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Digital video aerial survey of seabirds and marine mammals at Île d'Yeu project: draft final report

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Executive Summary

1 The marine sector of Île d'Yeu was classified as a Special Protection Area ("SPA") in July 2008 (site FR5212015). It is located off the Vendée coast of western France and covers an area of approximately 2450.1 km². The large marine area around and off the Ile d'Yeu is a major site for seabirds on the Atlantic coast, with importance for Balearic shearwater *Puffinus mauretanicus* in the post-breeding season in July and August. Individuals of this species concentrate in the area between the island and the mainland each year, and France has a particular responsibility for its conservation (approximately 40% of the world population can be found in this area).

2 As part of process to establish an ecological monitoring programme for the Marine Sector of the Île d'Yeu, the Agence des Aires Marines Protégées ("AAMP") conducts annual surveys of birds using the site. AAMP now wants to improve to the process by conducting a survey campaign using ultra high-resolution digital video, complementing existing surveys carried out using vessels.

3 In July 2016, AAMP commissioned HiDef Aerial Surveying Limited ("HiDef"), in partnership with Biotope, to undertake a programme of digital video aerial marine megafauna, ornithological and human activity surveys in support of the ecological designations in the Île d'Yeu area.

4 One survey was commissioned to be undertaken between 1 August 2016 and 15 September 2016, with the targeted date of 15 August 2016 being preferred subject to weather and other operation considerations. This date was selected to ensure the aerial survey was conducted at the same time as the boat-based survey. The HiDef survey design consists of identical transects to the boat-based survey with 3.7km (2 nautical miles) spacing over the whole survey area. This report ("the annual report") provides the results for the survey undertaken in August 2016.

5 Surveys were undertaken using an aircraft equipped with four ultra-high-resolution HiDef Gen II cameras with sensors set to a resolution of 2 centimetres ("cm") Ground Sample Distance ("GSD"). Each camera sampled a strip of 125m width, separated from the next camera by approximately 25m, thus providing a combined sampled width of 500m within an overall 575m strip. 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 require 90% agreement to be achieved.

6 Density and abundance estimates were calculated using strip transect analysis and a complex statistical method, known as kernel density estimation ("KDE") was used to create density surface maps.

7 A total of 1148 birds of 14 species and 135 marine mammals of 6 species were recorded during the survey. An identification rate to species level of 90.04% was achieved across the survey programme. The primary observations from the survey are that:

- The most abundant bird species was the Balearic shearwater with an estimated density of 1.79 birds per square kilometre and abundance estimate of 4401 with very wide confidence intervals of 158 – 13,596. They were mainly distributed towards the east and south-east of the survey area;
- Low densities of European storm-petrels *Hydrobates pelagicus* were recorded with no obvious distribution patterns;

- Density estimates for herring gulls *Larus argentatus* were relatively low;
- Herring gulls complex were recorded with high density estimates and were recorded across the east, north and south west of the survey area; and
- Common dolphin *Delphinus delphis* were the most abundant marine mammal species with the majority being recorded as submerged.

8 The results of this survey indicate that the programme was highly successful in observing and characterising a wide range of bird and mammal species across the Île d'Yeu survey area.

9 It is recommended that a different design of survey transects should be used in future with the addition of density surface modelling to improve the precision of abundance estimates.

1 Introduction

1 The marine sector of Île d'Yeu was classified as a Special Protection Area ("SPA") in July 2008 (site FR5212015). It is located off the Vendée coast of western France and covers an area of approximately 2450.1 km².

2 The marine area around the Ile d'Yeu is a major site for seabirds on the Atlantic coast, being particularly important for Balearic shearwater *Puffinus mauretanicus* in the post-breeding season in July and August. individuals of this species congregate in the area between the island and the mainland each year, and France has a particular responsibility for its conservation, as 40% of the world population can be found in the area.

3 Similarly, the site is very important during winter for the red-throated diver *Gavia stellata*, guillemot *Uria aalge*, razorbill *Alca torda* and little gull *Larus minutus*. The waters of the island are also frequented by two species in southern limit of their range and that may one day settle on the island of Yeu: fulmar *Fulmarus glacialis* and shag *Phalacrocorax aristotelis*. Finally, many species of marine birds frequent the site during migration and spring, sometimes in very large numbers, such as gannet *Morus bassanus*, great skua *Catharacta skua*, kittiwake *Rissa tridactyla*, Sandwich tern *Sterna sandvicensis* and European storm petrel *Hydrobates pelagicus*.

4 As part of process to establish an ecological monitoring programme for the Marine Sector of the Île d'Yeu, the Agence des Aires Marines Protégées ("AAMP") conducts annual surveys of birds using the site. In July 2016, AAMP commissioned HiDef Aerial Surveying Limited ("HiDef") in partnership with Biotope to undertake a programme of ultra-high-resolution digital video aerial surveys for marine megafauna, ornithological and human activity in support of ecological monitoring of the Natura 2000 site FR5212015 Marine sector of Île d'Yeu, to both improve to the process and complement existing boat-based surveys.

5 One survey was commissioned, to take place between 1 August and 15 September 2016 with the targeted date of 15 August 2016 being preferred subject to weather and other operational considerations. This date was selected to ensure the aerial survey was conducted at the same time as the boat-based survey. The HiDef survey design consists of identical transects to the boat-based survey with 3.7km (2 nautical miles) spacing over the whole survey area.

6 This report provides the results for the survey. Analysis is presented in the form of raw results, density surface distribution maps and abundance estimates with confidence estimates. Behaviour information has also been included as raw data. A discussion is also provided regarding the representativeness of the results.

2 Methods

2.1 Survey flights

7 A series of strip transects were flown in August 2016, following the protocol agreed with AAMP in July 2016 (reference HB00158-001).

8 HiDef designed the survey methodology to provide an accurate assessment of the abundance and distribution of seabirds and marine mammals and to enable environmental assessment to take place.

9 For this reason, HiDef designed a survey which was identical to the boat-based survey. Transects were spaced at 3.7km across the survey area and used a transect-based survey design in which strip transects were placed approximately perpendicular to the depth contours along the coast. Such a design ensures that each transect samples a similar range of habitats (primarily relating to water depth) and seeks to reduce the difference in bird and mammal abundance between each transect.

10 Surveys were undertaken using an aircraft equipped with four ultra-high-resolution HiDef Gen II cameras with sensors set to a resolution of 2 centimetres ("cm") Ground Sample Distance ("GSD"). Each camera is capable of sampling a strip of 125m width, separated from the next camera by approximately 25m, thus providing a potential combined sampled width of 500m within a 575m overall swathe. In order to achieve 12% coverage of the study area the total transect width was reduced to 445m.

11 The surveys were flown using a Diamond DA42 aircraft flying along the transect pattern shown in Figure 1 at a height of approximately 550m above sea level ("ASL"). Flying at this height ensures that there is no risk of flushing those species which have been proven to be easily disturbed by the aircraft[1].

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

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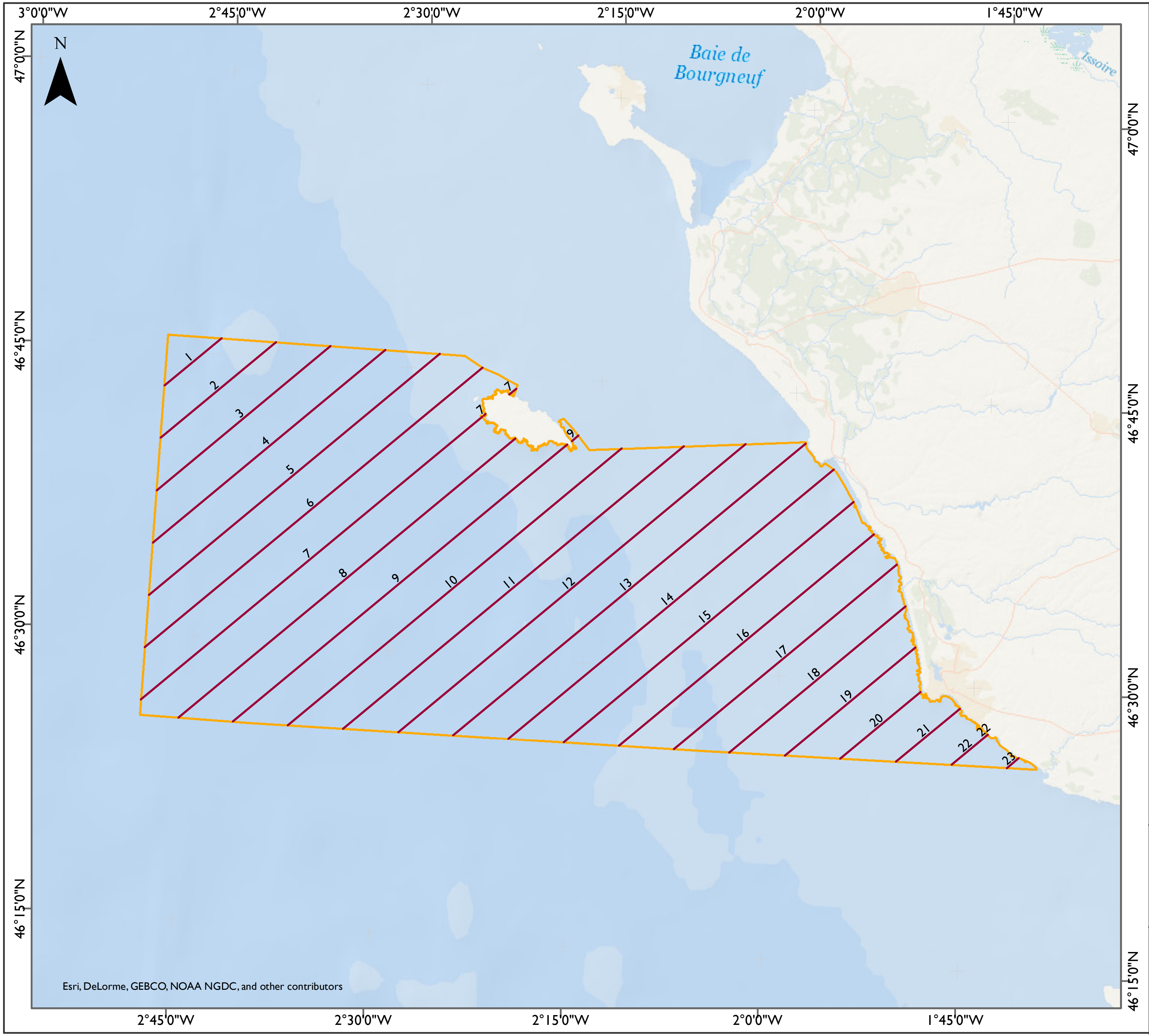
[1] Recent guidance (e.g. Thaxter *et al.* 2015) recommends that all aerial surveys should be undertaken at a minimum altitude of 500m. This is to prevent sensitive species exhibiting responsive movement to aircraft flying at altitudes below 500m ASL, which is known to bias abundance estimates.



LEGEND

- Transects
- Île d'Yeu project area

0 10 20
Kilometres

CLIENT	Biotope
PROJECT	HP00070 - Île d'Yeu
DRAWING TITLE	Figure 1 - Survey design showing transects for Île d'Yeu digital video aerial survey
DRAWING NUMBER	HP00070-701-001

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef AERIAL SURVEYING LIMITED

2.2 Data Review and Object Detection

13 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.

14 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.

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

2.3 Object Identification

16 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.

17 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[2].

18 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. All behaviour, such as flying (with direction), sitting (on the sea), taking off was recorded for seabirds with any feeding activity. For non-avian animals, surfacing behaviour was recorded and defined as submerged if all parts of the animal were below the surface in all frames; surfacing if any part of the animal broke the surface in any of the frames, and snapshot surfacing if the cetacean or shark's dorsal fin breaks the surface in the middle frame of the sequence (also referred to as surfacing at the red line).

2.4 Final processing

19 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 Lambert-93 (EPSG 2154) projection, RGF93 datum.

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[2] HiDef currently employs three (3) of the ten (10) current members of the British Birds Rarities Committee ("BBRC") as expert ornithologists, all of whom can be regarded as independent experts.

2.5 Data analysis

2.5.1 Data treatment

20 After basic presentation, data were processed for estimating abundance and distribution of the key species and species groups. All confidence levels of species identifications were used in the analysis. In the analysis of species groups, rationalisation of the full list of species groups was carried out in order to simplify the interpretation.

21 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.

2.5.2 Abundance Estimates

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

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

24 The density estimate is expressed as the average number of animals per square km surveyed over the whole site, and the population estimate is then calculated as the average density multiplied up to the area of the whole site. The standard deviation is a measure of the variance of the population estimate, standardised by the number of samples (transects). The upper and lower CI define the range that the population estimate falls 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. A CV value of less than 16% allows a 50% decline or 100% increase in abundance between two samples to be detected with greater power than 0.8. This is usually regarded as the minimum precision required for monitoring effects of developments on key species.

