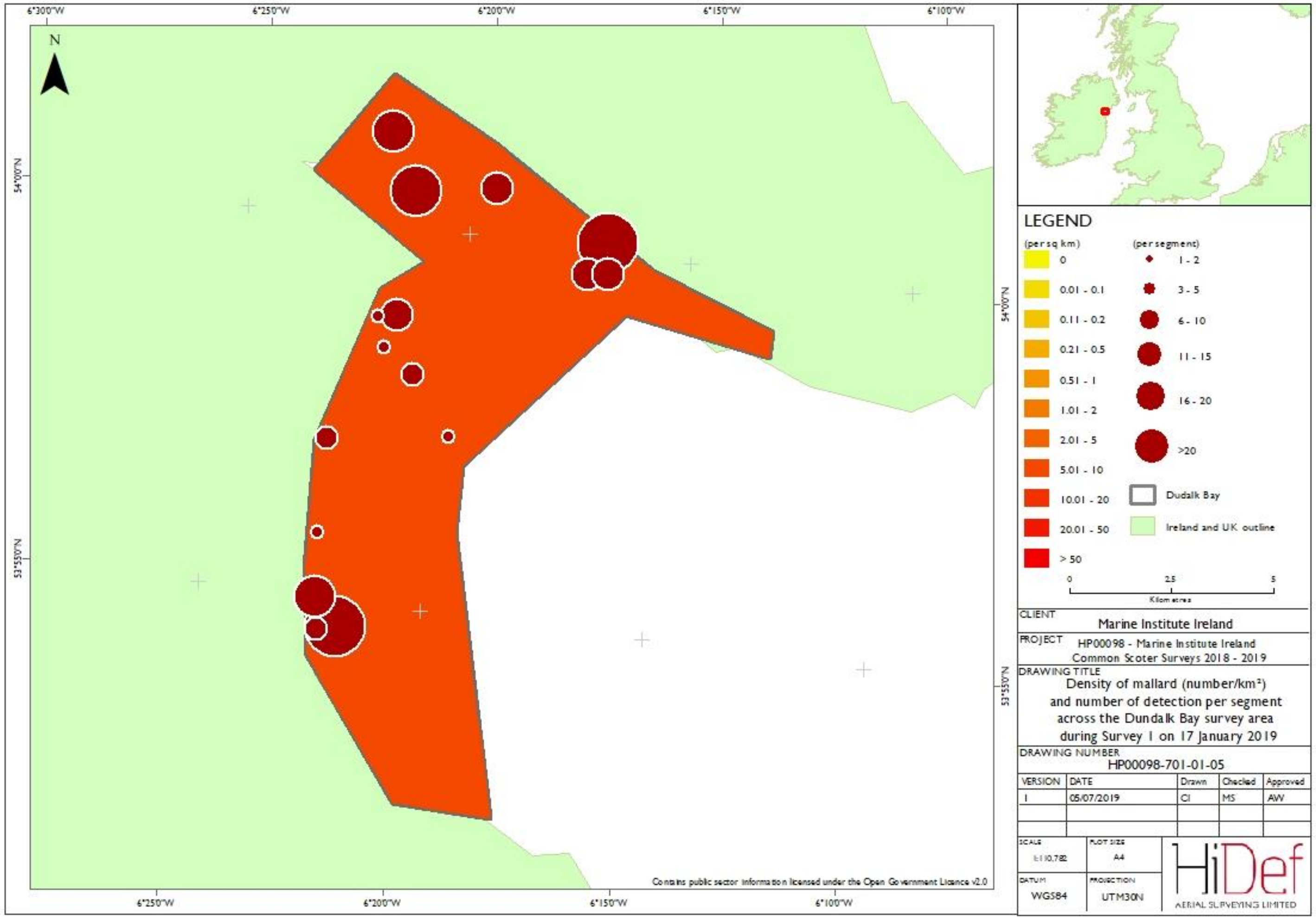
Figure 6 Density of teal (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.6 Distribution and seasonal abundance for mallard

53 Mallards were more widely distributed across the survey area than other duck species with observations in the west, north and north-west (**Figure 7**).

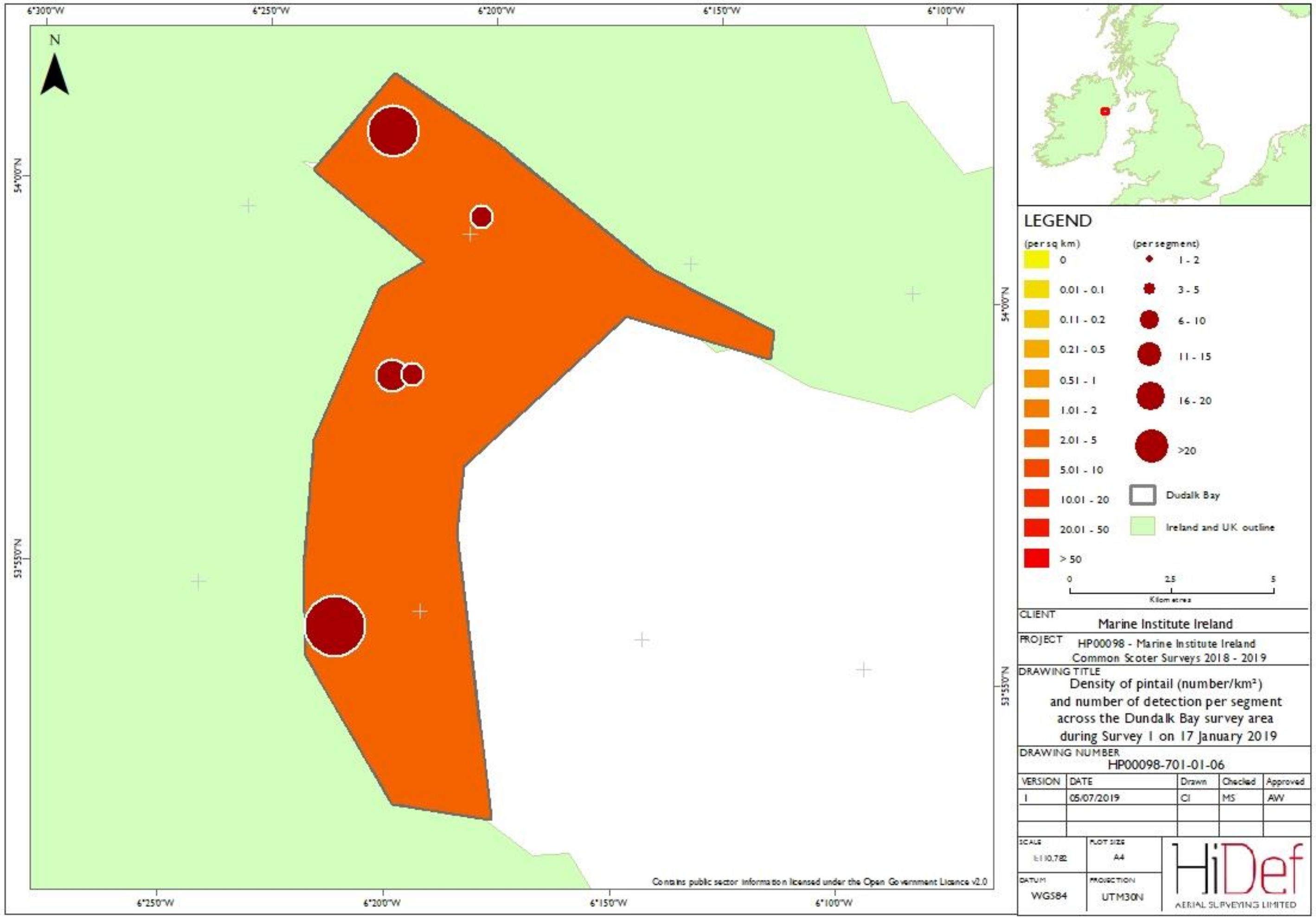
Figure 7 Density of mallards (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.7 Distribution and seasonal abundance for pintail

54 Pintail were mainly concentrated in the north and west of the survey area (**Figure 8**).

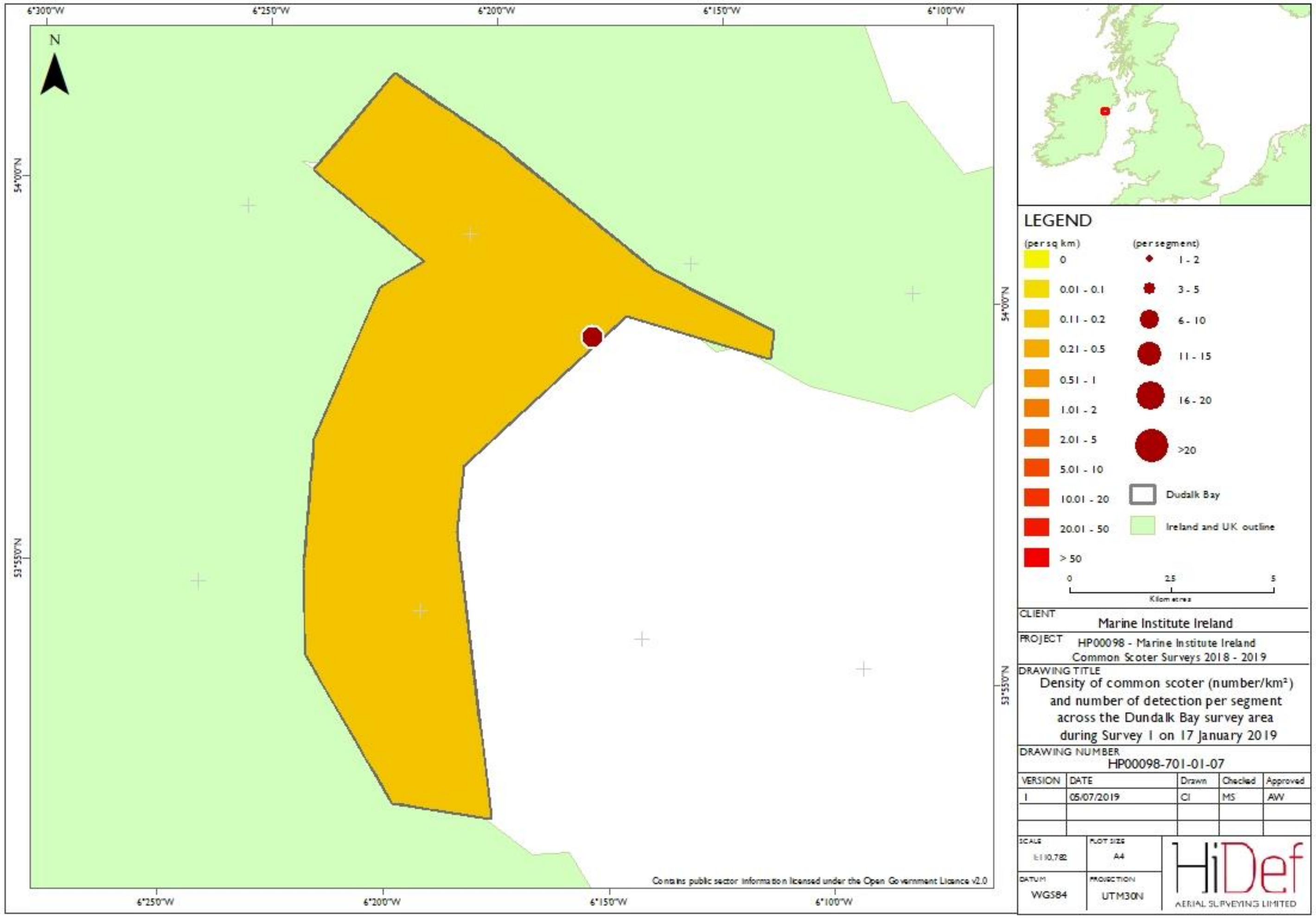
Figure 8 Density of pintail (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.8 Distribution and seasonal abundance for common scoter

55 Common scoter numbers were relatively low with only 23 observations of this seaduck on the eastern edge of the survey area (**Figure 9**).

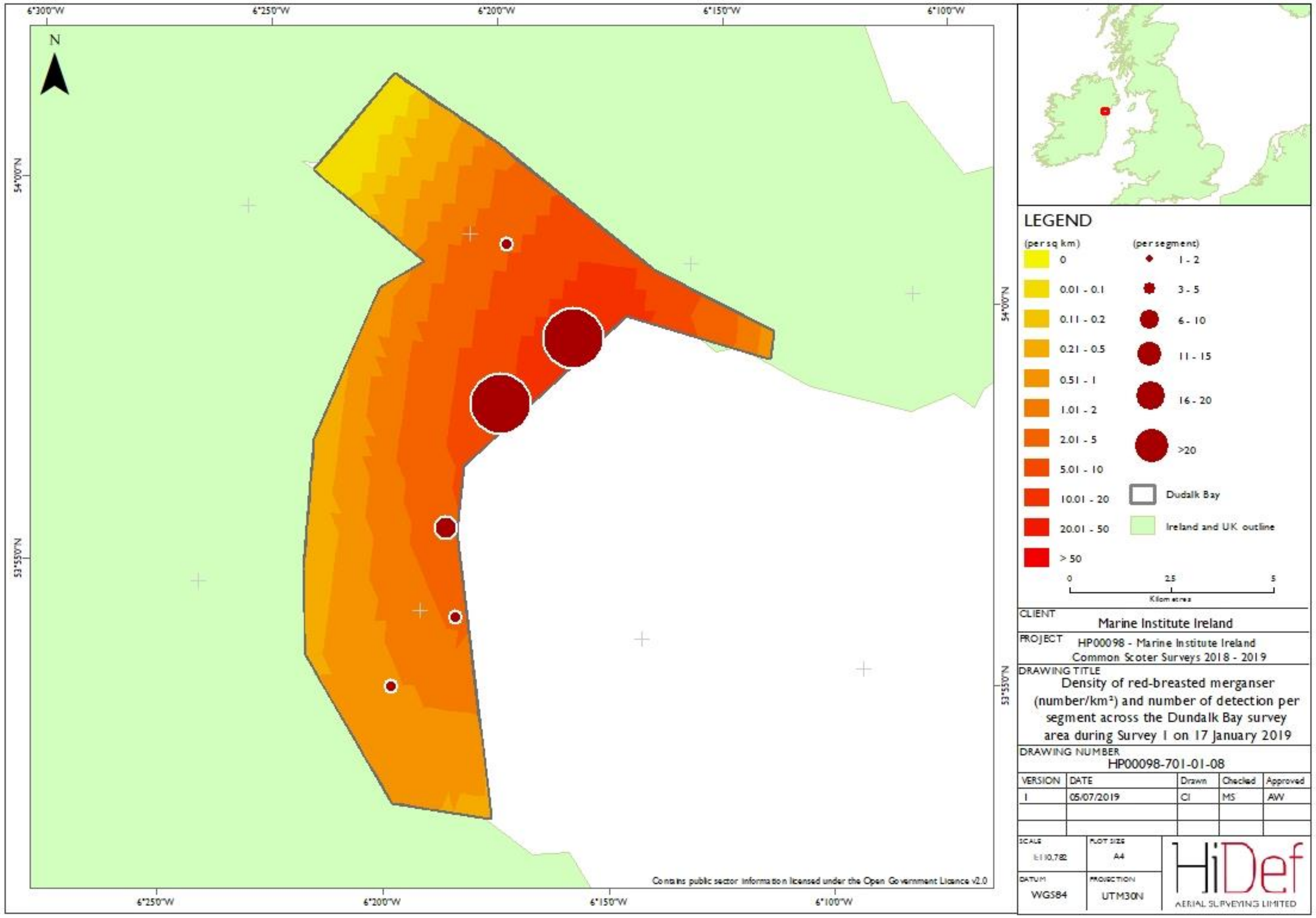
Figure 9 Density of common scoter (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.9 Distribution and seasonal abundance for red-breasted merganser

56 Red-breasted mergansers were concentrated on the eastern, seaward, side of survey area (**Figure 10**).

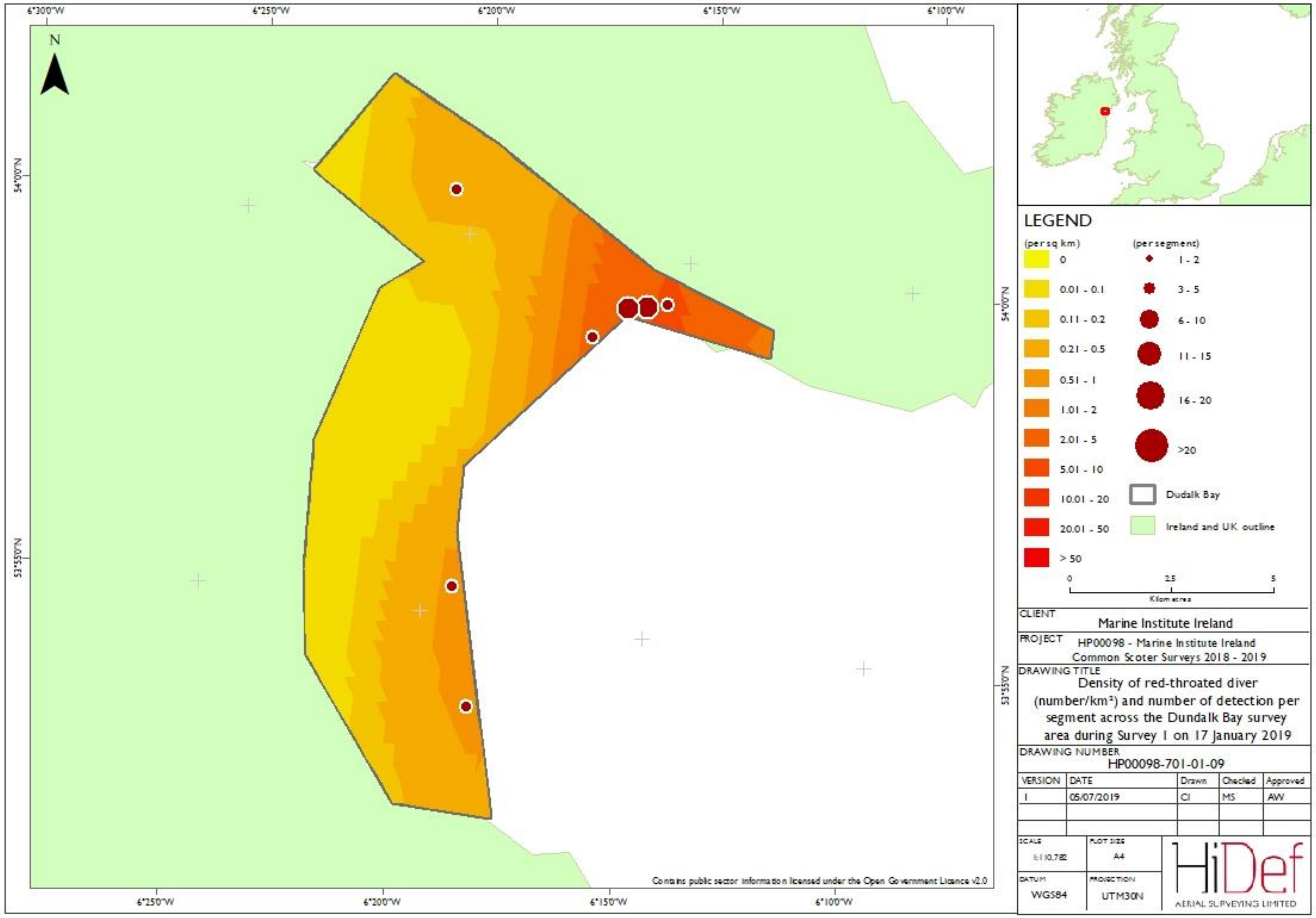
Figure 10 Density of red-breasted mergansers (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.10 Distribution and seasonal abundance for red-throated diver

57 Red-throated divers were concentrated on the eastern, seaward, side of the survey area, with the exception of a single record to the north-west. (**Figure 11**).

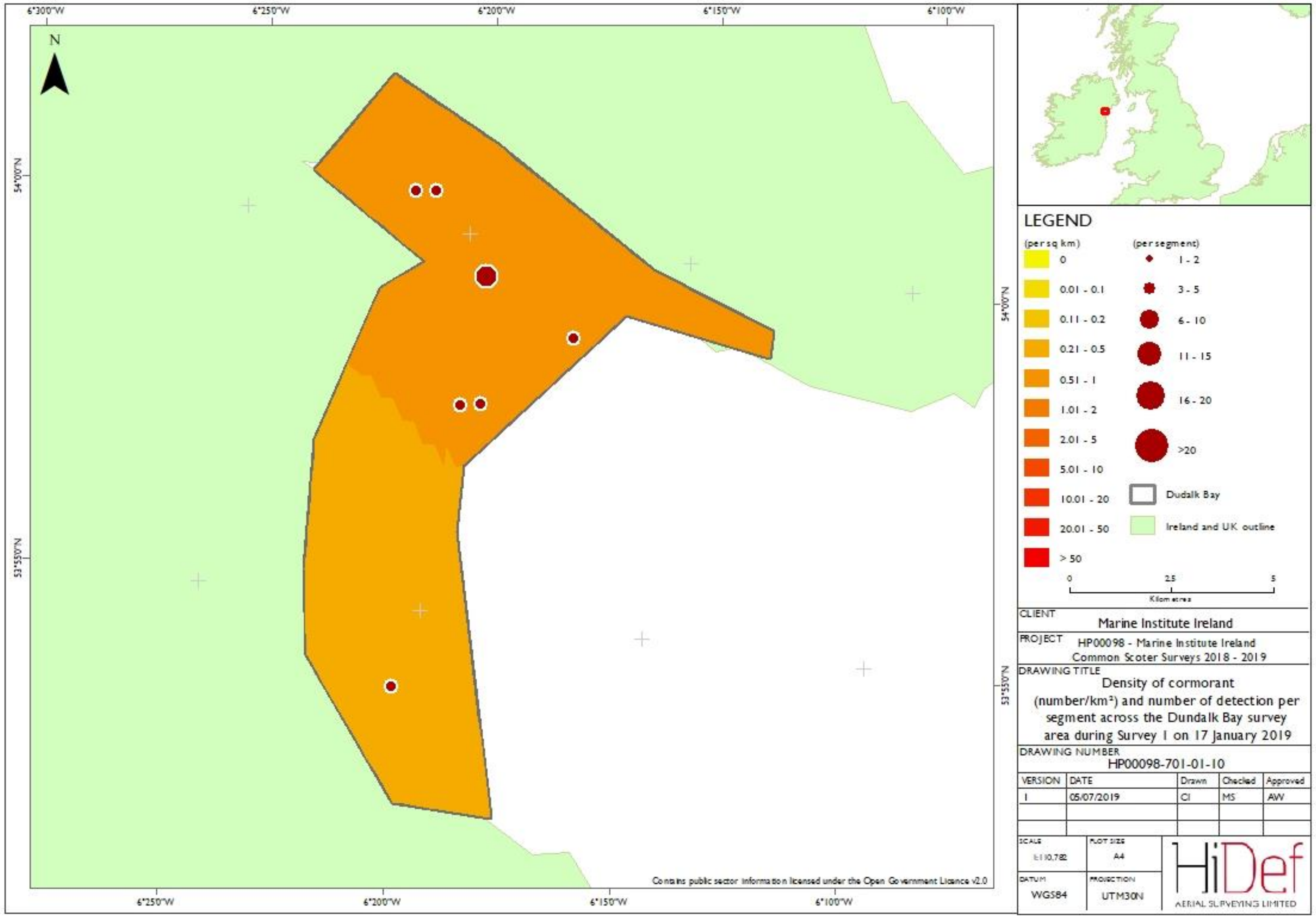
Figure 11 Density of red-throated divers (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.11 Distribution and seasonal abundance for cormorant

58 Cormorants were almost entirely in the northern half of the survey area, with only a single record in the southern half (**Figure 12**).

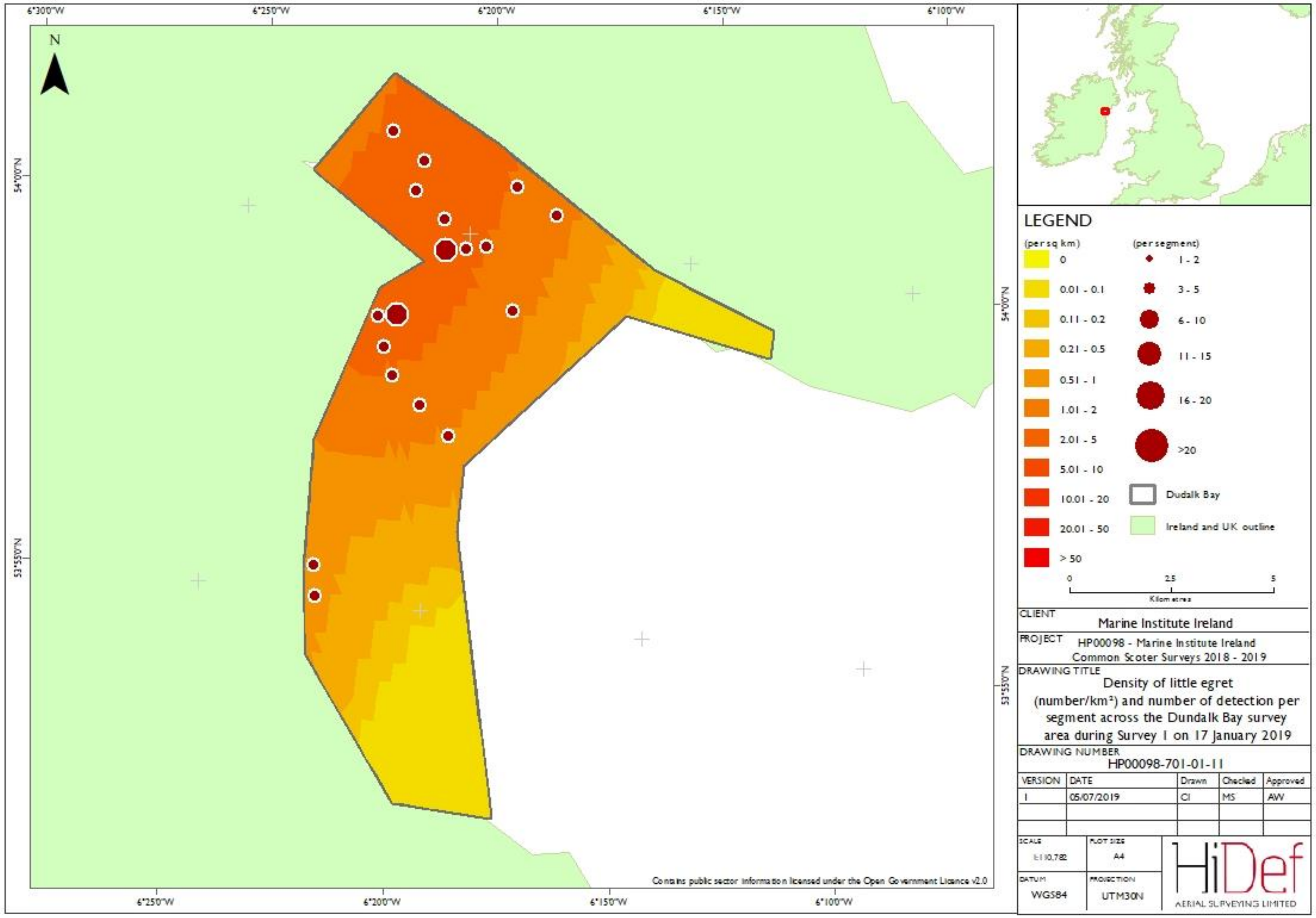
Figure 12 Density of cormorants (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.12 Distribution and seasonal abundance for little egret

59 Little egrets were concentrated in the northern half of the survey area (**Figure 13**).

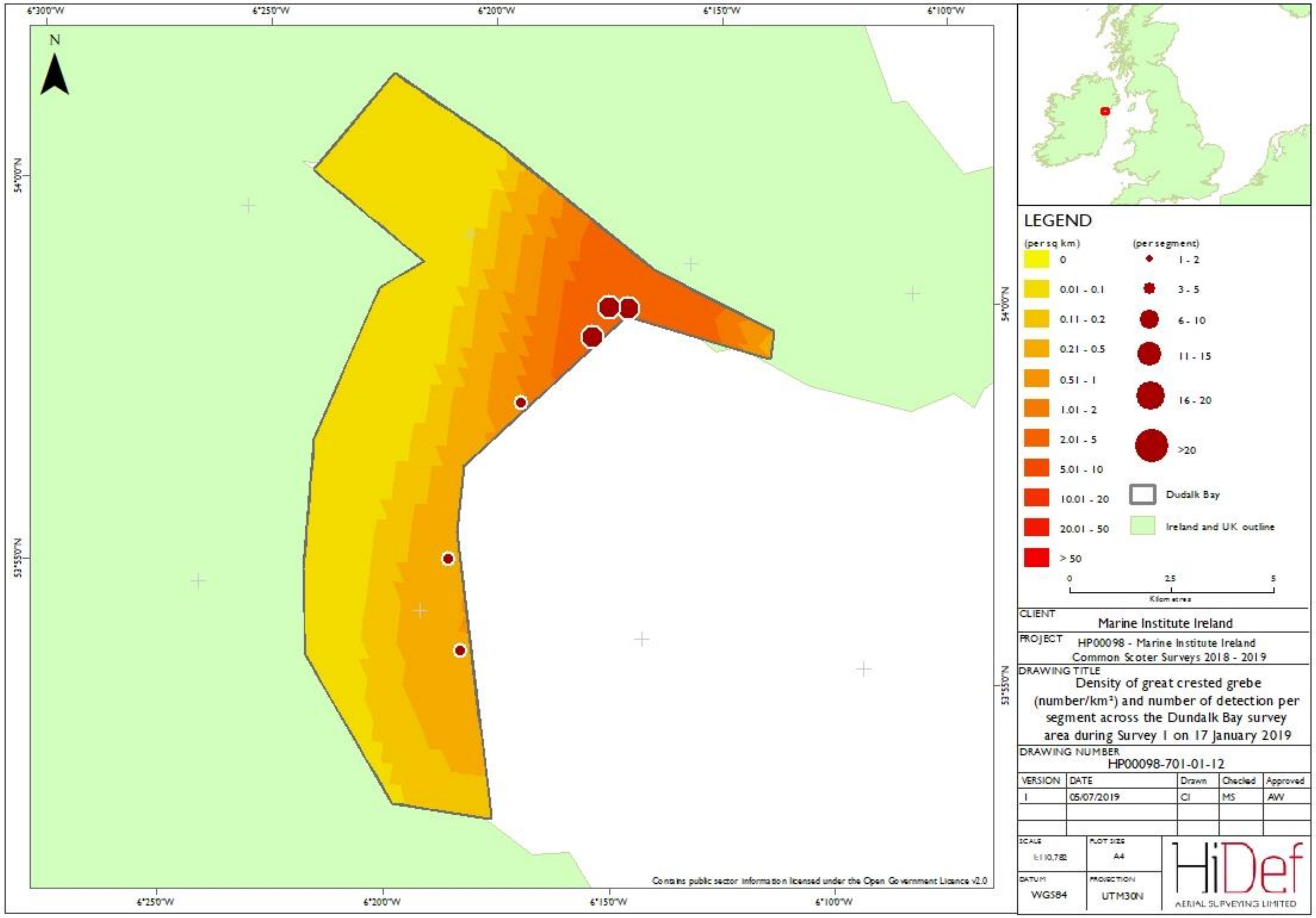
Figure 13 Density of little egrets (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.13 Distribution and seasonal abundance for great crested grebe

60 Great crested grebes were found on the eastern, seaward, side of the Dundalk Bay survey area (**Figure 14**). They were particularly on the northern coast of the bay, in a similar location to red-throated diver concentrations.