2.5.3 Density Mapping

25 The density maps have been derived using a Watson-Nadaraya type kernel density estimation ("KDE") technique (Simonoff, 1996). In KDE, a small 'window' function (the kernel) is used to calculate a local density at each point in the study area. To evaluate the density at a given point, the kernel is centred on that point and all the observations within the window are summed to obtain a local count. The total area of the transect(s) intersecting the window is then summed to obtain a local measure of effort. By

dividing the local count by the local effort, a local density estimate is obtained. To build a density map, the study area is covered with a fine mesh of study points and the density is calculated at each point in the mesh in turn.

26 Kernel techniques are robust techniques because they have few parameters, with the only variables being 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 is determined by a single width parameter; the selection of this parameter is the only variable in the computation of the density maps.

27 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.

28 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 of the process is a smooth density estimate which has been derived without any manual parameter selection. The whole process is repeated from scratch for each map, as different kernel sizes are appropriate for different species.

29 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 can also happen for very sparse distributions. In the case of sparse distributions, the ‘flat’ map does not necessarily mean that the true underlying distribution is ‘flat’; it could mean that the data 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.

3 Results

3.1 Survey effort

30 The date, number of transects and survey effort (as expressed by length of transects) undertaken on 11 August 2016 are shown in Table 1. The number of transects and the total length of transects are those used in subsequent analysis.

Table 1 Survey effort across Île d'Yeu on August 2016

Survey date	Number of transects analysed	Total length of transects analysed (km)	Area analysed (km²)
11 August 2016	23	651.02	295.61

3.2 Survey results

31 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 survey being shown in Table 2.

Table 2 Survey identification rates at the Île d'Yeu in August 2016

Survey date	ID rate (%)
11 August 2016	90.04%
Average	**90.04%**

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

Table 3 Number of objects detected during each survey assigned to species level on 11 August 2016

Species	Scientific Name	Total recorded
Fulmar	*Fulmarus glacialis*	2
Balearic shearwater	*Puffinus mauretanicus*	446
European storm-petrel	*Hydrobates pelagicus*	12
Gannet	*Morus bassanus*	26
Redshank	*Tringa totanus*	4
Black-headed gull	*Chroicocephalus ridibundus*	1
Mediterranean gull	*Larus melanocephalus*	2
Lesser black-backed gull	*Larus fuscus*	291
Herring gull	*Larus argentatus*	8
Herring gull complex	*Larus fuscus/michahellis/argentatus*	223
Great black-backed gull	*Larus marinus*	40
Sandwich tern	*Sterna sandvicensis*	31
Common tern	*Sterna hirundo*	14
Guillemot	*Uria aalge*	47
Puffin	*Fratercula arctica*	1
Ocean sunfish	*Mola mola*	14
Blue shark	*Prionace glauca*	3
Common dolphin	*Delphinus delphis*	94
Bottlenose dolphin	*Tursiops truncatus*	13

Species	Scientific Name	Total recorded
Harbour porpoise	*Phocoena phocoena*	11
Total		**1283**

Table 4 Number of objects with no species ID detected during each survey assigned to species groups on 11 August 2016

Species group (No ID)	Total
Small gull species	3
Large gull species	98
Gull species	18
Tern / small gull	1
Auk / shearwater species	1
Fish species	4
Dolphin species	27
Cetacean species	2
Seal / small cetacean species	1
Squid	2
Total	**157**

3.3 Abundance estimates

33 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 and Table 6.

34 All birds and non-avian animals were assigned to a species group, and over 90% of these were also assigned to a species, therefore the species group density and abundance estimates use individuals that have a species assigned to them as well as a minority that do not.

35 The highlights for the species observed are provided in this section after the tables. All species and species groups showed wide confidence intervals to the abundance estimates, and this should be borne in mind when reading the point abundance estimates for each species.

Table 5 Abundance estimates of species in the study area during Survey 1 on 11 August 2016

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Fulmar	0.01	20	0	50	13	63.47%
Balearic shearwater	1.79	4401	158	13596	3631	82.51%
European storm-petrel	0.05	120	8	315	82	67.83%
Gannet	0.11	261	125	457	86	33.04%
Black-headed gull	0.00	10	0	33	9	88.44%
Mediterranean gull	0.01	20	0	50	13	63.83%
Lesser black-backed gull	1.02	2504	838	4739	1011	40.39%
Herring gull	0.03	80	25	158	34	42.95%
Herring gull complex	0.86	2115	656	4075	885	41.82%
Great black-backed gull	0.16	400	208	639	111	27.74%
Sandwich tern	0.12	297	25	813	209	70.43%
Common tern	0.06	138	17	357	92	66.35%
Guillemot	0.19	471	116	938	215	45.62%
Puffin	0.00	10	0	33	9	88.99%
Ocean sunfish	0.06	139	75	216	37	26.79%
Common dolphin	0.38	941	407	1627	312	33.22%

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Bottlenose dolphin	0.05	129	33	266	64	49.89%
Harbour porpoise	0.04	109	42	183	36	33.18%
Blue shark	0.01	30	0	75	20	66.15%
Squid	0.00	10	0	33	9	88.42%

Table 6 Abundance estimates of species groups in the study area during Survey 1 on 11 August 2016

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All birds	4.89	12009	3254	26395	6157	51.28%
All non-avian animals	0.69	1691	963	2556	405	23.93%
Species group						
Fulmar / gull species	0.01	20	0	50	13	63.47%
Shearwater species	1.74	4262	133	13264	3550	83.29%
Storm-petrel species	0.05	120	8	315	82	67.83%
Gannet species	0.11	261	125	457	86	33.04%
Small gull species	0.02	41	8	91	22	54.98%
Large gull species	2.41	5923	2191	10774	2213	37.37%
Gull species	0.11	258	25	730	191	73.91%
Arctic / common tern	0.04	99	8	249	66	66.26%
Tern species	0.13	327	33	880	227	69.56%
Tern / small auk species	0.01	20	0	66	18	91.78%
Large auk	0.18	431	100	872	202	46.76%
Auk species	0.00	10	0	33	9	88.99%
Auk / shearwater species	0.08	198	25	481	122	61.51%
Fish species	0.07	180	91	282	49	27.35%

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 (%)
Shark species	0.01	30	0	75	20	66.15%
Dolphin species	0.54	1333	672	2125	372	27.91%
Cetacean species	0.05	128	58	208	39	30.16%
Seal / small cetacean species	0.00	10	0	33	9	90.82%

36 Fulmars were recorded at very low densities of 0.01 birds/km² which equated to an abundance estimate of 20 (± 95% CI 0 – 50) individuals.

37 Balearic shearwaters were the most abundant species recorded in the survey. Density was 1.79 birds/km² which equated to 4401 birds (± 95% CI 158 – 13596) across the survey area.

38 Low densities of European storm-petrels were recorded of 0.05 birds/km², with the density estimate being 120 birds (± 95% CI 8 – 315).

39 Gannets were recorded at a relatively low density of 0.11 birds/km², equating to an abundance estimate of 261 individuals (± 95% CI 125 – 457).

40 Very low densities of Mediterranean gull *Larus melanocephalus* were recorded with 0.01 birds/km² and an abundance estimate of 20 (± 95% CI 0 – 50) birds.

41 Lesser black-backed gull *L. fuscus* had one of the highest recorded density estimates with 1.02 birds/km². The density equated to 2504 individuals (± 95% CI 838 – 4739).

42 Herring gulls were recorded with a relatively low density of 0.03 birds/km² which equated to 80 (± 95% CI 25 – 158) birds.

43 High densities of herring gull complex (lesser black-backed, yellow-legged *L. michahellis* or herring gull) were recorded with 0.86 birds/km² and an abundance estimate of 2115 individuals (± 95% CI 656 – 4075).

44 Great black-backed gulls *L. marinus* had a density estimate of 0.16 birds/km² which equated to 400 birds (± 95% CI 208 – 639).

45 Sandwich terns had a low density estimate of 0.12 birds/km² and an abundance estimate of 297 (± 95% CI 25 – 813) individuals.

46 Common tern *Sterna hirundo* had a low density estimate within the survey area at 0.06 birds/km² which equated to 138 individuals (± 95% CI 17 – 357).

47 Guillemot had a density estimate of 0.19 birds/km² and an abundance estimate of 471 (± 95% CI 116 – 938) individuals.

48 Common dolphins *Delphinus delphis* were the most abundant non-avian animal species with a density estimate of 0.38 animals/km². This equated to an abundance estimate of 941 individuals (± 95% CI 407 – 1627).

49 Bottlenose dolphin *Tursiops truncatus* had a low density estimate of 0.05 animals/km² and an abundance estimate of 129 animals (± 95% CI 33 – 266).

50 Low densities of harbour porpoise *Phocoena phocoena* were recorded with 0.04 animals/km² and an abundance estimate which equated to 109 (± 95% CI 42 – 183) individuals.

3.4 Distribution patterns

51 The distribution patterns for the most abundant species and species groups are presented as density maps, in which a density surface depicts the estimated density of individuals per km² (Figure 2 to Figure 12 and Figure 15 to Figure 16). Species or species groups for which there were few observations are presented as dot maps (Figure 13 to Figure 14 and Figure 20 to Figure 22).

52 The figure for all bird species show birds were recorded across the whole survey area (Figure 2), although most detections were made around the shoreline.

53 Balearic shearwater were mainly distributed towards the east and south-east of the survey area (Figure 3).

54 There was no obvious distribution pattern for European storm-petrels (Figure 4).

55 Gannet distribution varied across the survey area with highest densities towards the north (Figure 5).

56 Lesser black-backed gulls were recorded across the survey area and were strongly concentrated towards the edges of the whole survey area (Figure 6).

57 Density patterns for herring gulls show concentrations towards the south east of the survey area (Figure 7).

58 Herring gull complex were concentrated at high densities towards the east of the survey area (Figure 8) and were also strongly concentrated in the north and the south west.

59 Great black-backed gulls were widely distributed across the survey area (Figure 9). The highest densities for this species were recorded in the south east and south west.

60 Sandwich terns were strongly concentrated towards the east of the survey area near the shoreline (Figure 10).

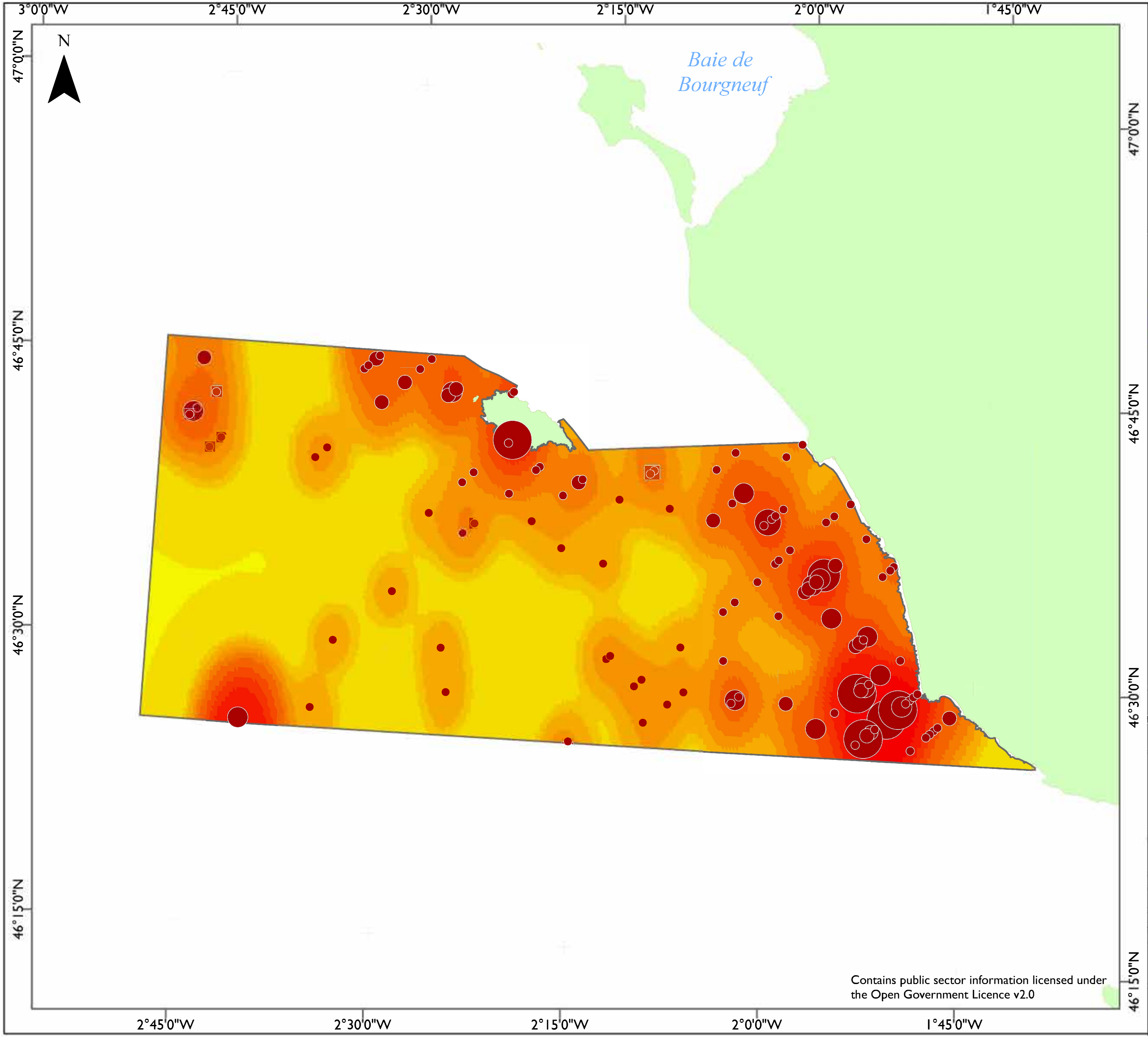
61 Common terns were present in the east of the survey area (Figure 11).