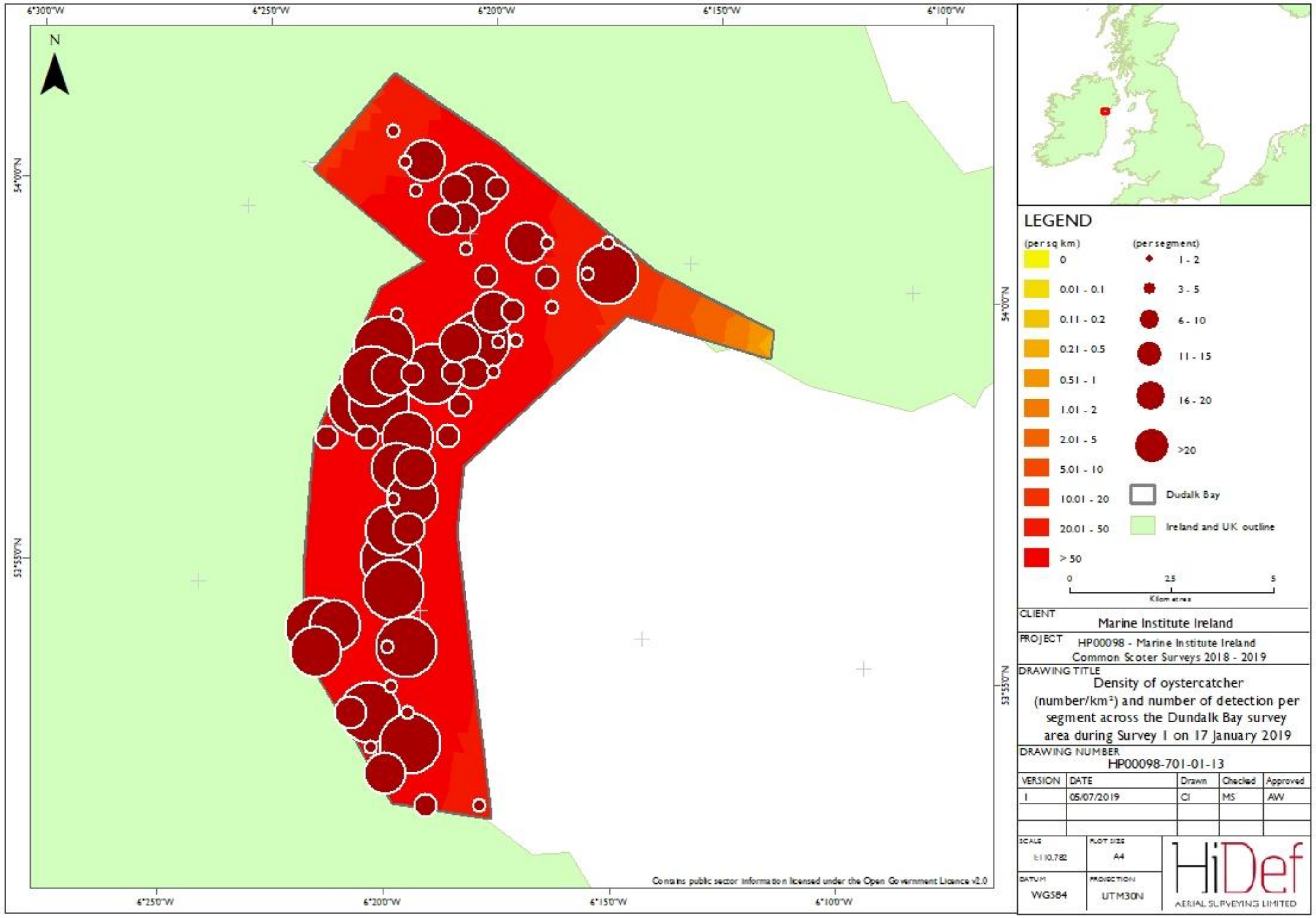
Figure 14 **Density of great crested grebes (number/km²) and number of detections per segment during Survey 1 on 17 January 2019**



3.4.14 Distribution and seasonal abundance for oystercatcher

61 Oystercatchers were numerous and evenly distributed across the survey area in Dundalk Bay (**Figure 15**).

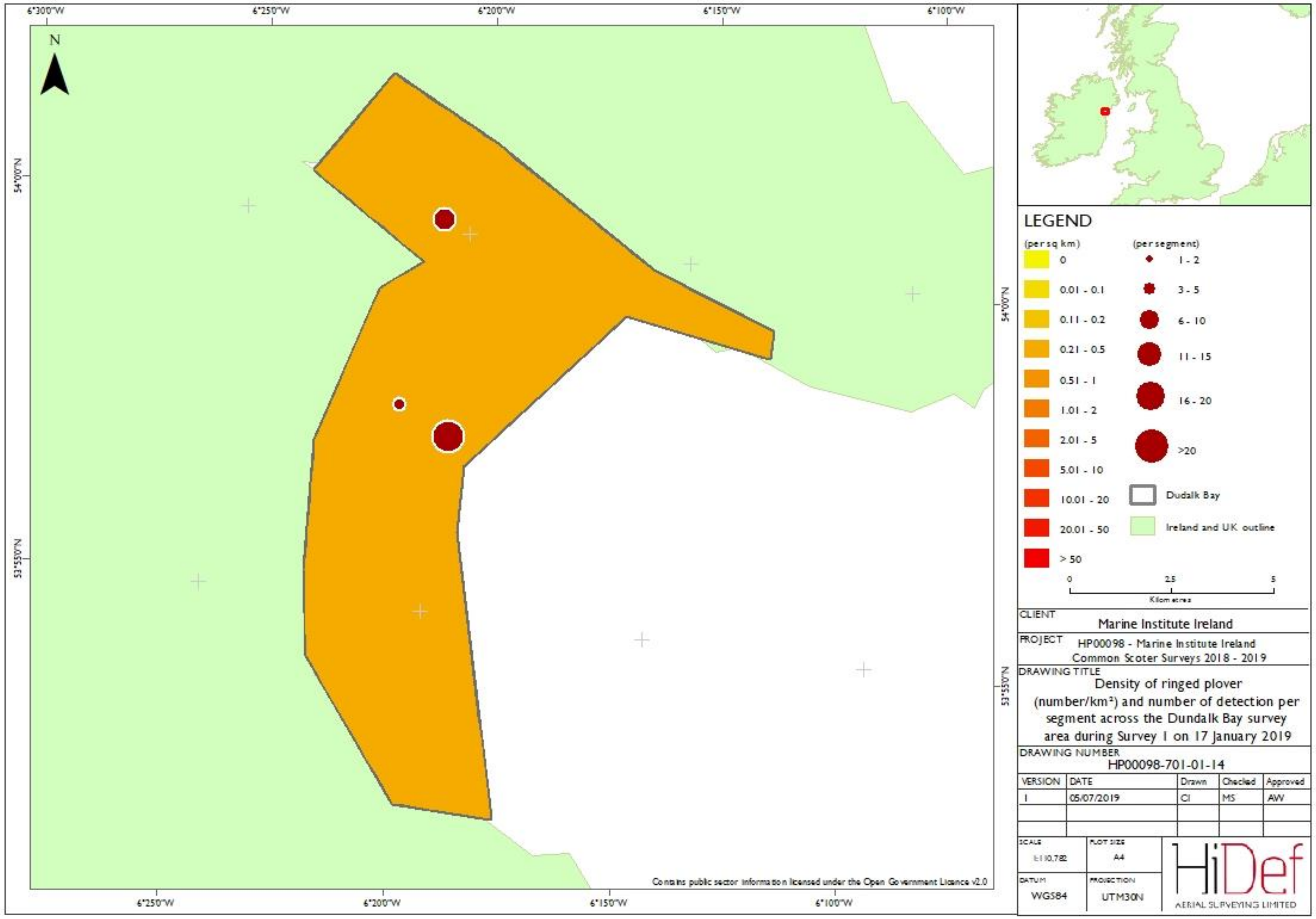
Figure 15 Density of oystercatchers (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.15 Distribution and seasonal abundance for ringed plover

62 Ringed plover was not abundant and only occurred in the northern half of the survey area (**Figure 16**).

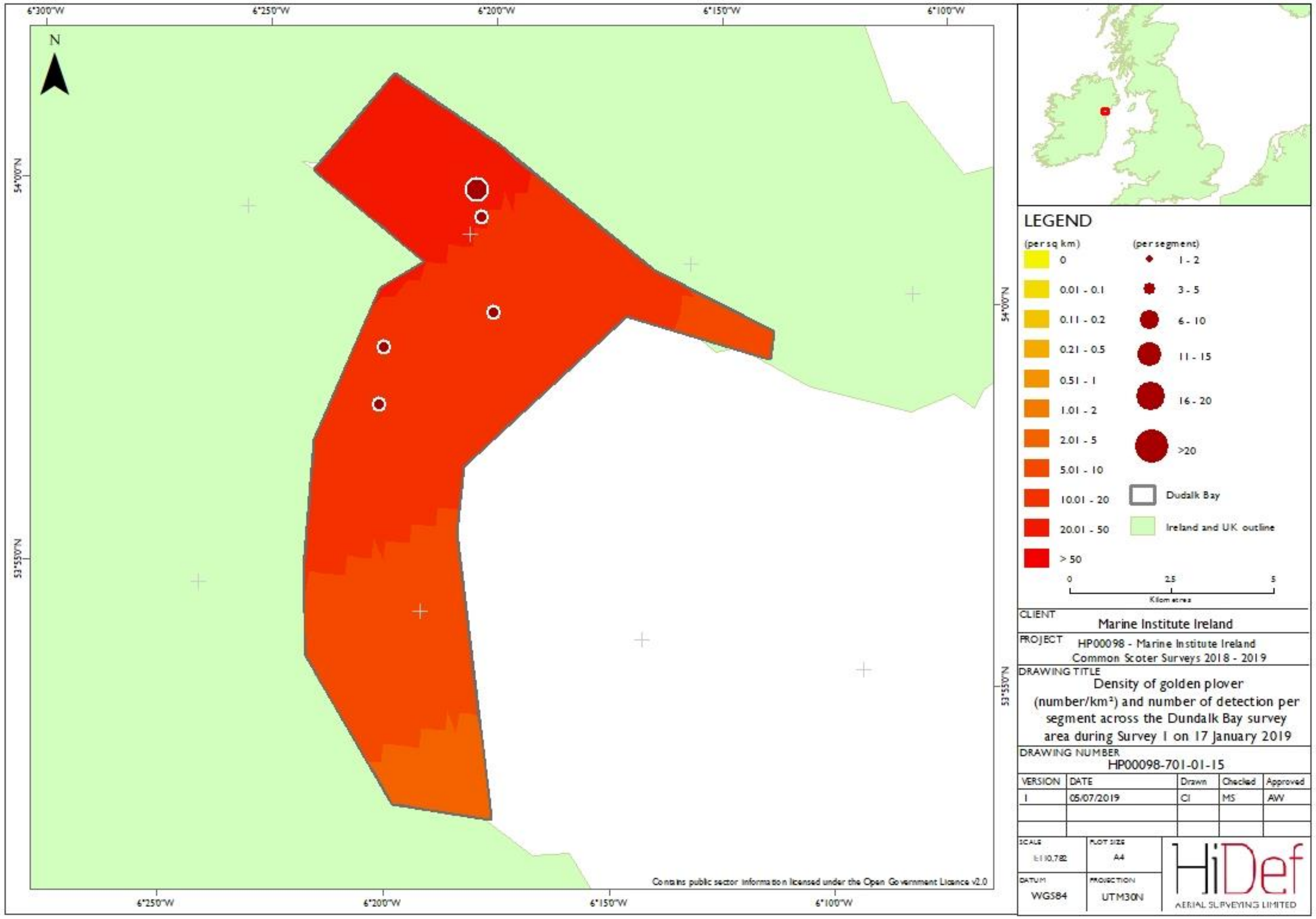
Figure 16 Density of ringed plover (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.16 Distribution and seasonal abundance for golden plover

63 Golden plover was not numerous and occurred only in the northern half of the survey area (**Figure 17**).

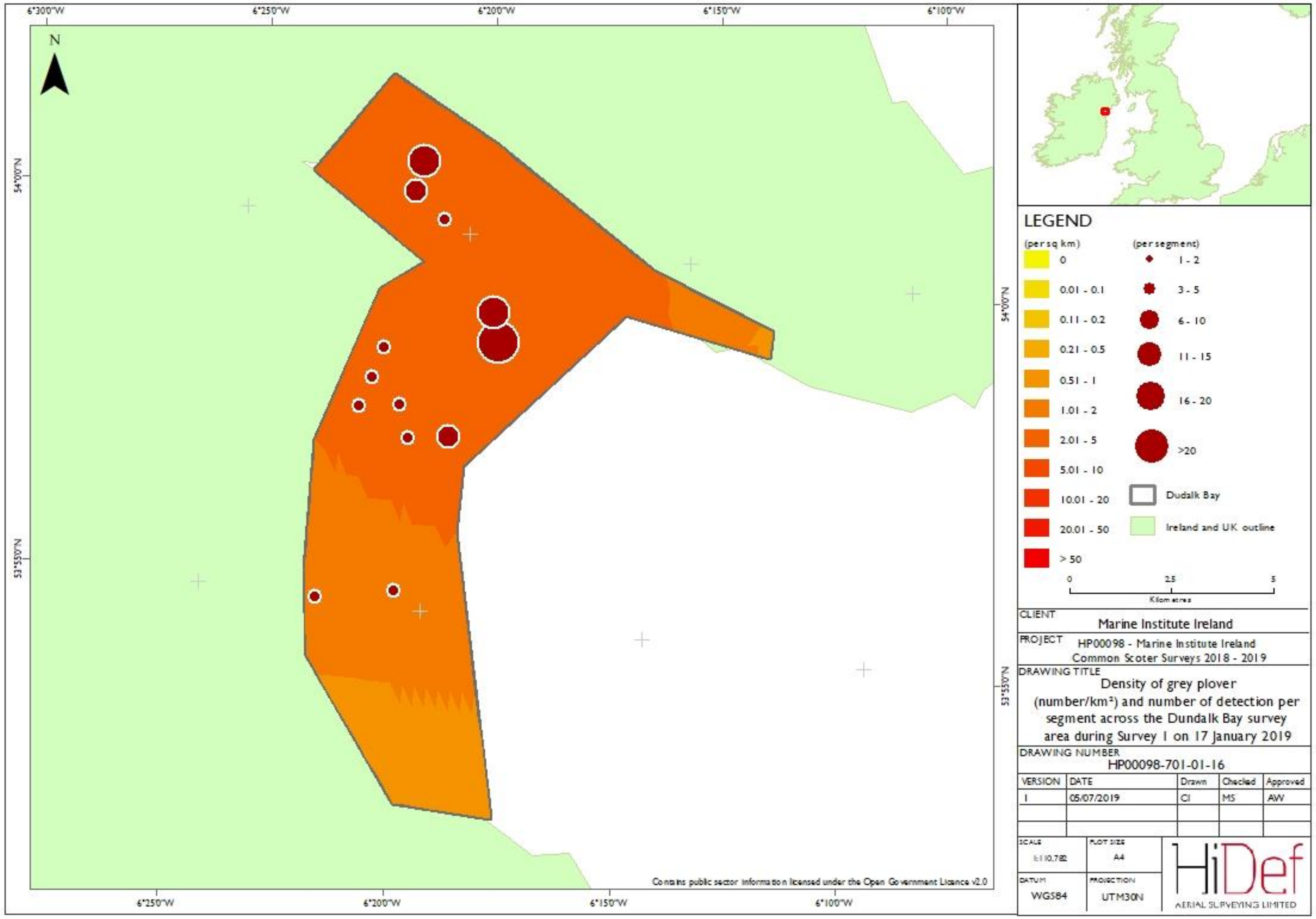
Figure 17 **Density of golden plover (number/km²) and number of detections per segment during Survey 1 on 17 January 2019**



3.4.17 Distribution and seasonal abundance for grey plover

64 Grey plover were more numerous than golden plover and more widely distributed. However, most birds were also in the northern half of the survey area (**Figure 18**).

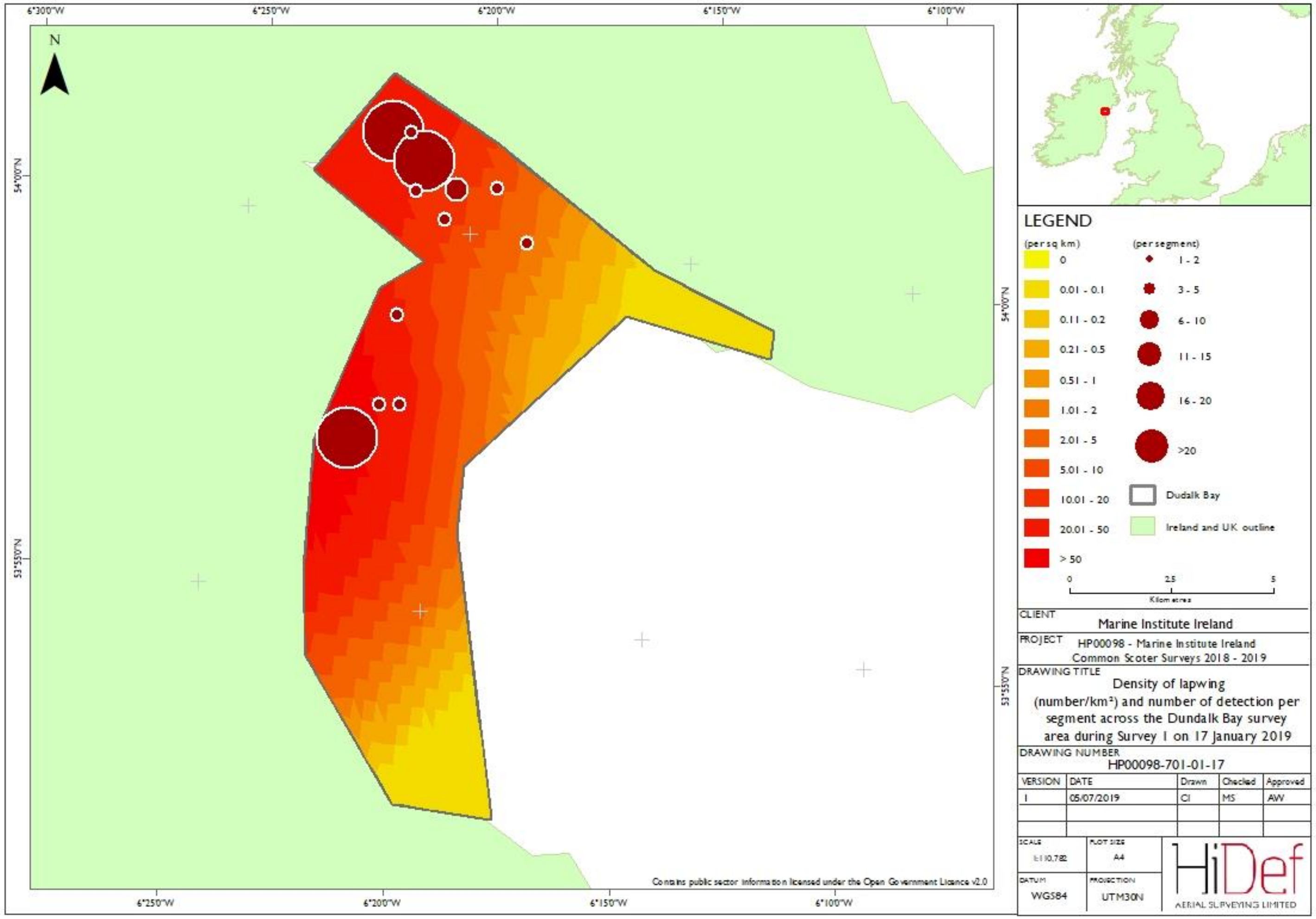
Figure 18 Density of grey plover (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.18 Distribution and seasonal abundance for lapwing

65 Lapwing occurred in the northern half of the survey area, in more coastal (landward) part of the bay (**Figure 19**).

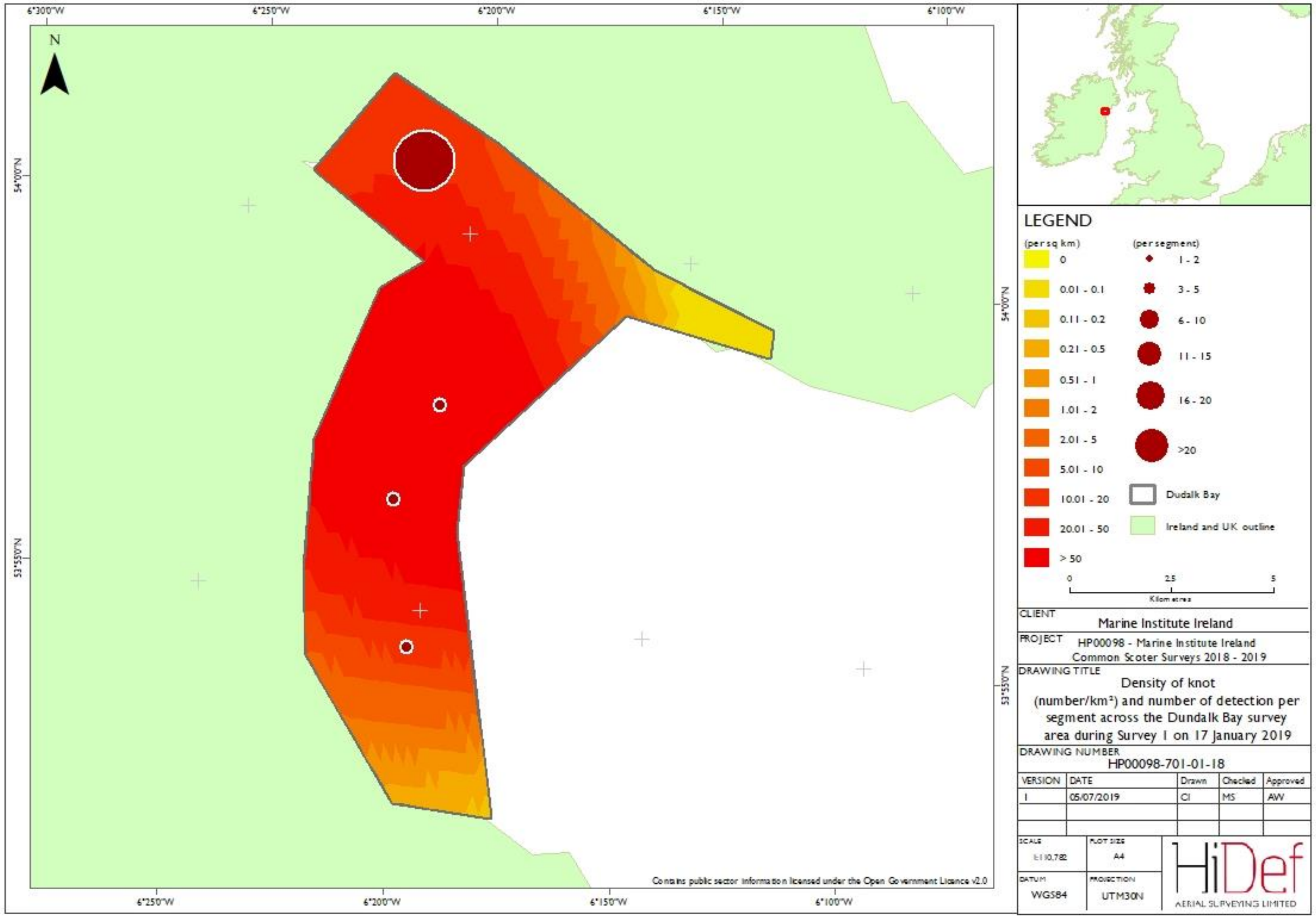
Figure 19 Density of lapwing (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.19 Distribution and seasonal abundance for knot

66 Knot were concentrated in the north-west of the survey area, with only a few records towards the central part of the bay (**Figure 20**).

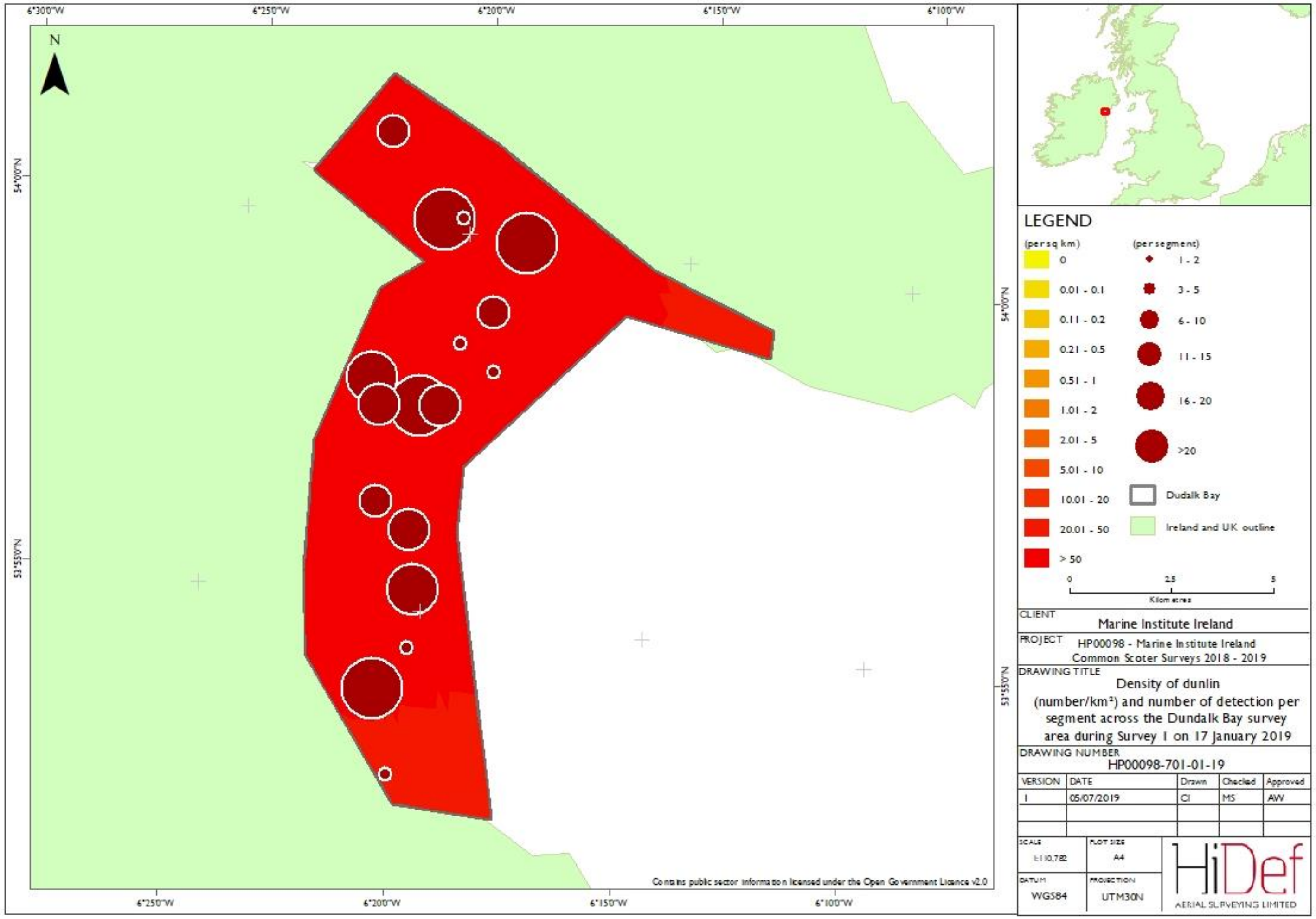
Figure 20 Density of knot (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.20 Distribution and seasonal abundance for dunlin