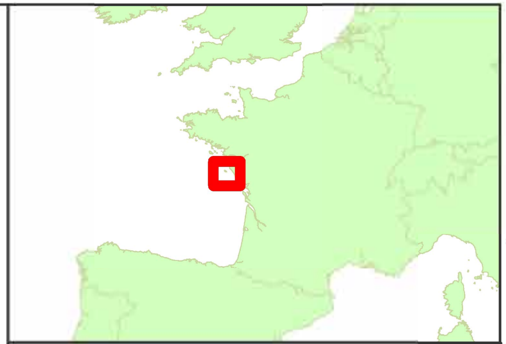
62 High densities of guillemot were seen towards the south east of the survey area (Figure 12). This species was also observed to the north of the survey area.

63 Non-avian animals were observed across the whole survey area although higher densities were recorded towards the west (Figure 15) of the survey area. Ocean sunfish were distributed from the middle of the survey area to the west (Figure 16). Common dolphin distribution varied across the survey area with strong concentrations in the west, north east and south east (Figure 17), while bottlenose dolphin distribution was towards the south west of the survey area (Figure 18). Harbour porpoise observations varied across the survey area with no obvious distribution pattern (Figure 19).

3.4.1 Distribution maps for all bird species

65 A distribution map for all species recorded is presented as Figure 2.





LEGEND

(per sq km)
- 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.5
- 0.51 - 1
- 1.01 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 20
- 20.01 - 50
- > 50

(per segment)
- 1 - 2
- 3 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- >20

Île d'Yeu project area

Europe

0 10 20 Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 2 - Density of all birds (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-002

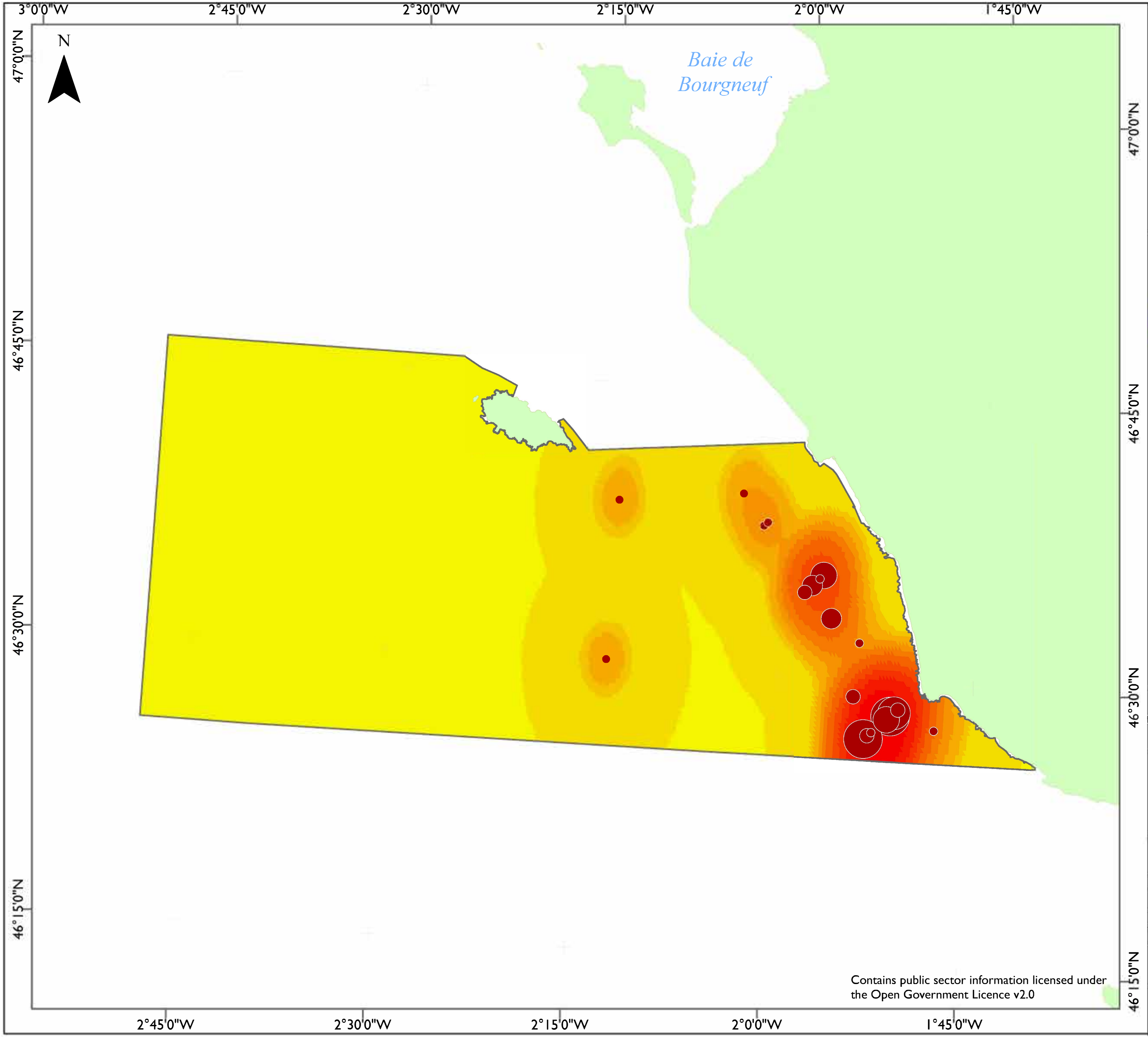
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

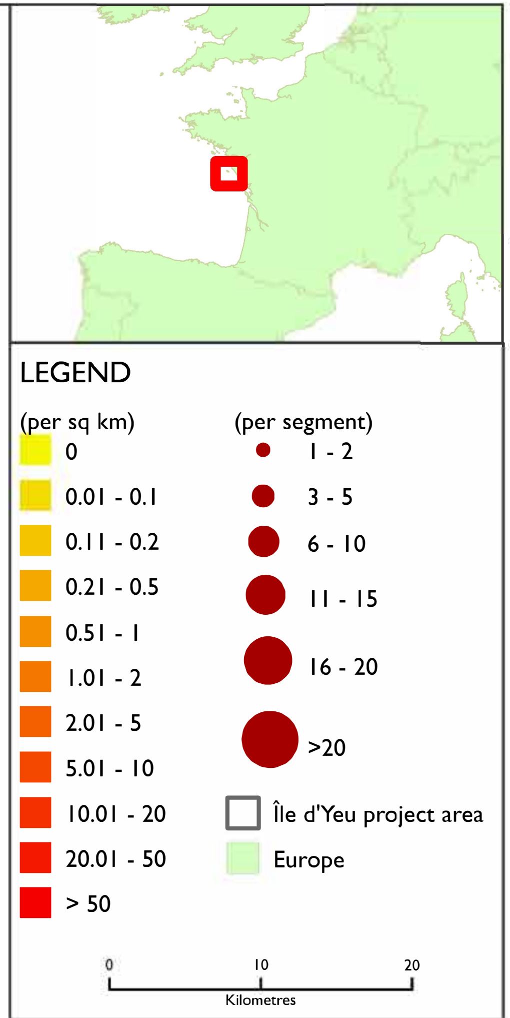
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef AERIAL SURVEYING LIMITED

3.4.2 Distribution maps for Balearic shearwater

66 A distribution map for Balearic shearwater is presented as Figure 3.





CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 3 - Density of all Balearic shearwater (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-003

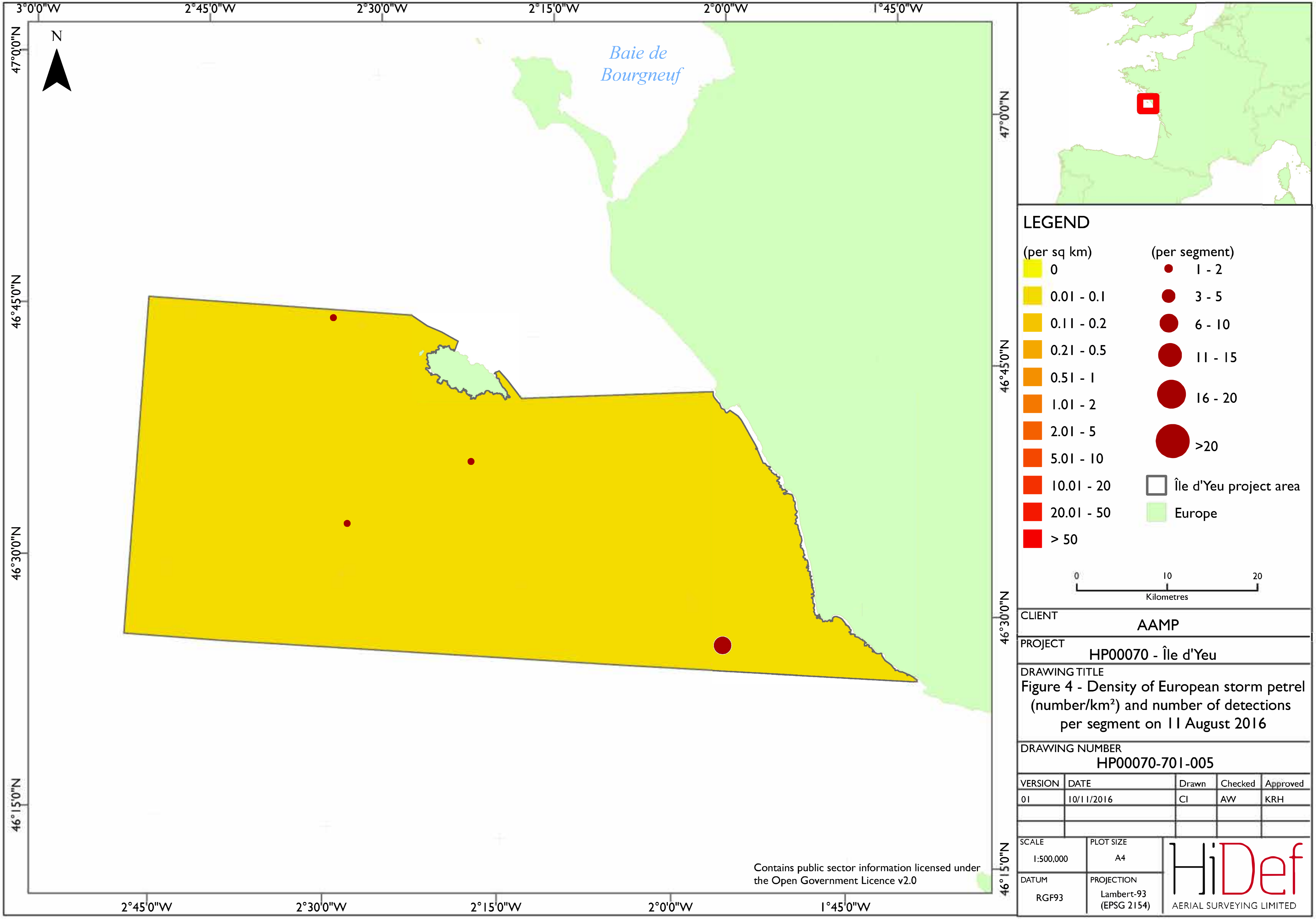
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef AERIAL SURVEYING LIMITED

3.4.3 Distribution maps for European storm-petrel

67 A distribution map for European storm-petrel is presented as Figure 4.


3°0'0"W
2°45'0"W
2°30'0"W
2°15'0"W
2°0'0"W
1°45'0"W
47°0'0"N
46°45'0"N
46°30'0"N
46°15'0"N
N
Baie de Bourgneuf
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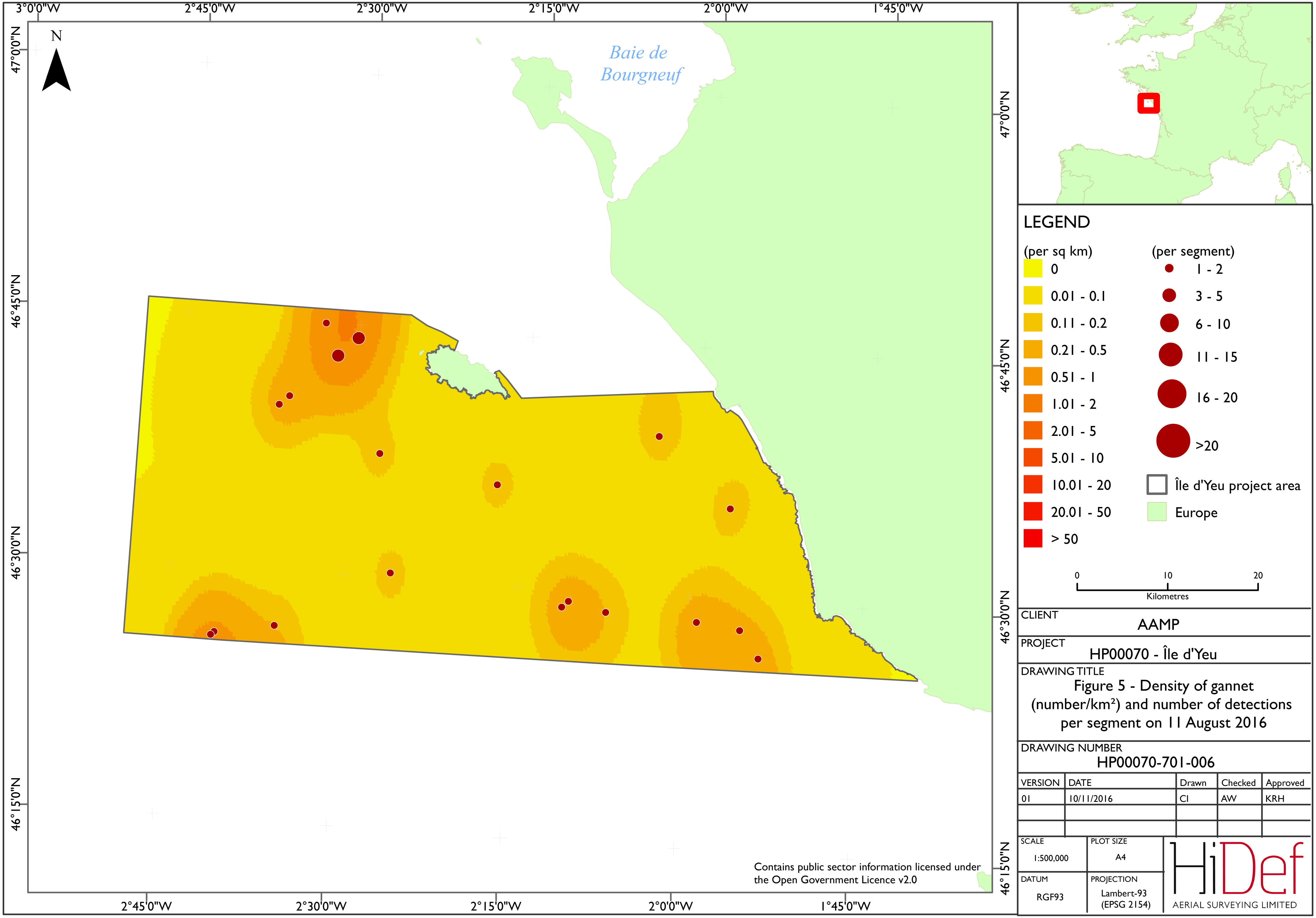
LEGEND
(per sq km)
0
0.01 - 0.1
0.11 - 0.2
0.21 - 0.5
0.51 - 1
1.01 - 2
2.01 - 5
5.01 - 10
10.01 - 20
20.01 - 50
> 50
(per segment)
1 - 2
3 - 5
6 - 10
11 - 15
16 - 20
>20
Île d'Yeu project area
Europe
0
10
20
Kilometres
CLIENT
AAMP
PROJECT
HP00070 - Île d'Yeu
DRAWING TITLE
Figure 4 - Density of European storm petrel (number/km²) and number of detections per segment on 11 August 2016
DRAWING NUMBER
HP00070-701-005
VERSION
DATE
Drawn
Checked
Approved
01
10/11/2016
CI
AW
KRH
SCALE
1:500,000
PLOT SIZE
A4
DATUM
RGF93
PROJECTION
Lambert-93 (EPSG 2154)
HiDef
AERIAL SURVEYING LIMITED

3.4.4 Distribution maps for gannet

68 A distribution map for Gannet is presented as Figure 5.

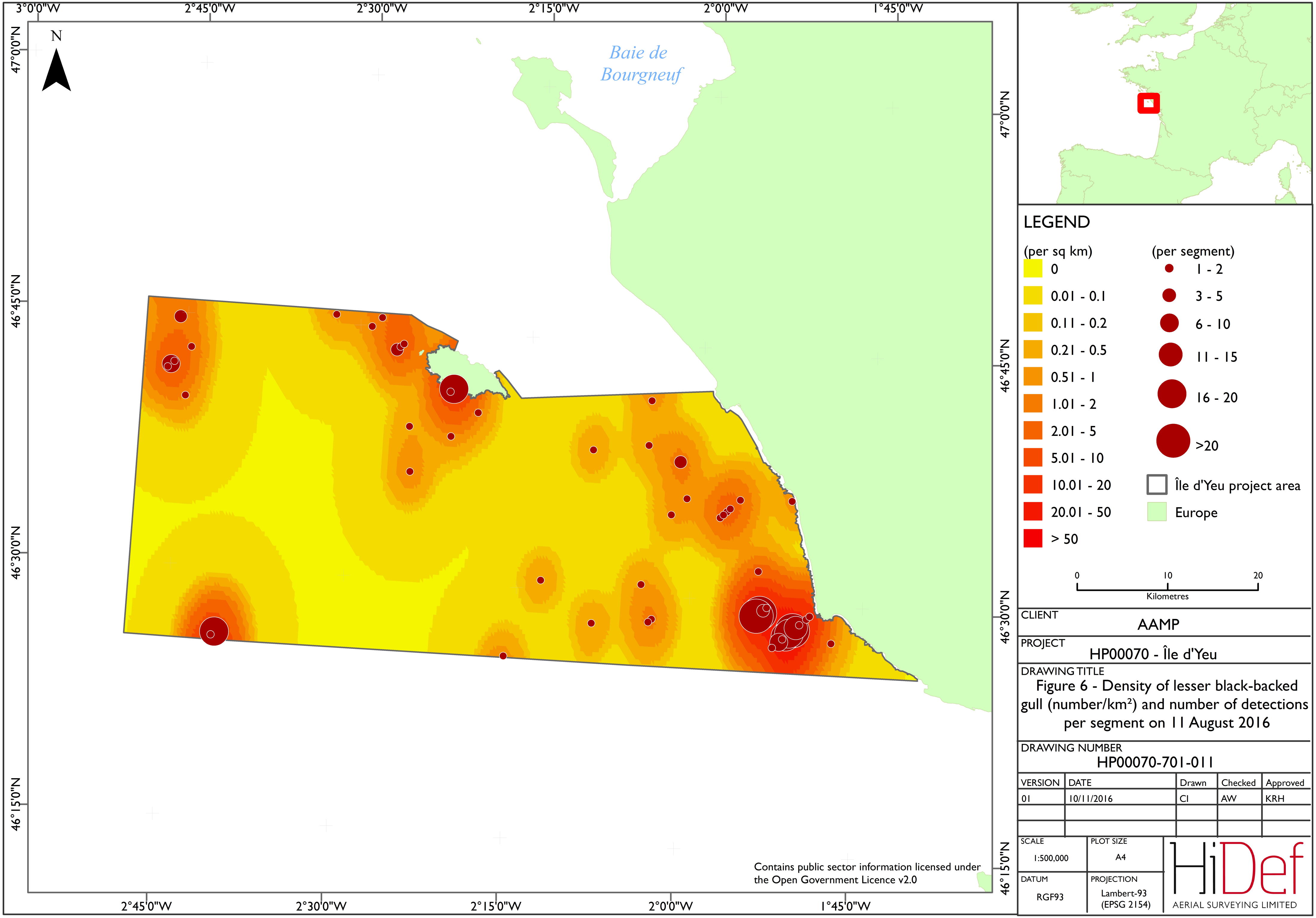


CLIENT				
AAMP				
PROJECT				
HP00070 - Île d'Yeu				
DRAWING TITLE				
Figure 5 - Density of gannet (number/km²) and number of detections per segment on 11 August 2016				
DRAWING NUMBER				
HP00070-701-006				
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH
SCALE	PLOT SIZE			
1:500,000	A4			
DATUM	PROJECTION			
RGF93	Lambert-93 (EPSG 2154)			

HiDef AERIAL SURVEYING LIMITED

3.4.5 Distribution maps for lesser black-backed gull

69 A distribution map for Lesser black-backed gull is presented as Figure 6.



CLIENT	AAMP
PROJECT	HP00070 - Île d'Yeu
DRAWING TITLE	Figure 6 - Density of lesser black-backed gull (number/km²) and number of detections per segment on 11 August 2016
DRAWING NUMBER	HP00070-701-011

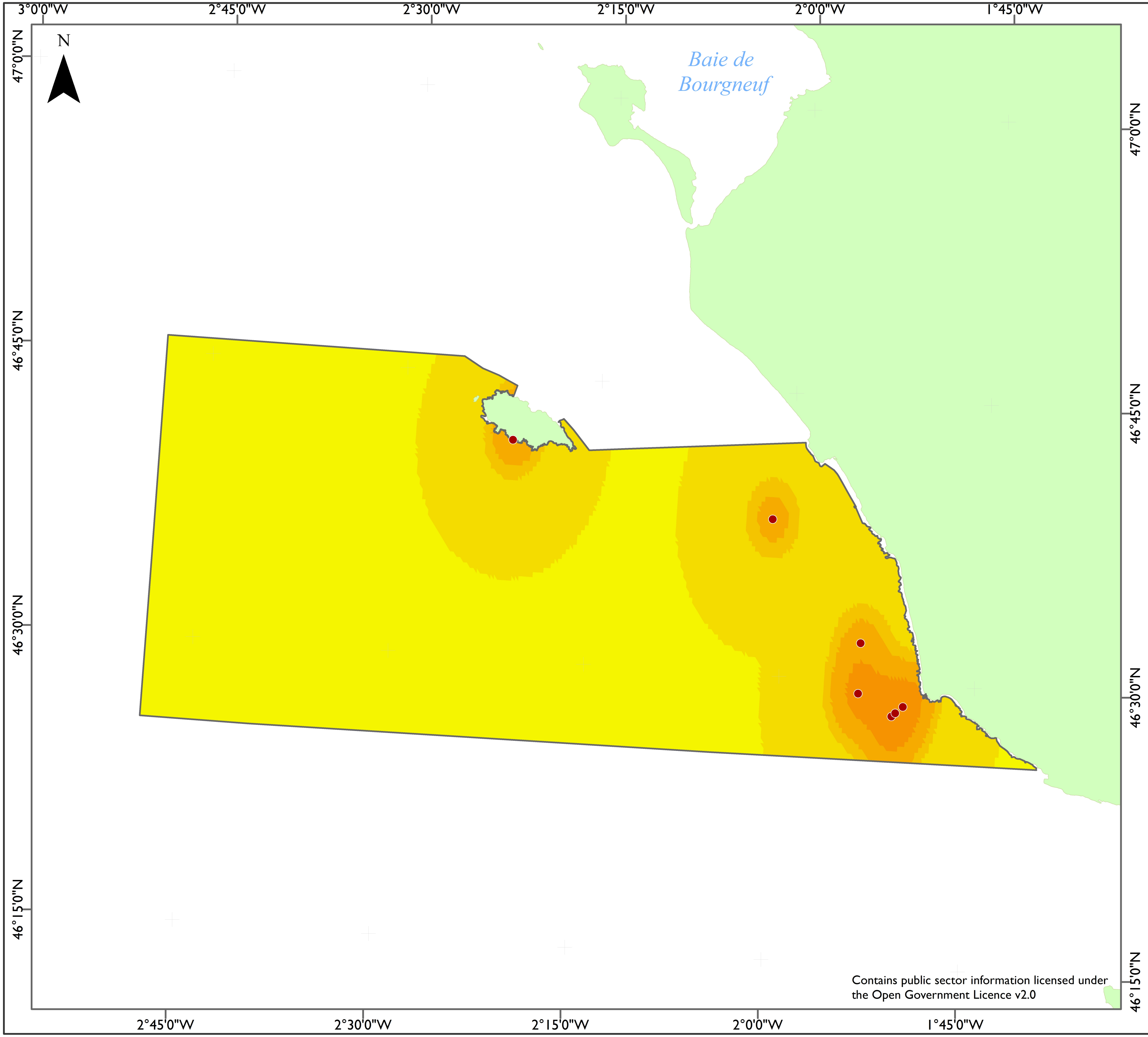
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