67 Dunlin were quite numerous and widely spread across the survey area (**Figure 21**).

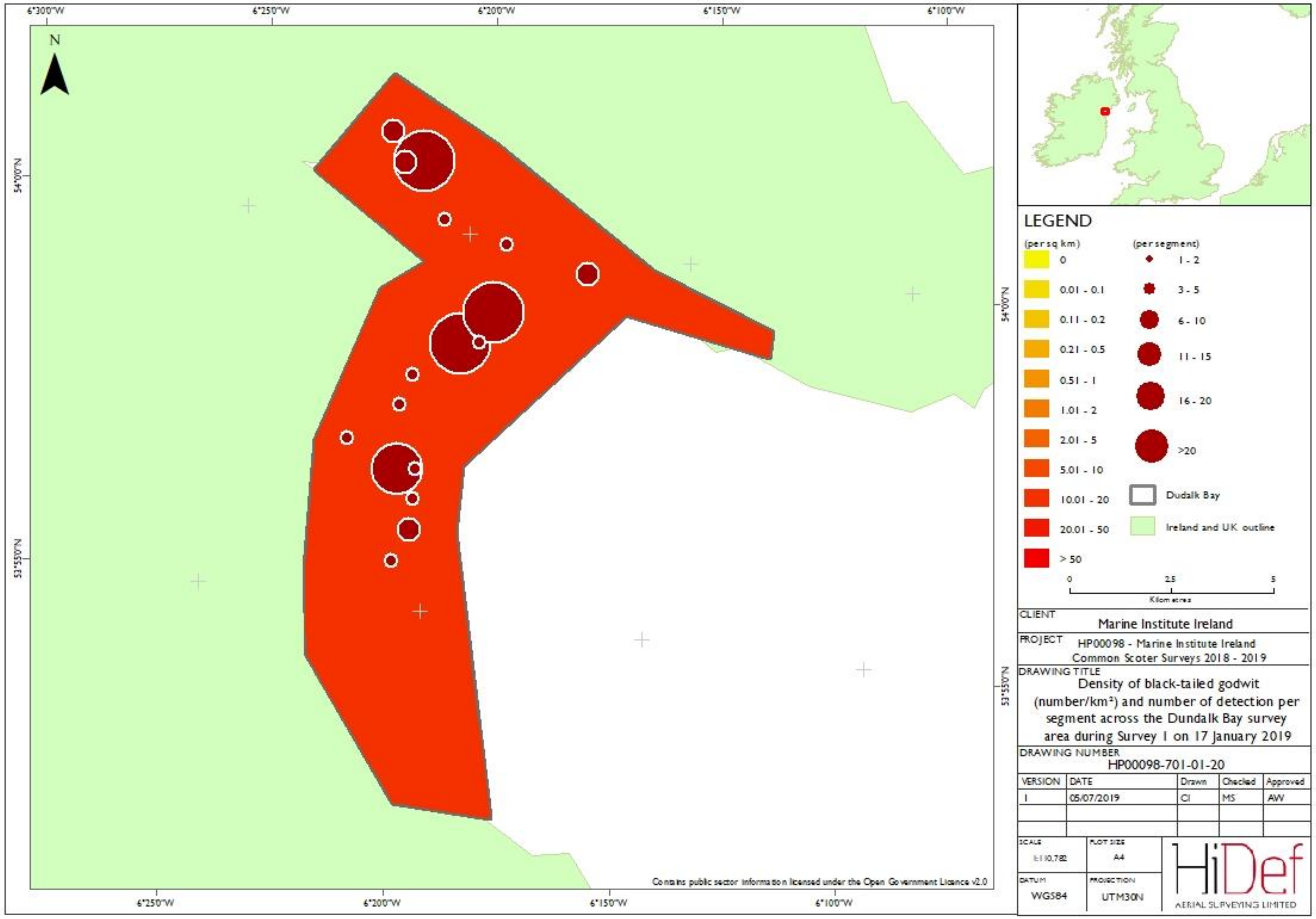
Figure 21 Density of dunlin (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.21 Distribution and seasonal abundance for black-tailed godwit

68 Black-tailed godwit occurred across most the survey area, except the very south of the bay (**Figure 22**).

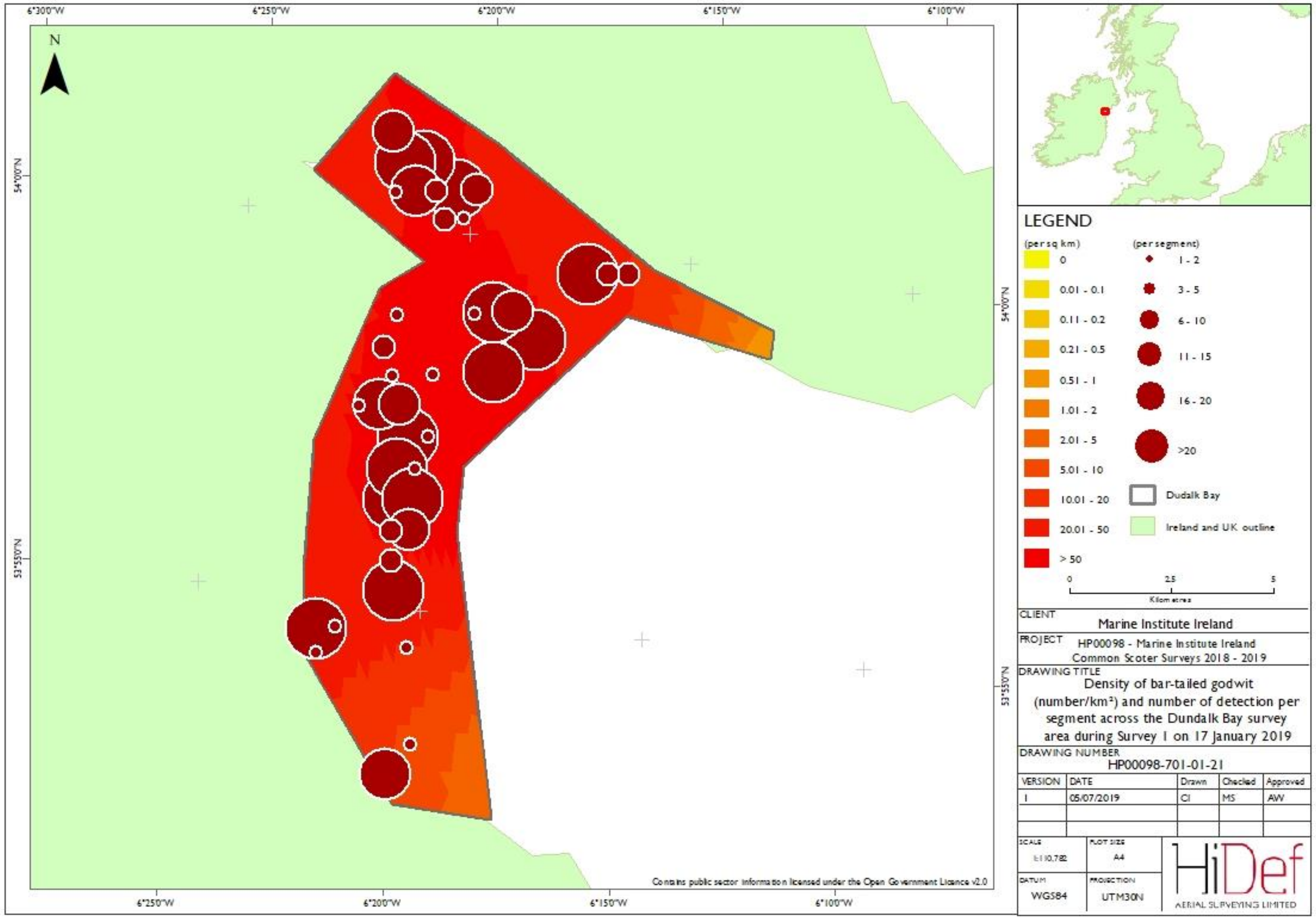
Figure 22 Density of black-tailed godwits (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.22 Distribution and seasonal abundance for bar-tailed godwit

69 Bar-tailed godwit were more numerous and more widely distributed than black-tailed godwits, occurring in most parts of the survey area (**Figure 23**).

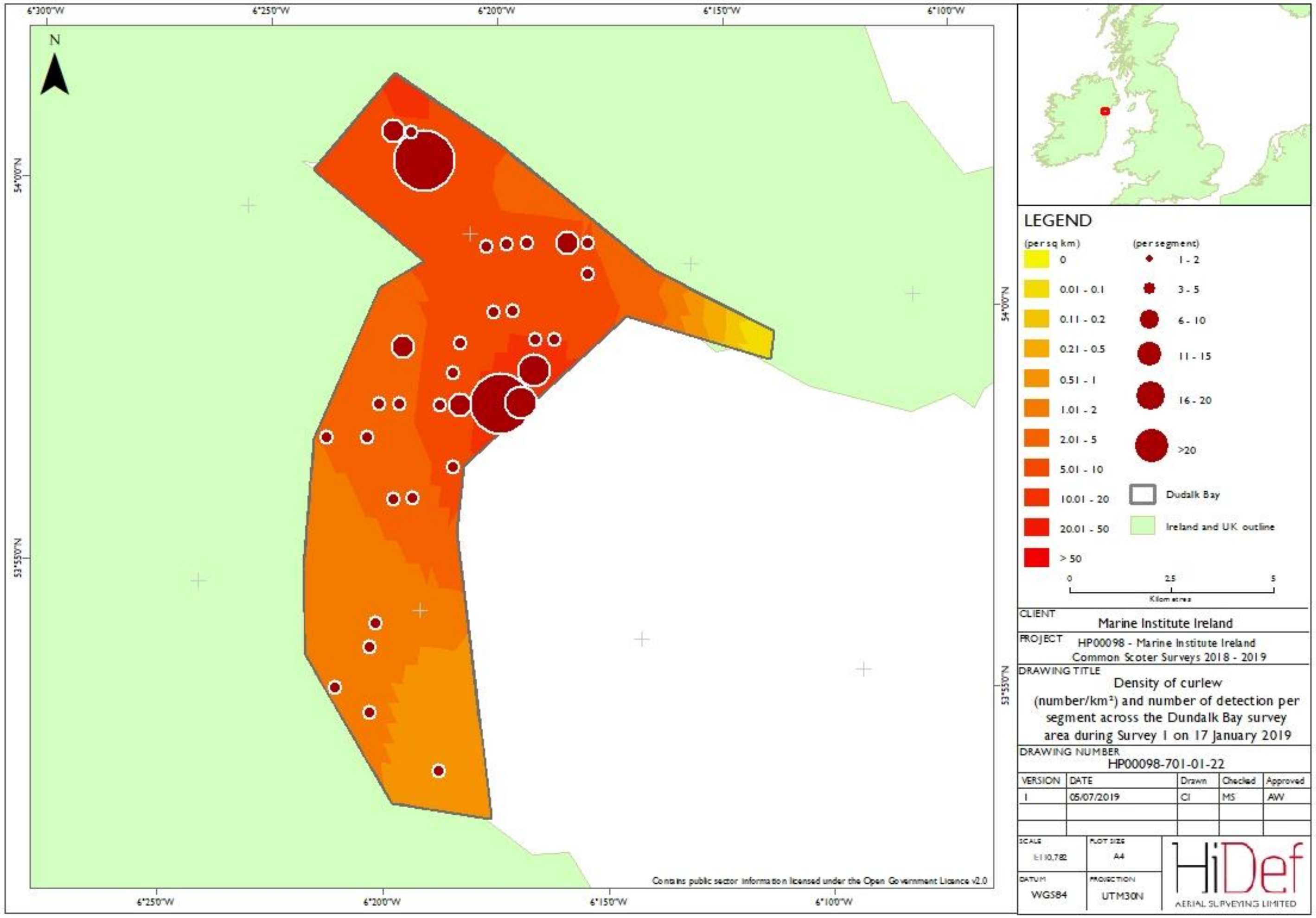
Figure 23 Density of bar-tailed godwits (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.23 Distribution and seasonal abundance for curlew

70 Curlew were also fairly wide-spread bit with concentrations in the north-west and the eastern edge of Dundalk Bay (**Figure 24**).

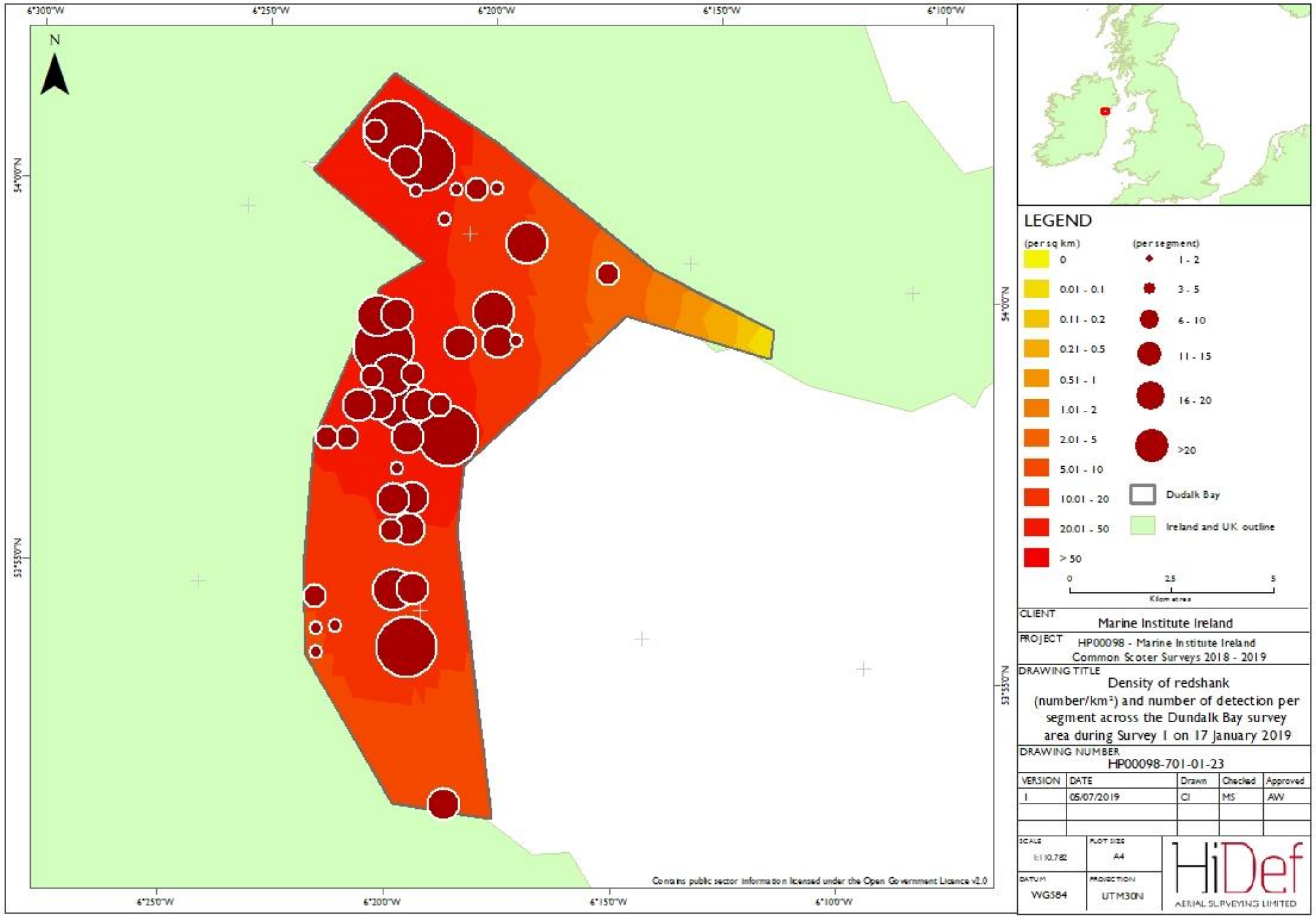
Figure 24 Density of curlew (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.24 Distribution and seasonal abundance for redshank

71 Redshank were numerous and widespread, although there were some concentrations recorded towards the middle of the bay (**Figure 25**).