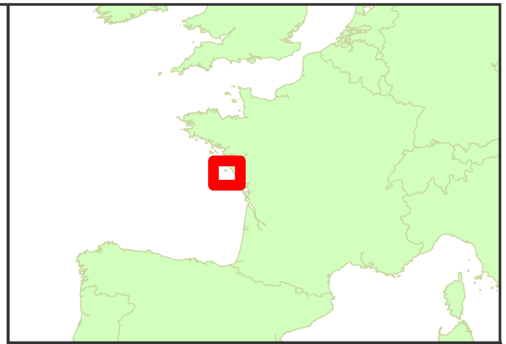
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef AERIAL SURVEYING LIMITED

3.4.6 Distribution maps for herring gull

70 A distribution map for Herring gull is presented as Figure 7.





LEGEND

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 7 - Density of herring gull (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-009

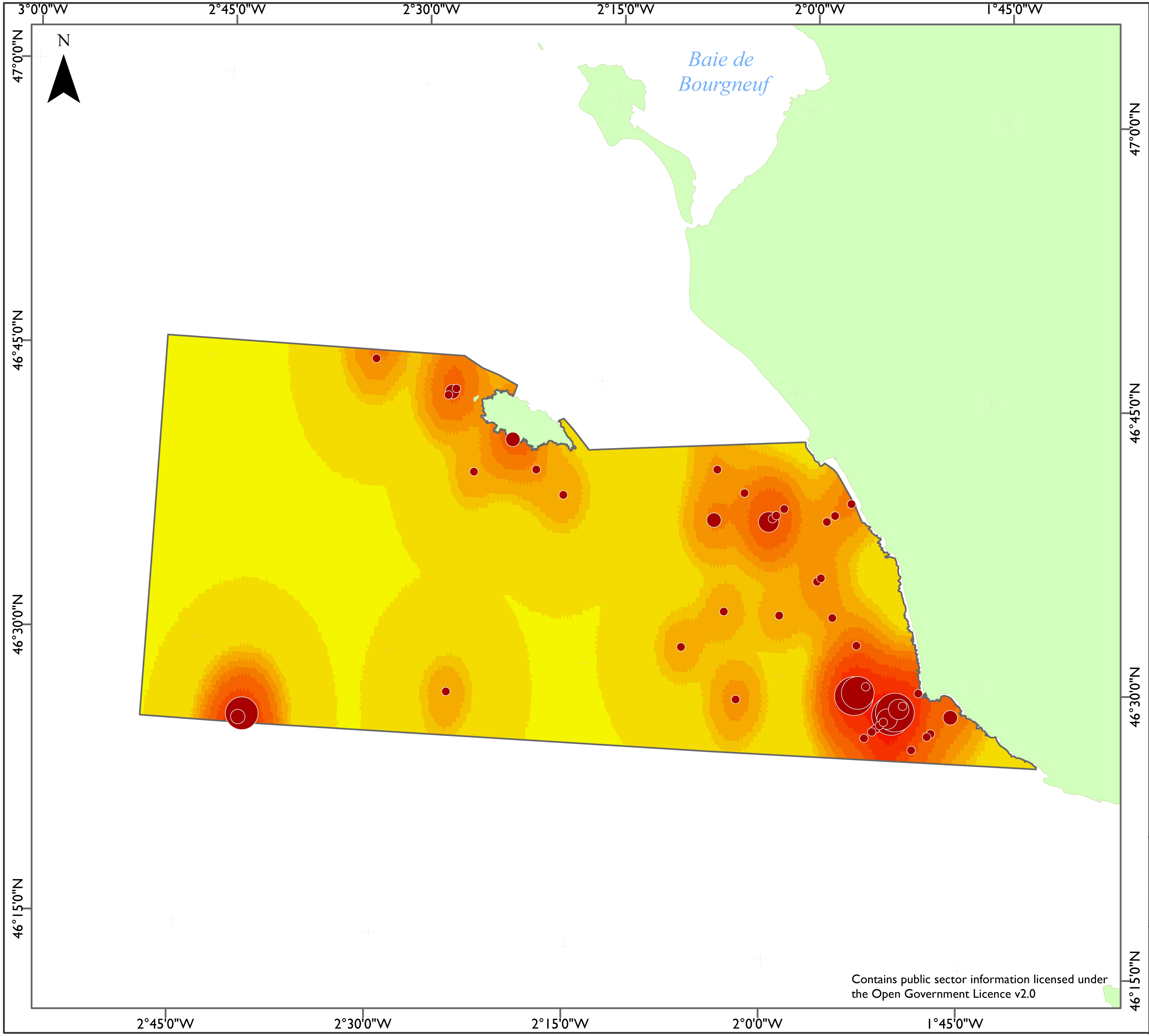
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

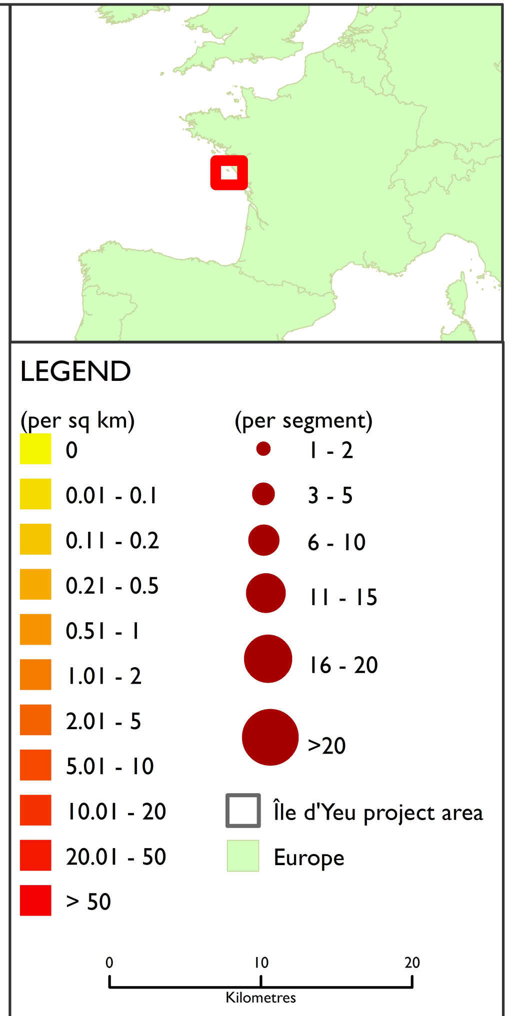
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef
AERIAL SURVEYING LIMITED

3.4.7 Distribution maps for herring gull complex

71 A distribution map for Herring gull complex is presented as Figure 8.





CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 8 - Density of herring gull complex (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-010

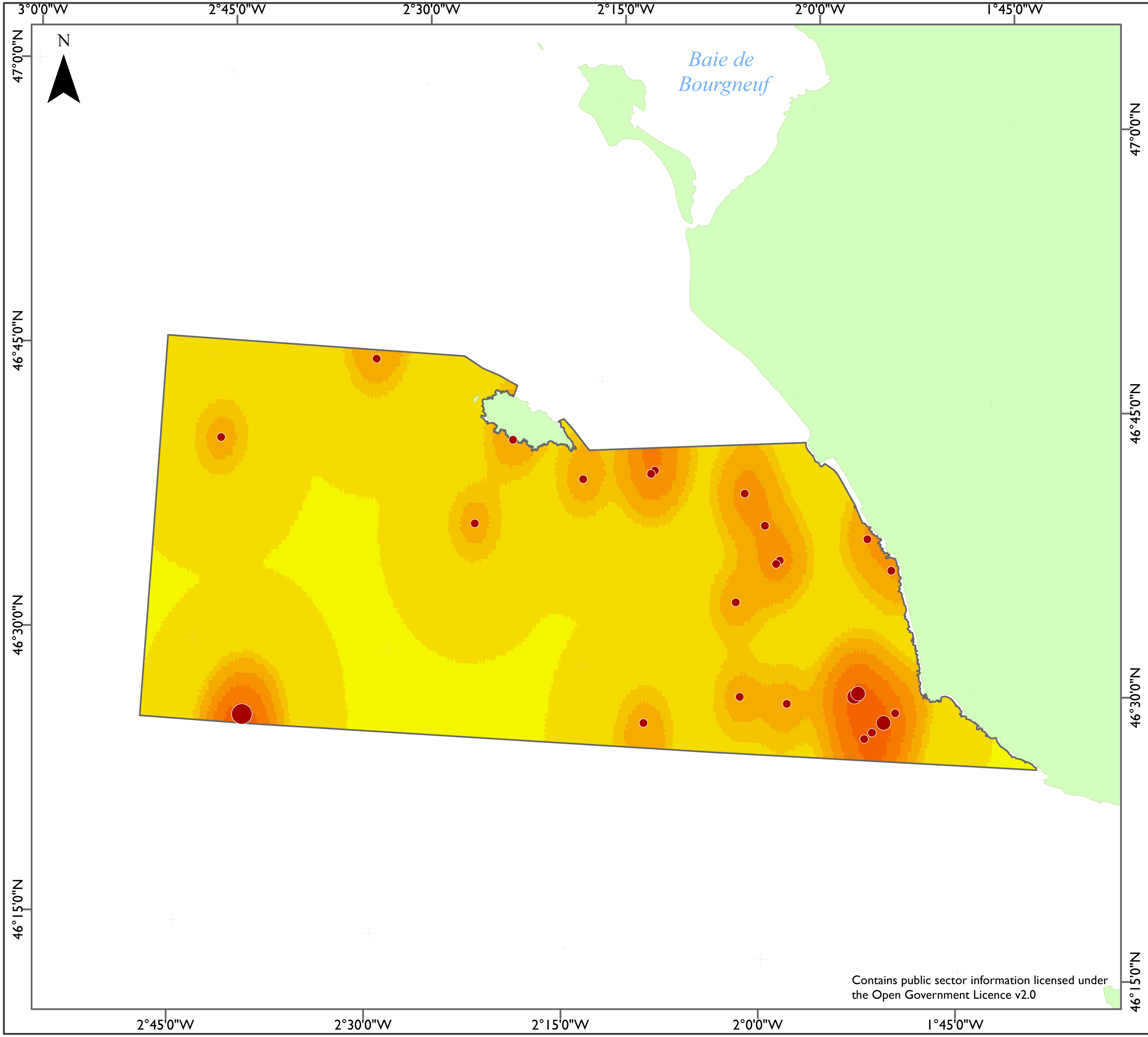
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

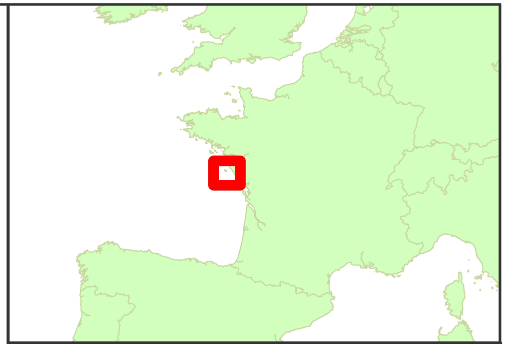
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef
AERIAL SURVEYING LIMITED

3.4.8 Distribution maps for great black-backed gull

72 A distribution map for Great black-backed gull is presented as Figure 9.





LEGEND

(per sq km)	(per segment)
0	1 - 2
0.01 - 0.1	3 - 5
0.11 - 0.2	6 - 10
0.21 - 0.5	11 - 15
0.51 - 1	16 - 20
1.01 - 2	>20
2.01 - 5	Île d'Yeu project area
5.01 - 10	Europe
10.01 - 20	
20.01 - 50	
> 50	

0 10 20
Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 9 - Density of great black-backed gull (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-007

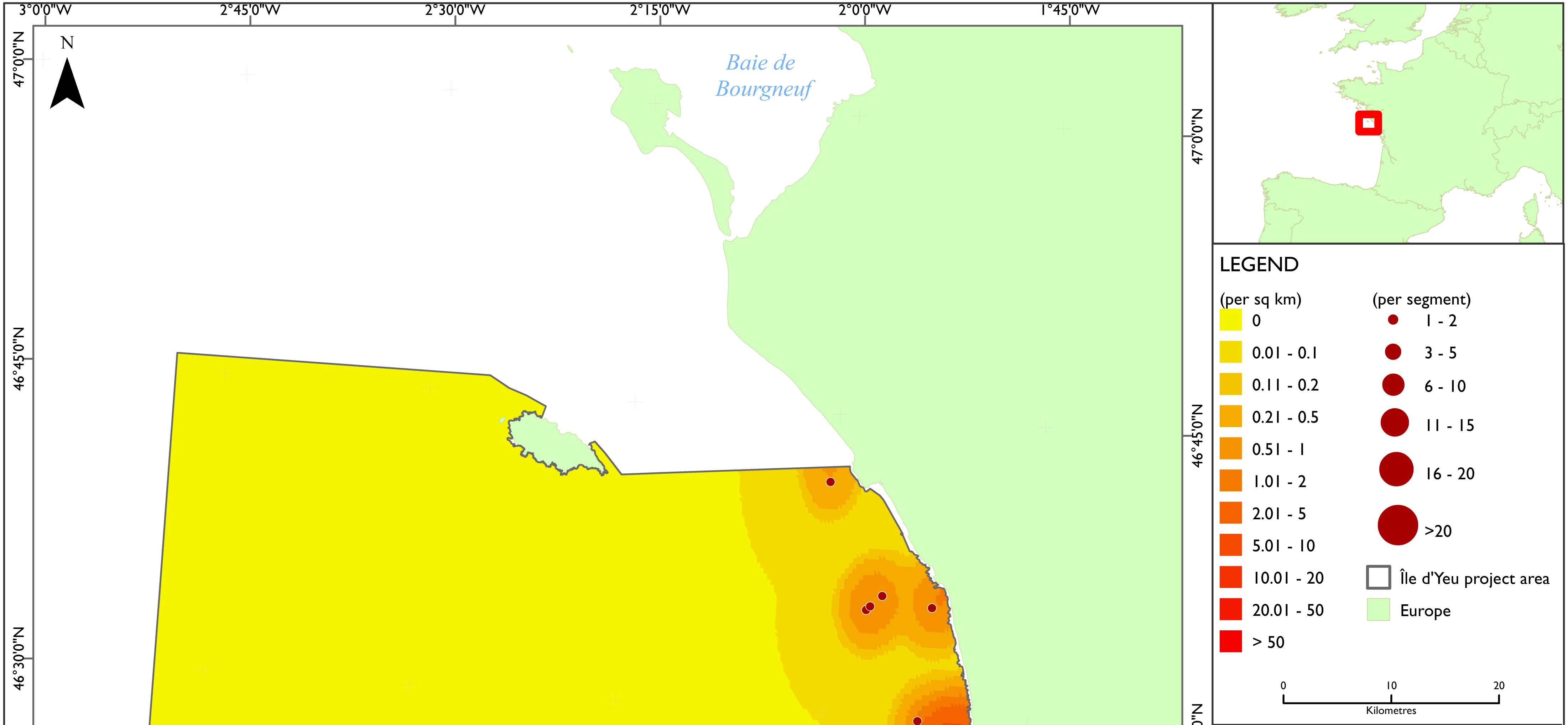
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef
AERIAL SURVEYING LIMITED

3.4.9 Distribution maps for Sandwich tern

73 A distribution map for Sandwich tern is presented as Figure 10.



CLIENT	AAMP
PROJECT	HP00070 - Île d'Yeu
DRAWING TITLE	Figure 10 - Density of sandwich tern (number/km²) and number of detections per segment on 11 August 2016
DRAWING NUMBER	HP00070-701-012

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

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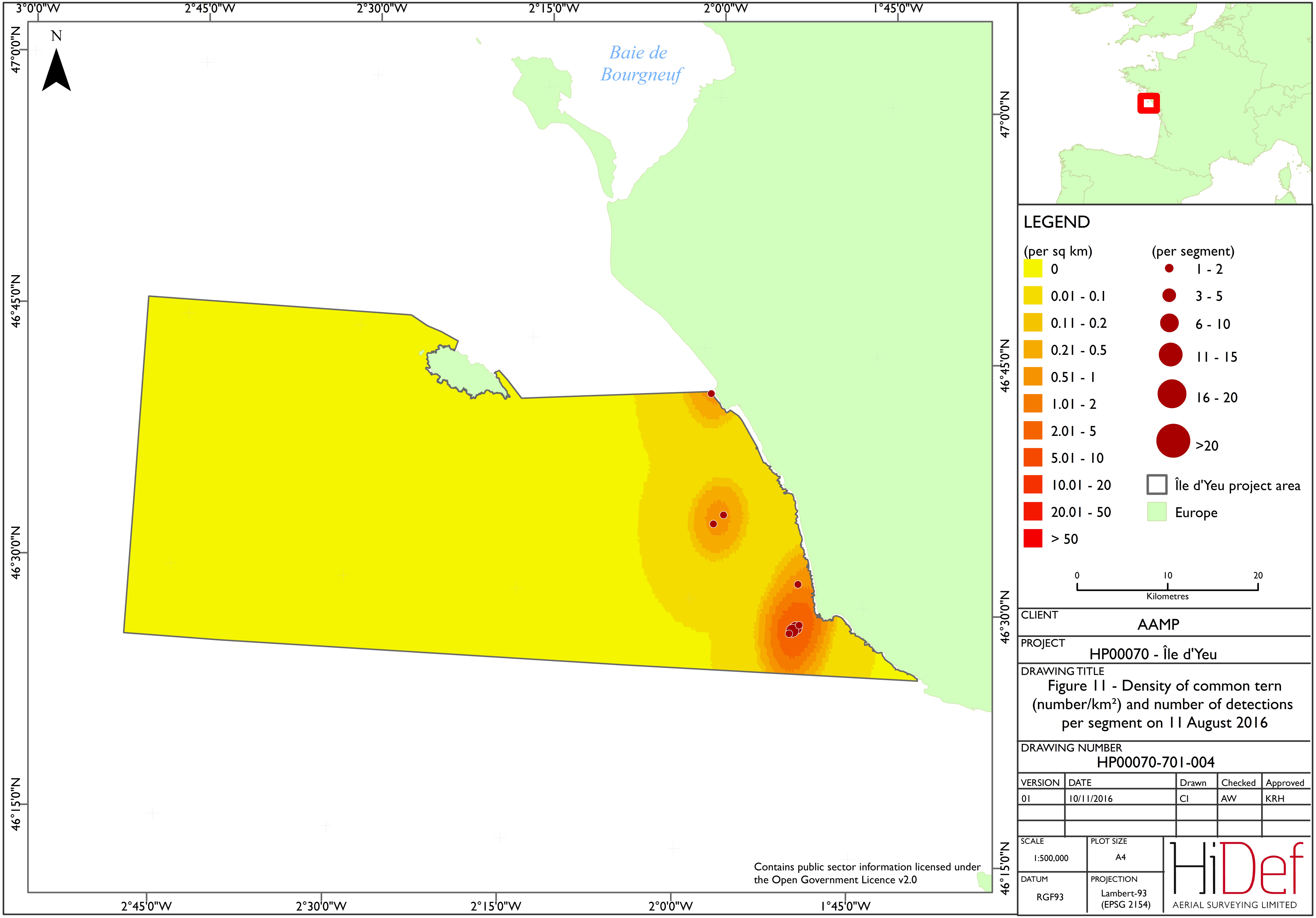
3.4.10 Distribution maps for common tern

74 A distribution map for Common tern is presented as Figure 11.



3°0'0"W
2°45'0"W
2°30'0"W
2°15'0"W
2°0'0"W
1°45'0"W
47°0'0"N
46°45'0"N
46°30'0"N
46°15'0"N
N
Baie de Bourgneuf
LEGEND
(per sq km)
0
0.01 - 0.1
0.11 - 0.2
0.21 - 0.5
0.51 - 1
1.01 - 2
2.01 - 5
5.01 - 10
10.01 - 20
20.01 - 50
> 50
(per segment)
1 - 2
3 - 5
6 - 10
11 - 15
16 - 20
>20
Île d'Yeu project area
Europe
0
10
20
Kilometres
CLIENT
AAMP
PROJECT
HP00070 - Île d'Yeu
DRAWING TITLE
Figure 11 - Density of common tern (number/km²) and number of detections per segment on 11 August 2016
DRAWING NUMBER
HP00070-701-004
VERSION
DATE
Drawn
Checked
Approved
01
10/11/2016
CI
AW
KRH
SCALE
1:500,000
PLOT SIZE
A4
DATUM
RGF93
PROJECTION
Lambert-93 (EPSG 2154)
HiDef
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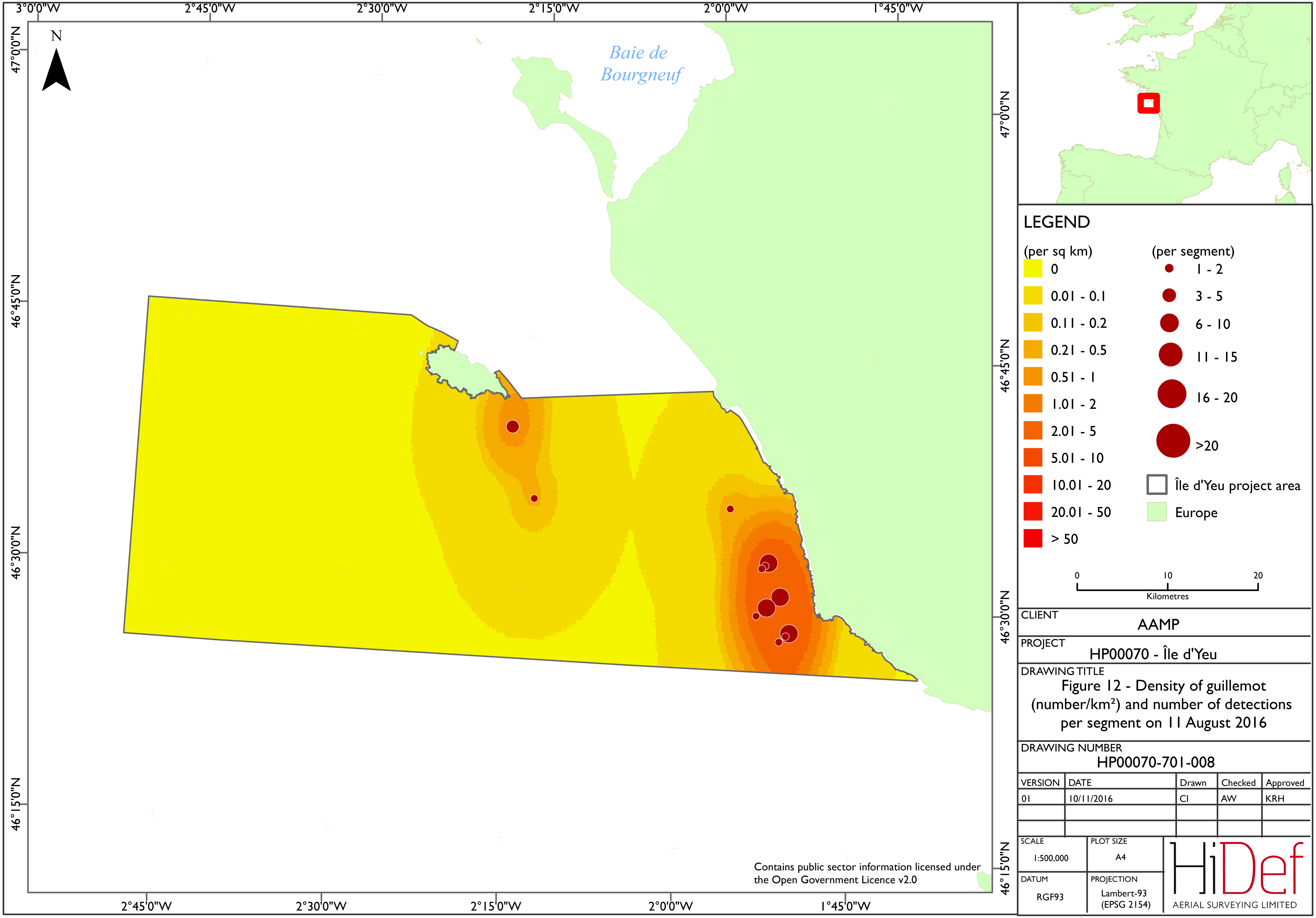
3.4.11 Distribution maps for guillemot