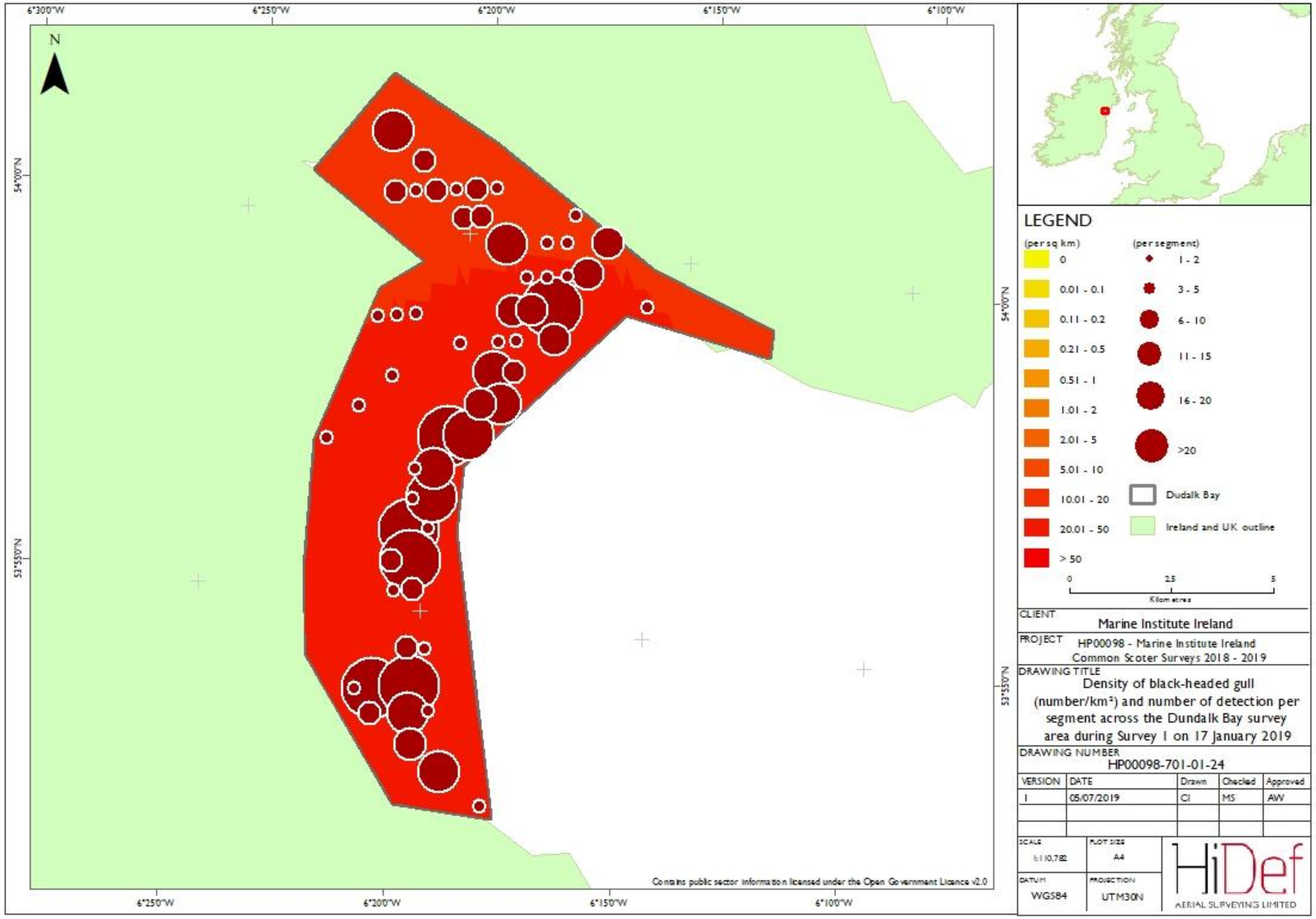
Figure 25 **Density of redshank (number/km²) and number of detections per segment during Survey 1 on 17 January 2019**



3.4.25 Distribution and seasonal abundance for black-headed gull

72 Black-headed gulls were widespread but with a concentrated line from north to south along the eastern half of the survey area (**Figure 26**).

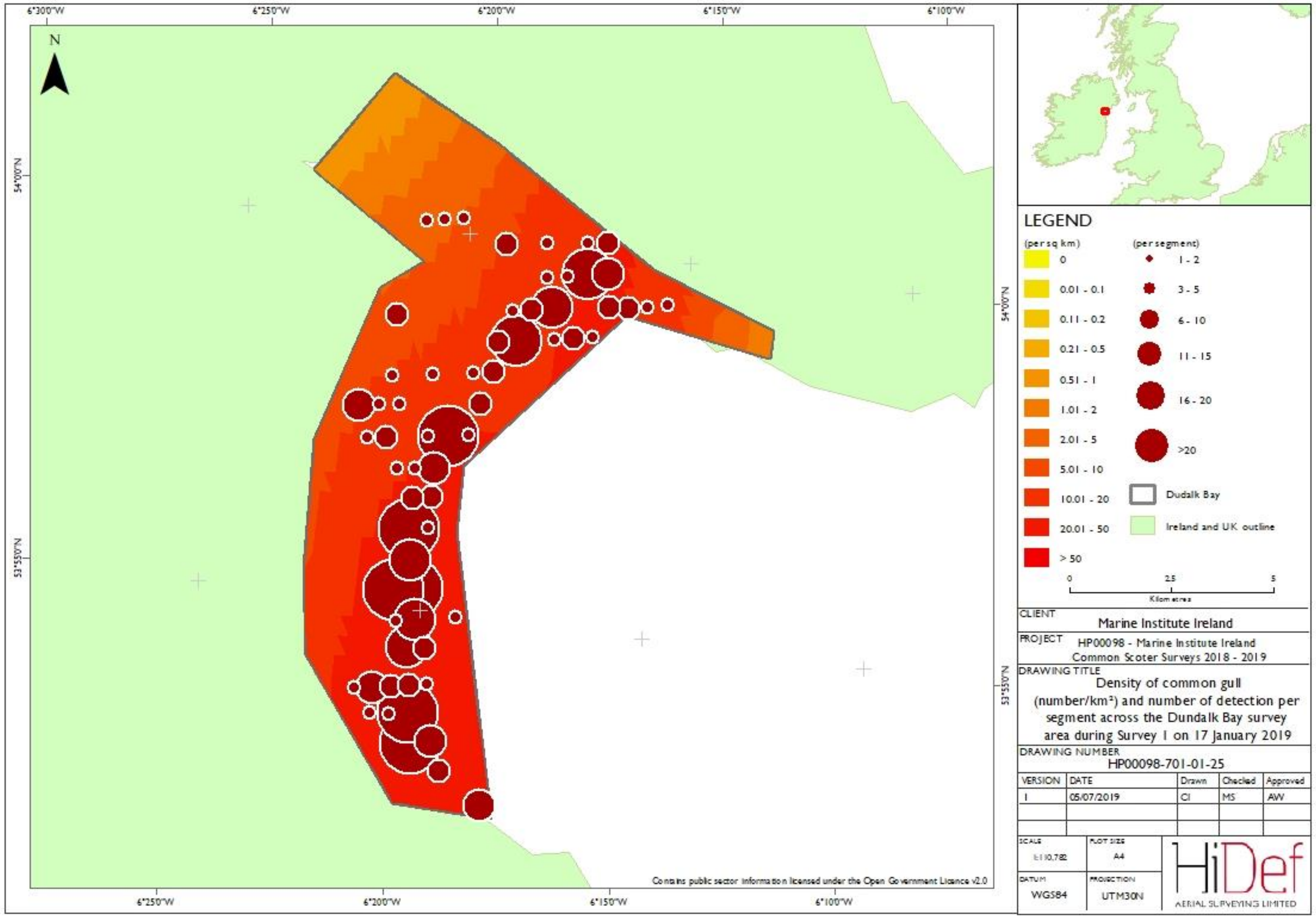
Figure 26 Density of black-headed gulls (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.26 Distribution and seasonal abundance for common gull

73 Common gulls were also widespread and had a similar pattern of occurrence to black-headed gull (Figure 27).

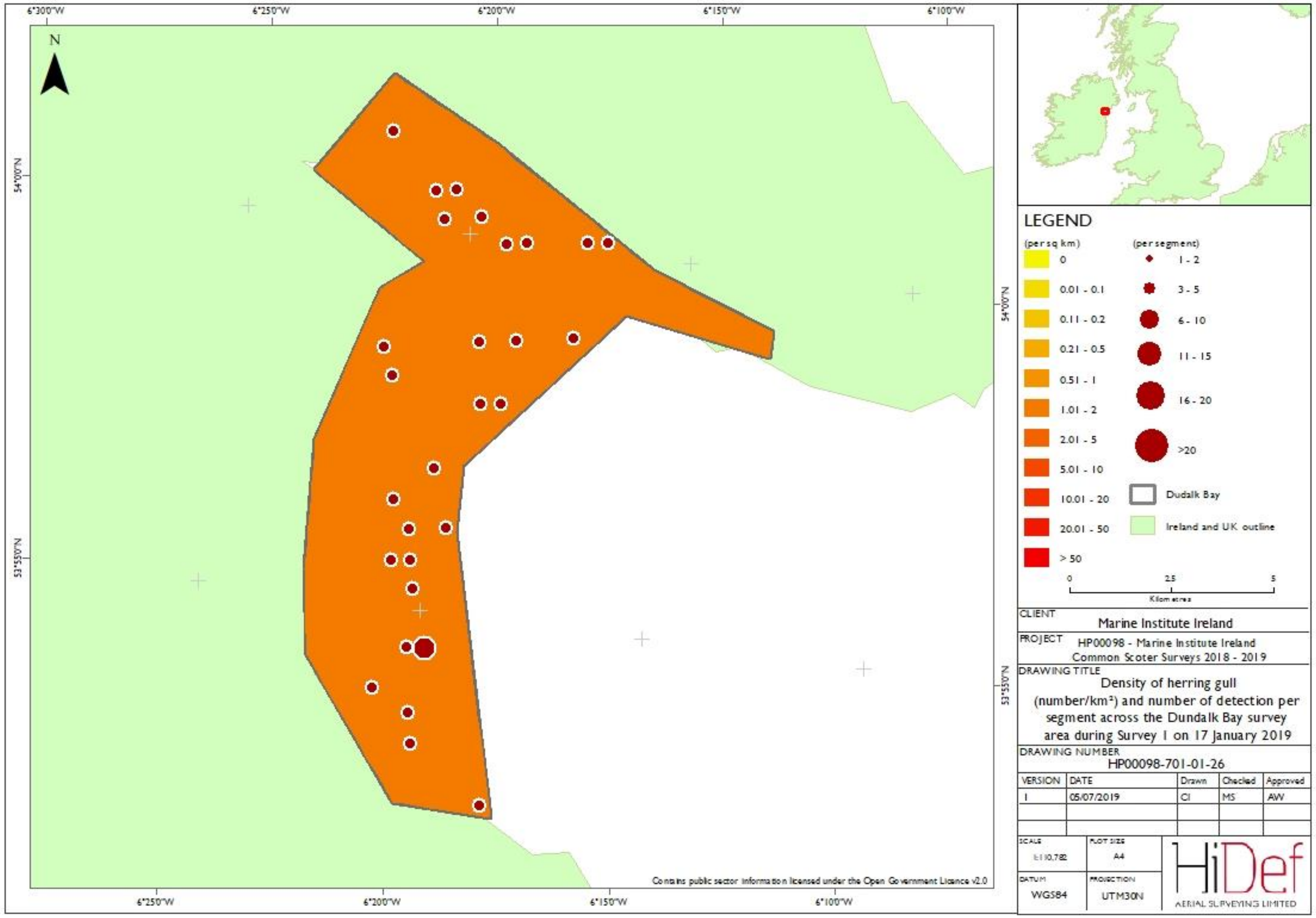
Figure 27 Density of common gulls (number/km²) and number of detections per segment during Survey 1 on 17 January 2019



3.4.27 Distribution and seasonal abundance for herring gull

74 Herring gulls occurred in relatively low densities across the whole of the bay (**Figure 28**).

Figure 28 **Density of herring gulls (number/km²) and number of detections per segment during Survey 1 on 17 January 2019**



3.4.28 Distribution analysis for less abundant bird species

75 Several less abundant bird species were recorded including sanderling and greenshank (**Figure 29**).

Figure 29 Number of less abundant bird species observed during Survey 1 on 17 January 2019