75 A distribution map for Guillemot is presented as Figure 12.



CLIENT				
AAMP				
PROJECT				
HP00070 - Île d'Yeu				
DRAWING TITLE				
Figure 12 - Density of guillemot (number/km²) and number of detections per segment on 11 August 2016				
DRAWING NUMBER				
HP00070-701-008				
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH
SCALE	PLOT SIZE			
1:500,000	A4			
DATUM	PROJECTION			
RGF93	Lambert-93 (EPSG 2154)			

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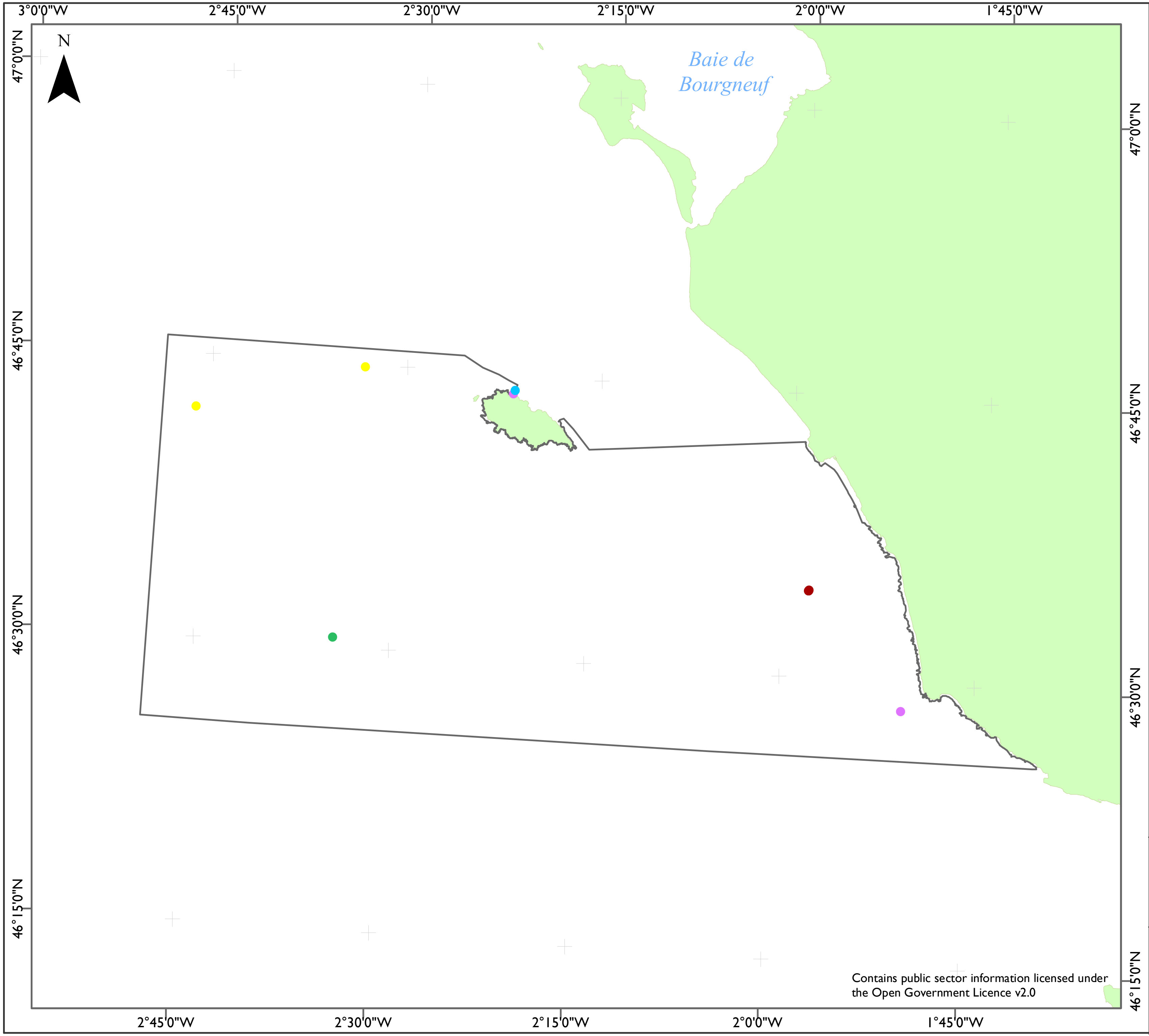
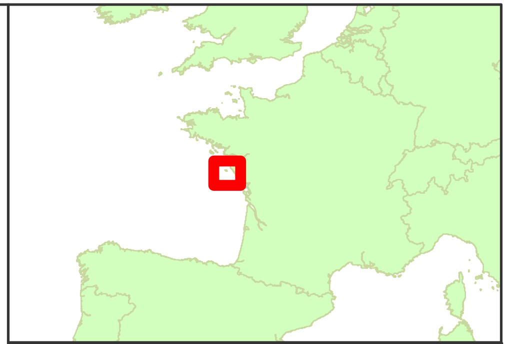
3.4.12 Distribution maps for less abundant bird species

76 A distribution map for less abundant bird species is presented in Figure 13 and include fulmar, redshank, black-headed gull, Mediterranean gull and puffin.





LEGEND

Species
- Black-headed gull
- Fulmar
- Mediterranean gull
- Puffin
- Redshank
- Île d'Yeu project area
- Europe

0 10 20
Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 13 - Detections of less abundant bird species (number/km²) on 11 August 2016

DRAWING NUMBER
HP00070-701-017

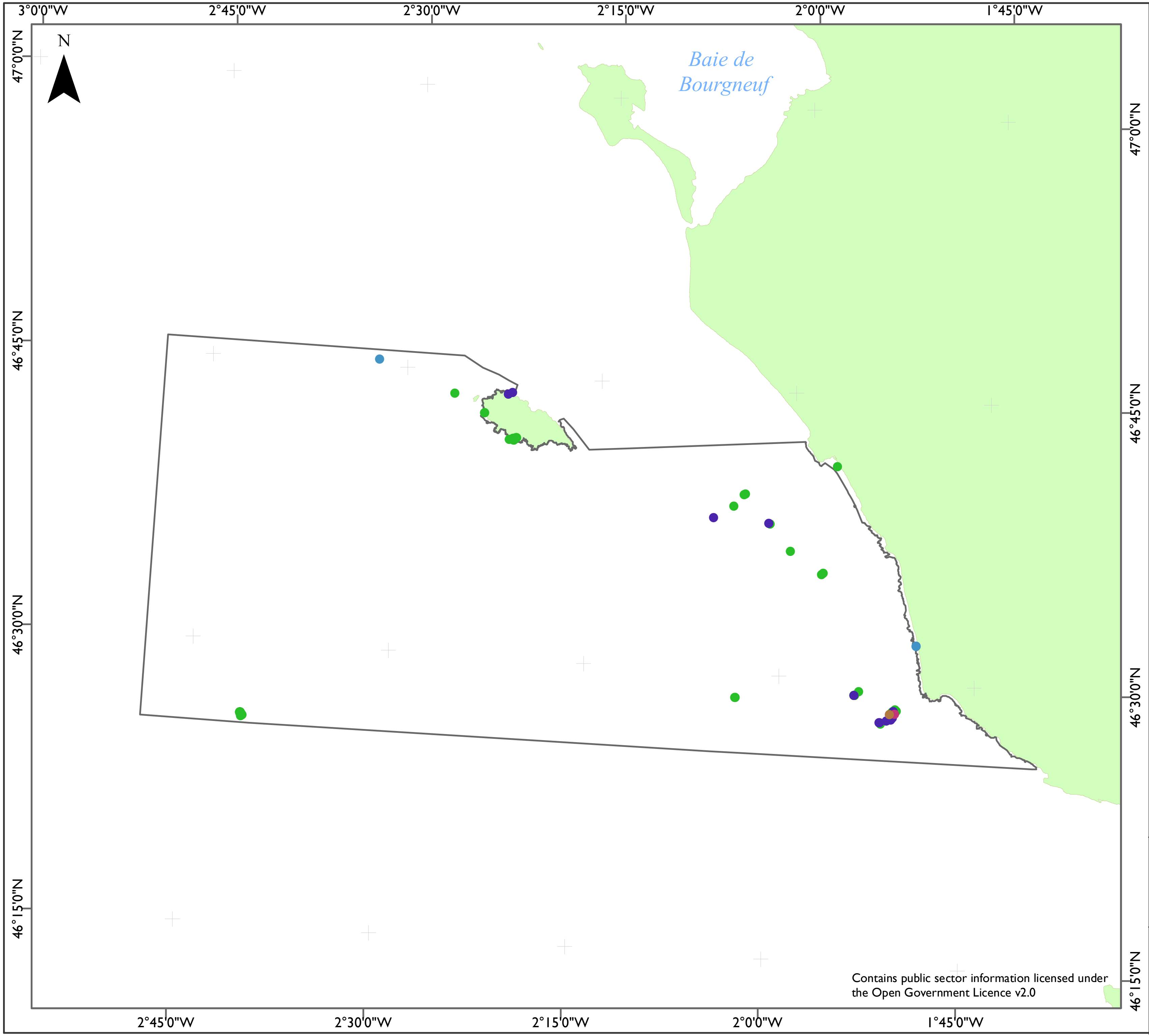
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

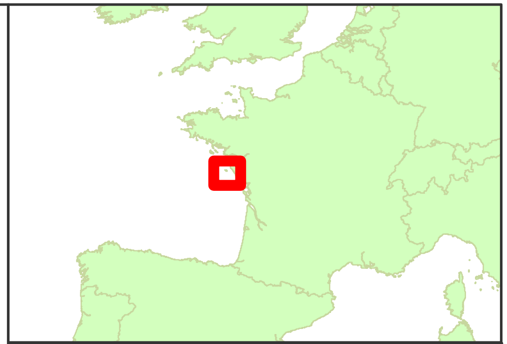
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef
AERIAL SURVEYING LIMITED

3.4.13 Distribution maps for unidentified bird species

77 A distribution map for unidentified bird species is presented as Figure 14.





LEGEND

No ID
- Auk / shearwater species
- Gull species
- Large gull species
- Small gull species
- Tern / small gull
- Île d'Yeu project area
- Europe

0 10 20
Kilometres

CLIENT				
AAMP				
PROJECT				
HP00070 - Île d'Yeu				
DRAWING TITLE				
Figure 14 - Detections of unidentified bird species (number/km²) on 11 August 2016				
DRAWING NUMBER				
HP00070-701-020				
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

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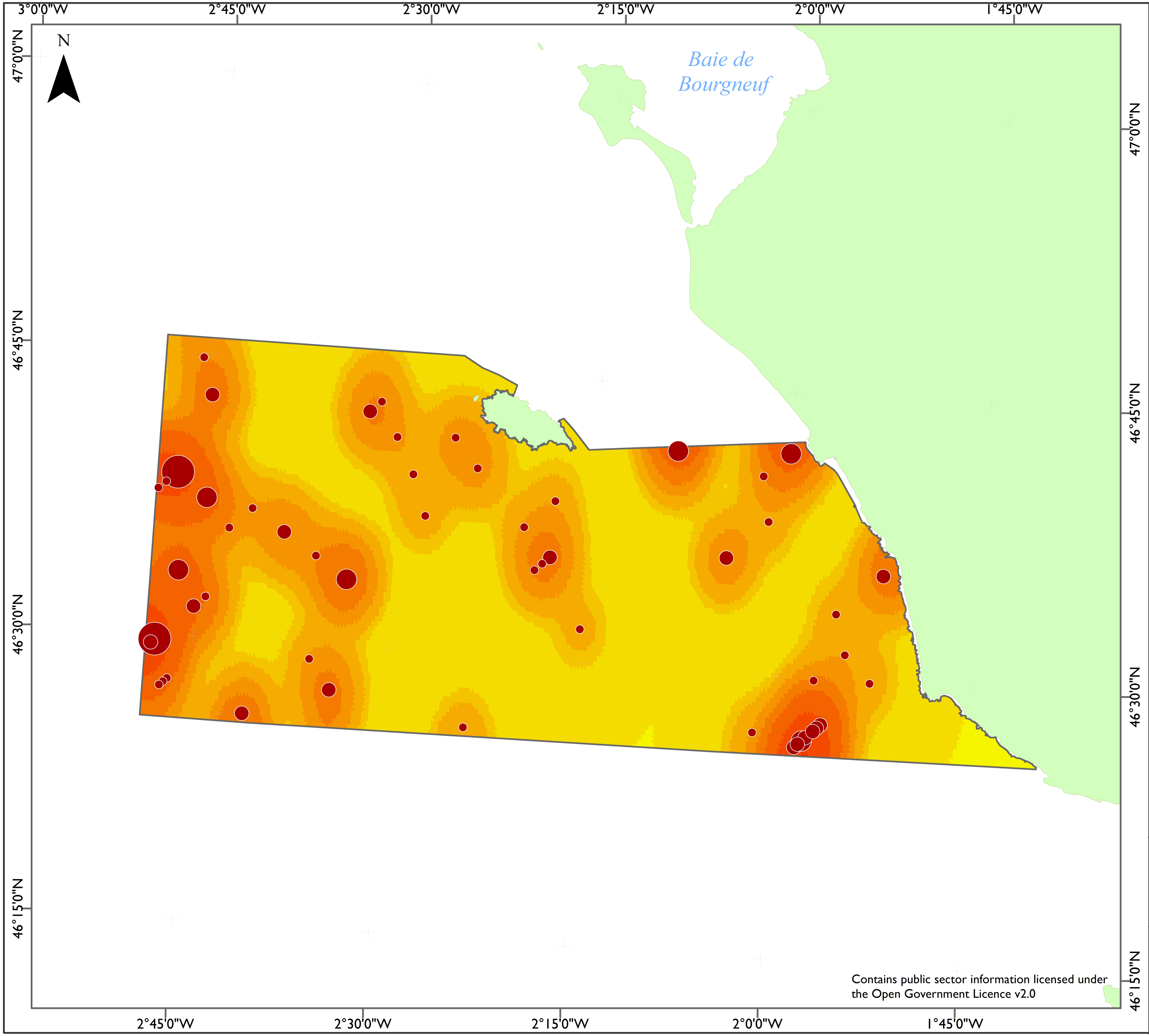
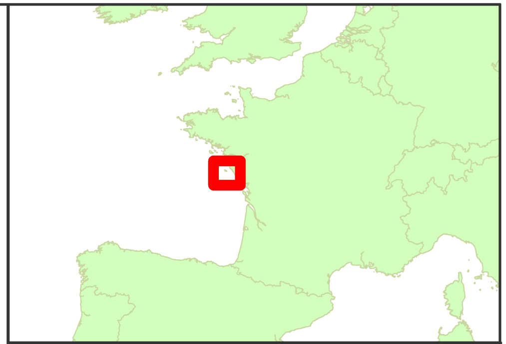
3.4.14 Distribution maps for all non-avian animals