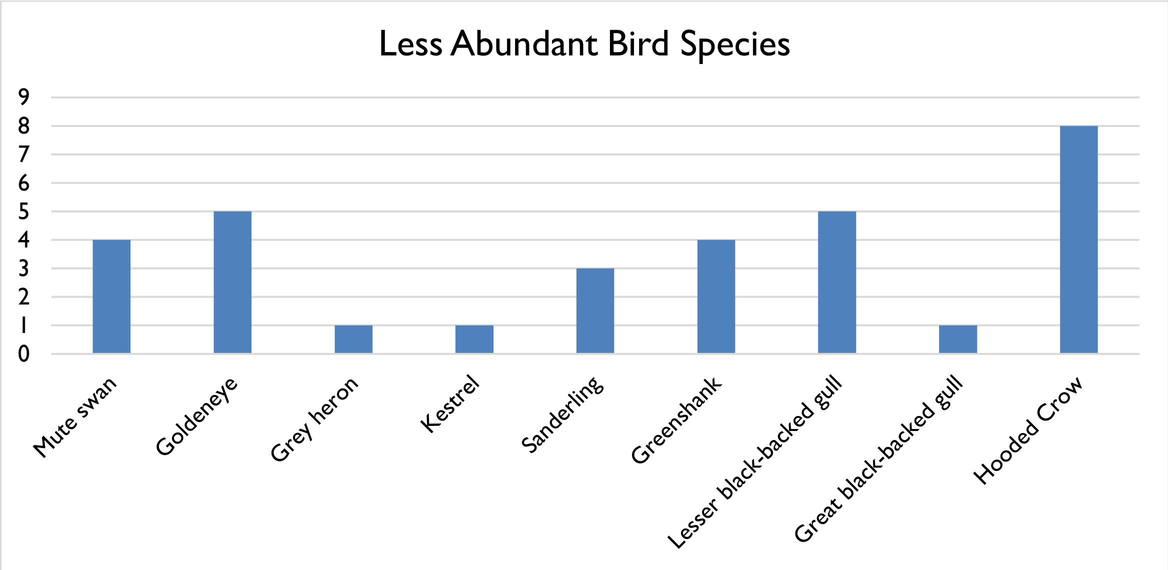
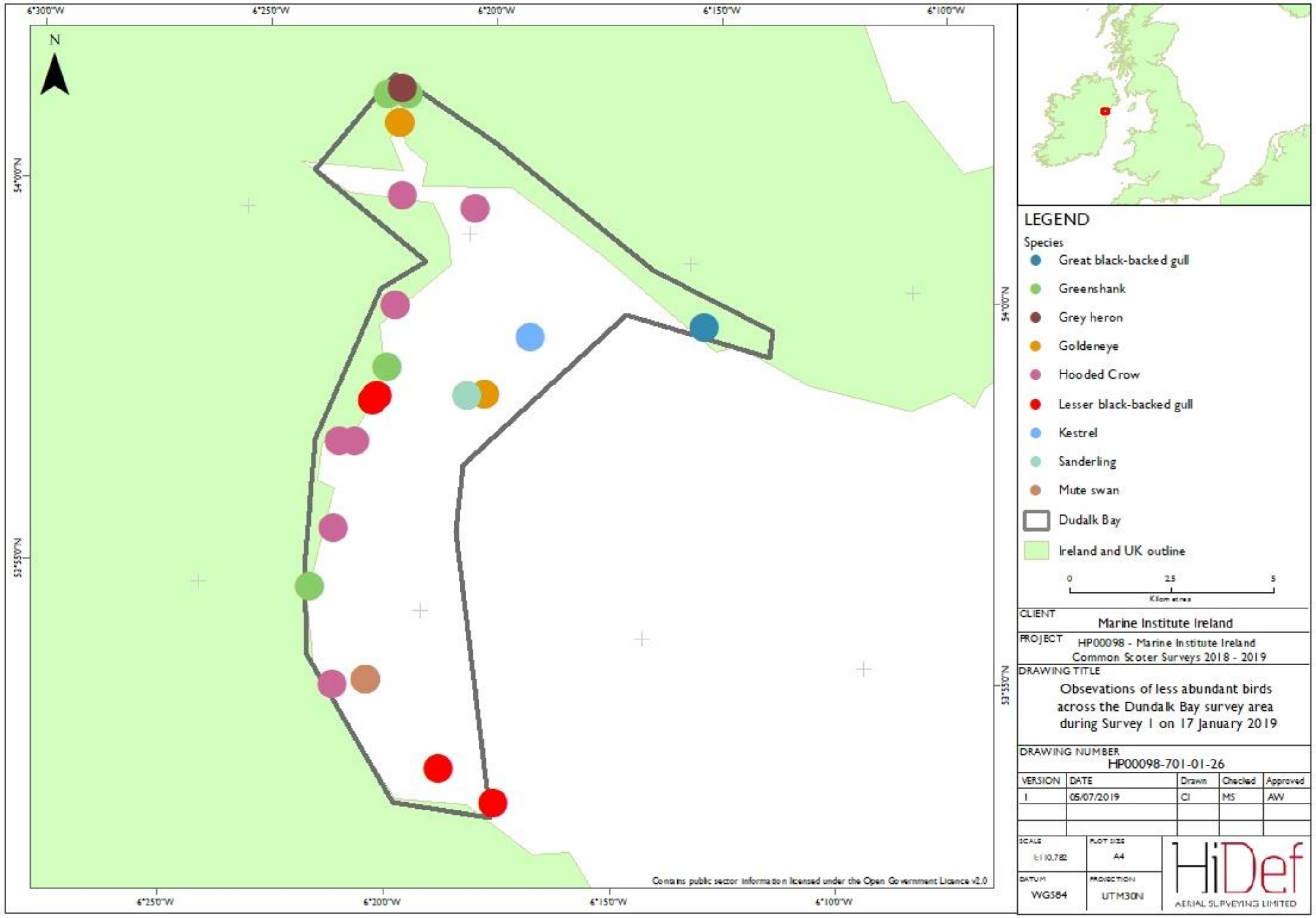


Figure 30 **Detections of less abundant bird species (number/km²) during Survey 1 on 17 January 2019**



3.4.29 Distribution analysis for unidentified birds

76 Unidentified birds were observed across the survey area, though the majority were unidentified waders (**Figure 31**).

Figure 31 Number of unidentified bird species observed during Survey 1 on 17 January 2019

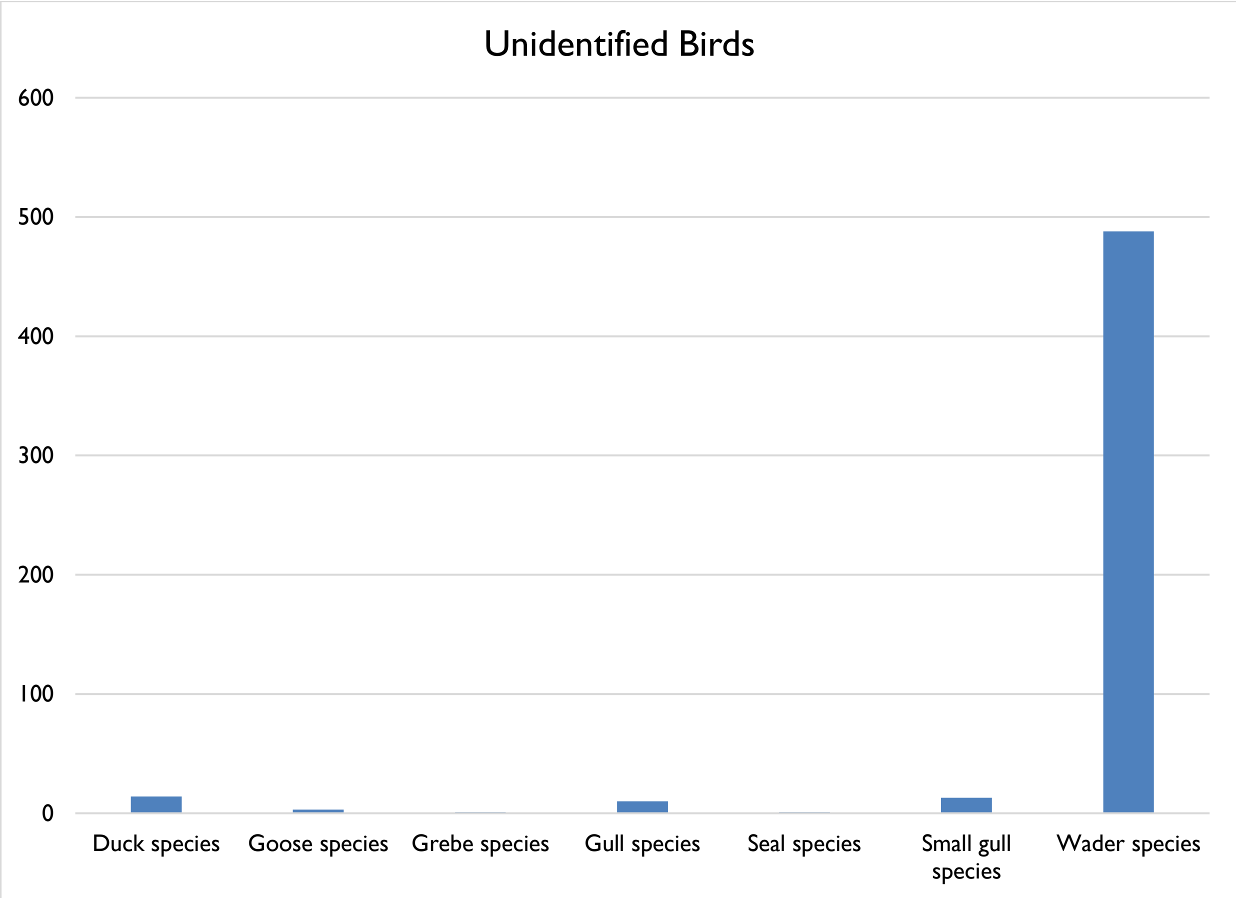
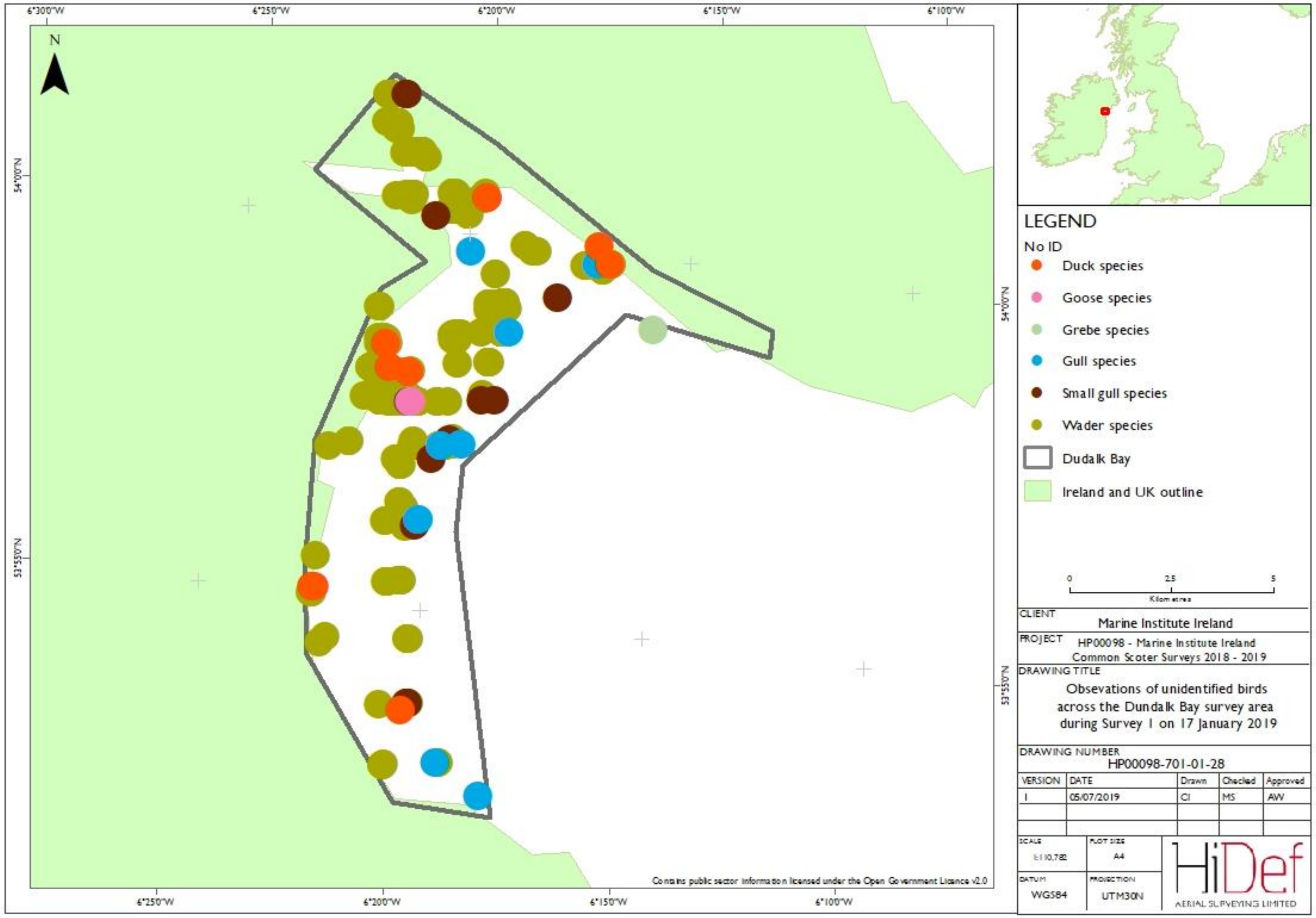


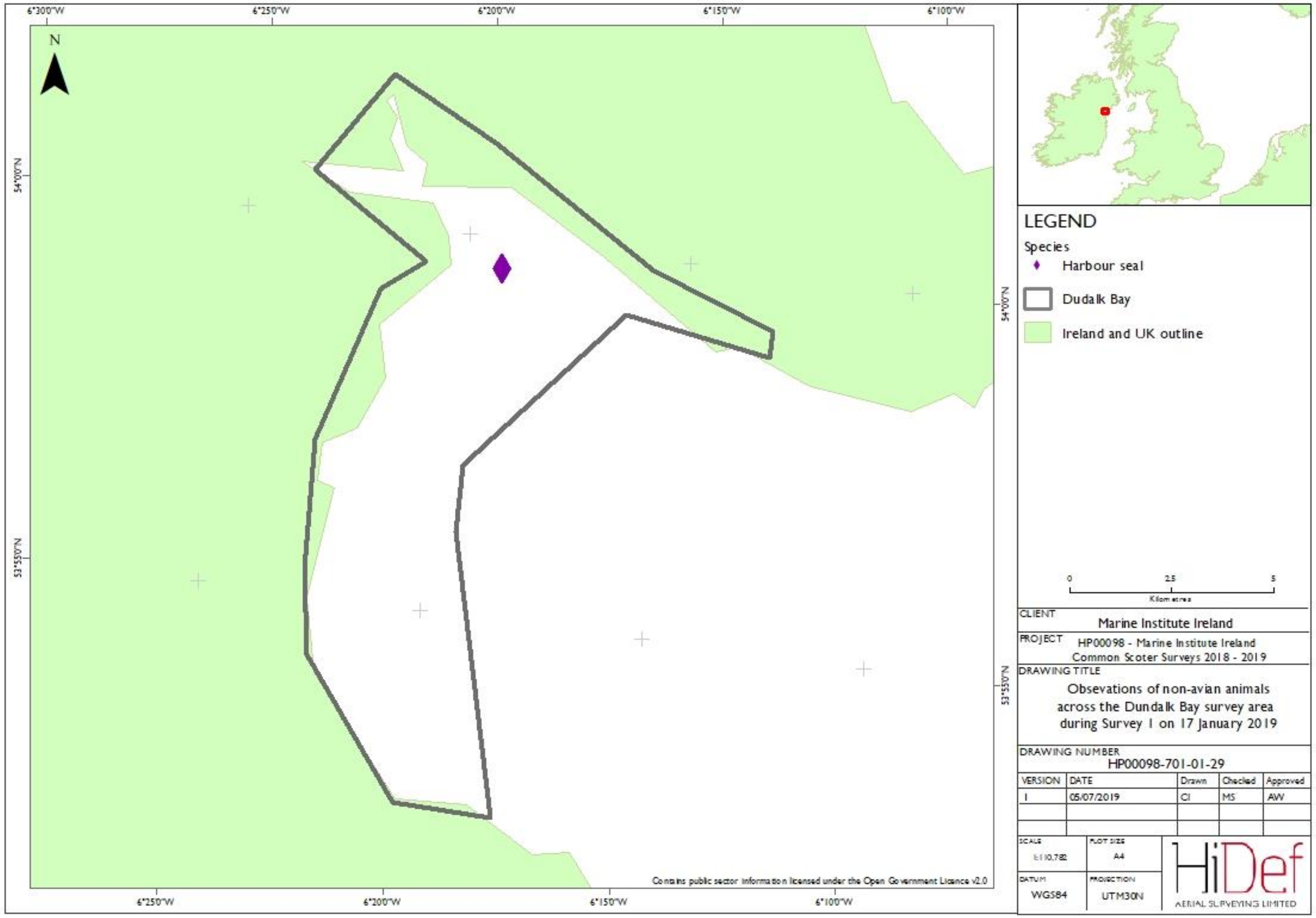
Figure 32 **Detections of unidentified bird species (number/km²) during Survey 1 on 17 January 2019**



3.4.30 Distribution analysis for less abundant non-avian animal species

77 Less abundant non-avian animal species were observed with 23 harbour seals recorded in the north of the bay. The location of this observation is shown in **Figure 33**.

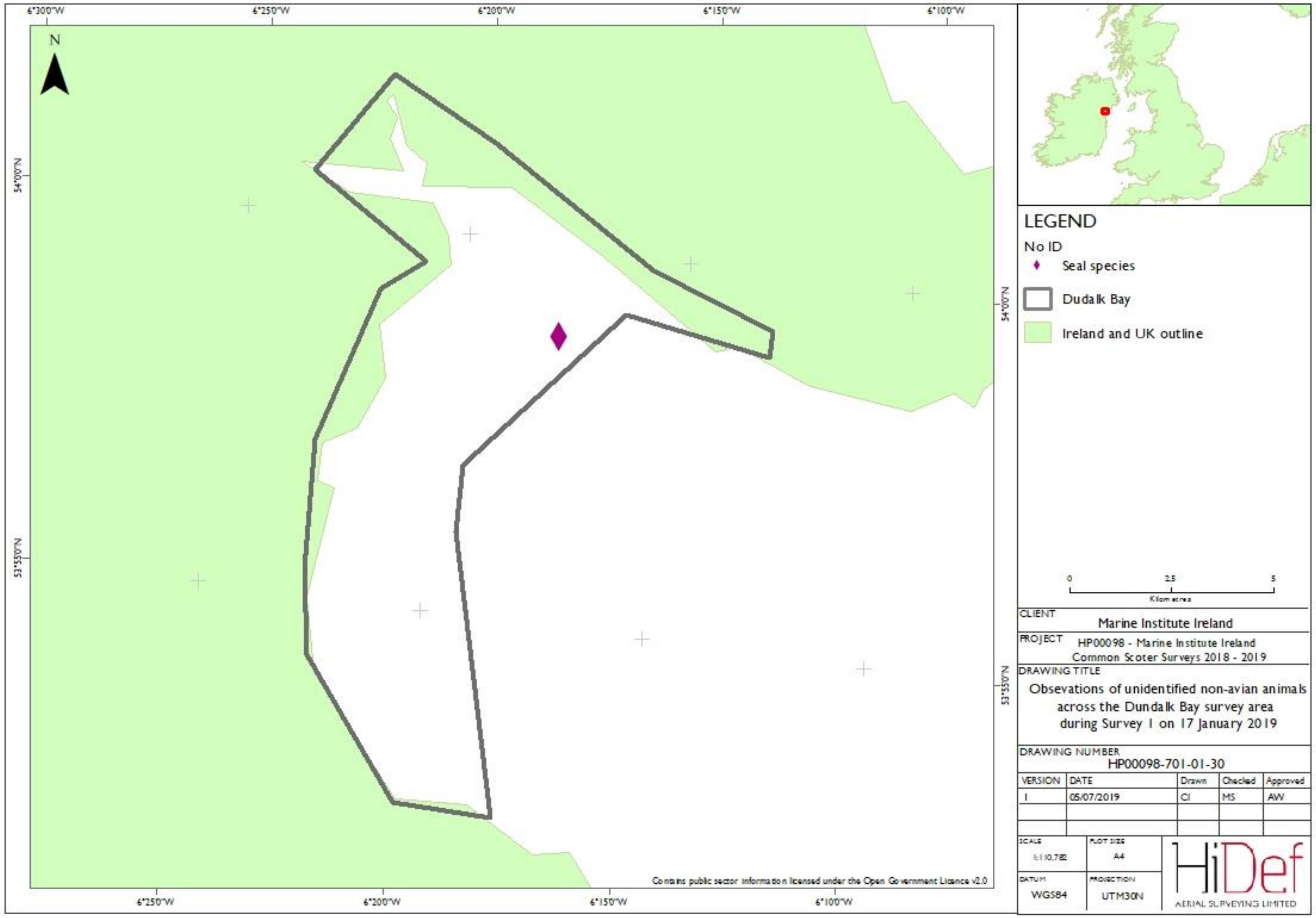
Figure 33 Detections of less abundant non-avian species (number/km²) during Survey 1 on 17 January 2019



3.4.31 Distribution analysis for unidentified non-avian animals

78 Unidentified non-avian animal species were limited to seals that could not be assigned to a particular species. The location of that observation is shown in **Figure 34**.

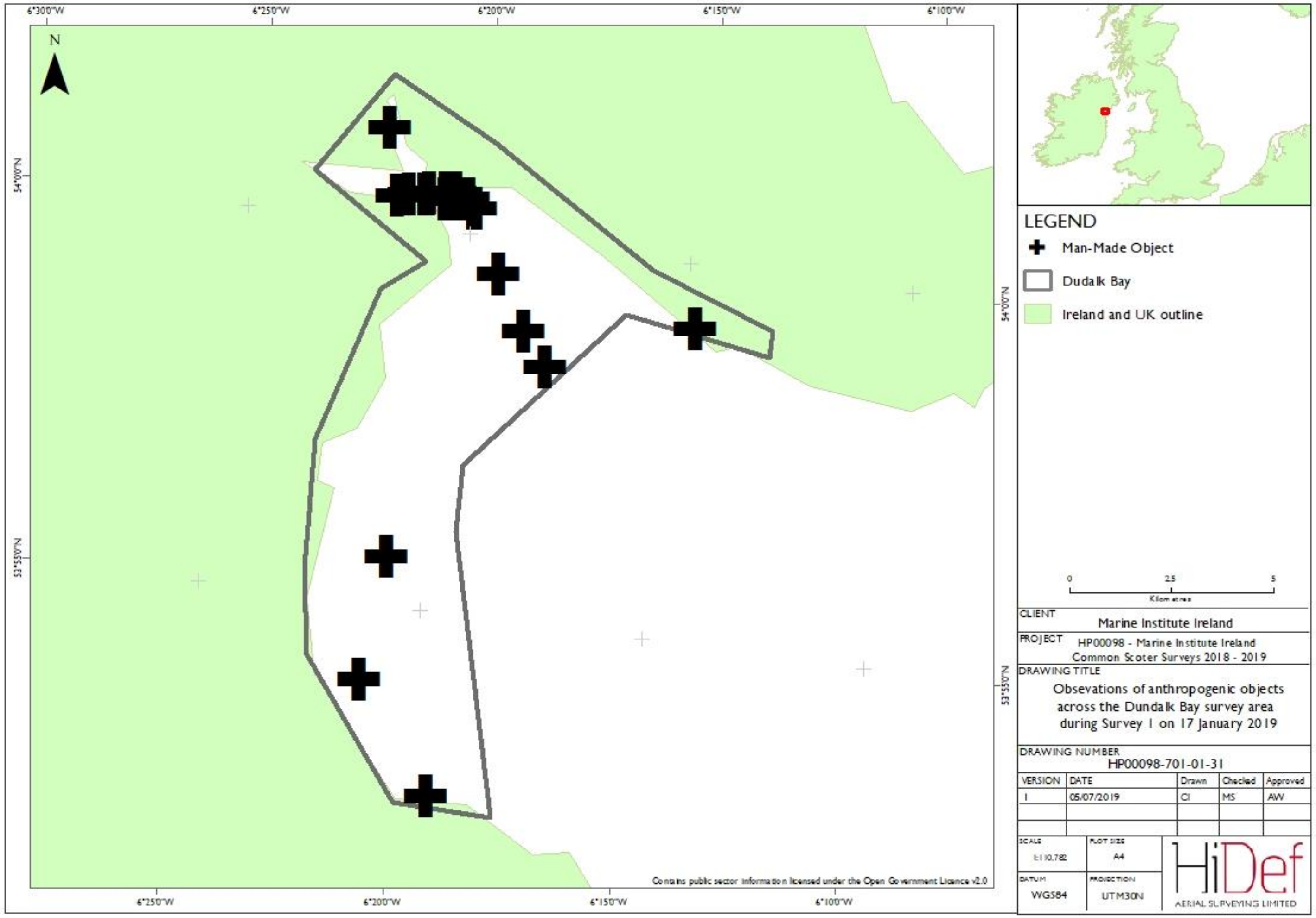
Figure 34 Detections of unidentified non-avian species (number/km²) during Survey 1 on 17 January 2019



3.4.32 Distribution and seasonal abundance for anthropogenic activity

79 Anthropogenic objects were observed across the bay during the surveys and detections are shown in **Figure 35**.

Figure 35 Detections of vessels and anthropogenic objects during Survey 1 on 17 January 2019



4 Discussion

80 The surveys were successful in characterising the bird and mammal species present across the Dundalk Bay survey area, recording a total of 11,256 birds of 35 species and one species of marine mammal (harbour seal).

81 The majority of birds observed during the survey were waders and waterfowl, most of which were species that were qualifying features of the Dundalk Bay SPA. The majority of the species detected were waders, with oystercatcher, dunlin, knot and bar-tailed godwit being the most abundant.

82 Teal and wigeon were the most abundant of the waterfowl and relatively few seaduck were observed. In comparison to the citation population sizes of the SPA most of the waterfowl features occurred in higher predicted abundances than the citation population size, and most of the waders occurred in lower predicted abundances than the citation population size (

83 Table **7**). To provide a more contemporary context to the citation populations, the five-year peak of mean counts from I-WeBS counts (Birdwatch Ireland 2019) is also presented in

84 Table **7**. Notable exceptions to this were bar-tailed godwit, which was 160% more abundant, and goldeneye, which was less than half the numbers at citation. As stated previously, few seaduck were observed compared to citation numbers for most species; many of these were likely to be feeding offshore of the study area used for this survey.

85 The biggest difference among those populations that had apparently declined were lapwing, grey and golden plover. Lapwing and golden plover are also notable as species that occur at inland sites, potentially outwith the study area for this project. The same issue is likely to be true also for Brent goose and curlew.

86 These comparisons should be interpreted with some care, as citation population sizes are derived from the peak abundances across multiple counts, typically in multiple years. This survey should be considered a snapshot and was only conducted in mid-winter, which is unlikely to provide a peak count for all the qualifying features.

Table 7 **Comparison of Dundalk Bay SPA qualifying features between citation and January 2019.**

Species	Scientific name	Population estimate	Citation	5-year mean peaks	Trend (citation)
Brent goose	*Branta bernicla*	671	337	1852	+
Shelduck	*Tadorna tadorna*	415	492	327	-
Wigeon	*Anas penelope*	968	394	475	+
Teal	*Anas crecca*	2,548	488	452	+
Mallard	*Anas platyrhynchos*	517	763	878	-
Pintail	*Anas acuta*	192	117	161	+
Goldeneye	*Bucephala clangula*	16	36	53	-
Red-breasted merganser	*Mergus serrator*	253	121	216	+
Great crested grebe	*Podiceps cristatus*	43	302	36	-
Cormorant	*Phalacrocorax carbo*	37	97	127	-
Oystercatcher	*Haematopus ostralegus*	7,794	8712	6012	-
Ringed plover	*Charadrius hiaticula*	37	147	285	-
Golden plover	*Pluvialis apricaria*	1,225	5967	7428	-
Grey plover	*Pluvialis squatarola*	156	204	232	-
Lapwing	*Vanellus vanellus*	1,304	14,850	4243	-
Knot	*Calidris canutus*	3,881	9710	7062	-
Dunlin	*Calidris alpina*	5,548	11,515	3366	-
Black-tailed godwit	*Limosa limosa*	863	1067	3708	-
Bar-tailed godwit	*Limosa lapponica*	3,188	1950	1673	+
Curlew	*Numenius arquata*	347	1234	713	-
Greenshank	*Tringa nebularia*	13	16	17	-
Redshank	*Tringa totanus*	1,210	1489	1688	-
Black-headed gull	*Chroicocephalus ridibundus*	1,817	6630	2042	-
Common gull	*Larus canus*	1,169	555	1594	+

5 Conclusions

87 The surveys were successful in characterising the bird and mammal species present in the Dundalk Bay area. They provided a valuable snapshot and a robust, unbiased spatial distributions of birds across a large area. This can be extremely challenging from more typical shore-based counts. The survey design provides a robust, highly repeatable, estimate of species spatial abundance, and the digital aerial platform provides a unique, auditable record of species identification.

88 The analytical methods used here were robust while being relatively simple. More complex density surface models can be applied to these types of data resulting in more accurate spatial predictions and typically with abundance estimates with tighter confidence intervals (though this can vary). These types of analytical approach are not typically possible with shore-based counts, due to the inherent problem of surveying across an ecological gradient (i.e. away from shore).

89 Comparisons of SPA qualifying feature citation population levels are suggestive of a general pattern of increases among some key waterfowl species and decreases among some key wader species. Care should be taken in making such comparisons, due to the differences in the data used to derive the abundance estimates. These differences are primarily that this was a single snapshot survey in the middle of winter compared to the citation and recent I-WeBS surveys which were based on a mean calculated from peak counts that occur intermittently or potentially at different times of the year. Also, the study areas for these different data sources, with I-WeBS counts likely to extend further offshore and include more terrestrial habitat than that used for the aerial surveys.

6 References

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