78 A distribution map for all non-avian species is presented as Figure 15.





LEGEND

(per sq km)
0
0.01 - 0.1
0.11 - 0.2
0.21 - 0.5
0.51 - 1
1.01 - 2
2.01 - 5
5.01 - 10
10.01 - 20
20.01 - 50
> 50

(per segment)
1 - 2
3 - 5
6 - 10
11 - 15
16 - 20
>20

Île d'Yeu project area
Europe

0 10 20
Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 15 - Density of all non-avian animal species (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-022

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

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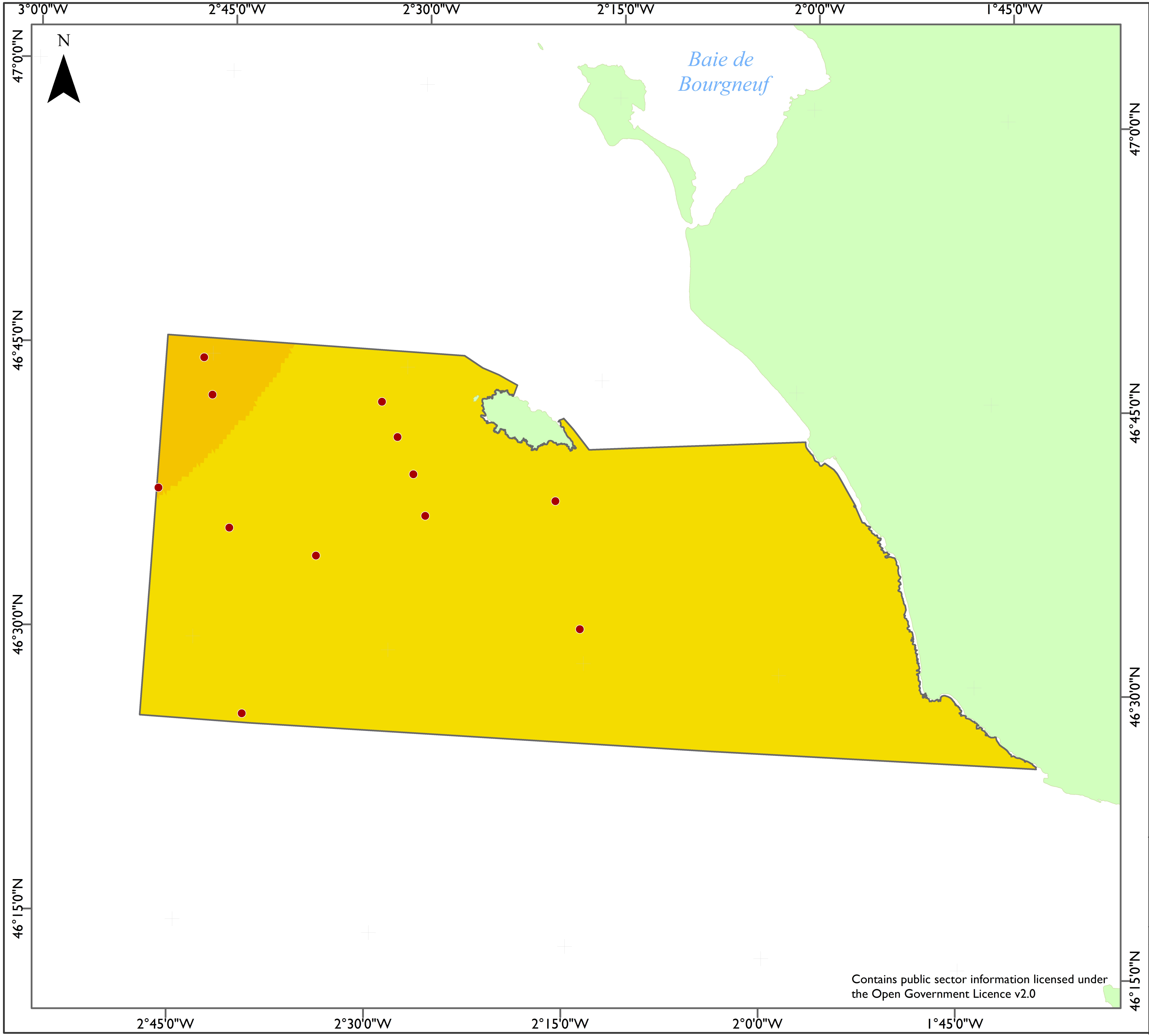
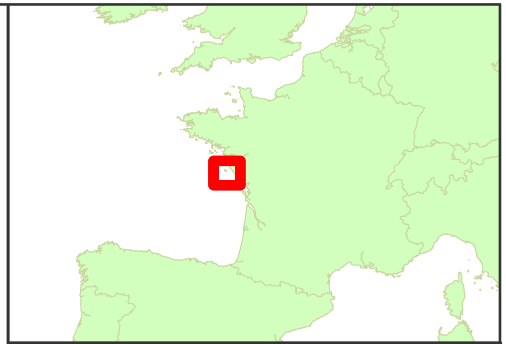
3.4.15 Distribution maps for ocean sunfish

79 A distribution map for Ocean sunfish is presented as Figure 16.





LEGEND

(per sq km)
0
0.01 - 0.1
0.11 - 0.2
0.21 - 0.5
0.51 - 1
1.01 - 2
2.01 - 5
5.01 - 10
10.01 - 20
20.01 - 50
> 50

(per segment)
1 - 2
3 - 5
6 - 10
11 - 15
16 - 20
>20

Île d'Yeu project area
Europe

0 10 20
Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 16 - Density of ocean sunfish (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-016

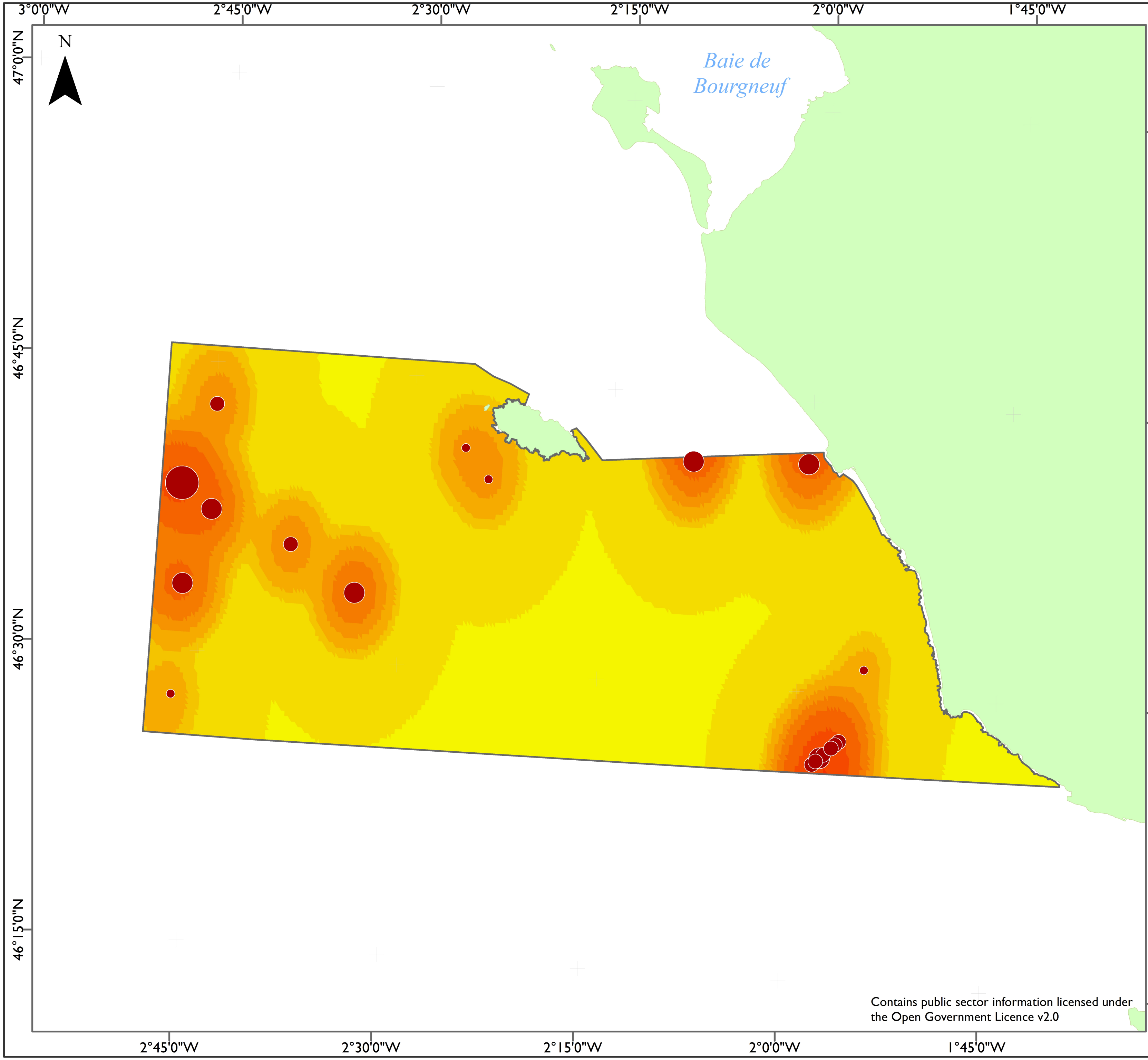
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

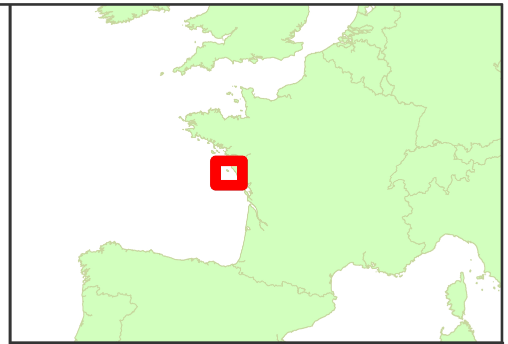
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef
AERIAL SURVEYING LIMITED

3.4.16 Distribution maps for common dolphin

80 A distribution map for common dolphin is presented as Figure 17.





LEGEND

(per sq km)	(per segment)
0	1 - 2
0.01 - 0.1	3 - 5
0.11 - 0.2	6 - 10
0.21 - 0.5	11 - 15
0.51 - 1	16 - 20
1.01 - 2	>20
2.01 - 5	Île d'Yeu project area
5.01 - 10	Europe
10.01 - 20	
20.01 - 50	
> 50	

0 10 20
Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 17 - Density of common dolphin (number/km^2) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-014

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

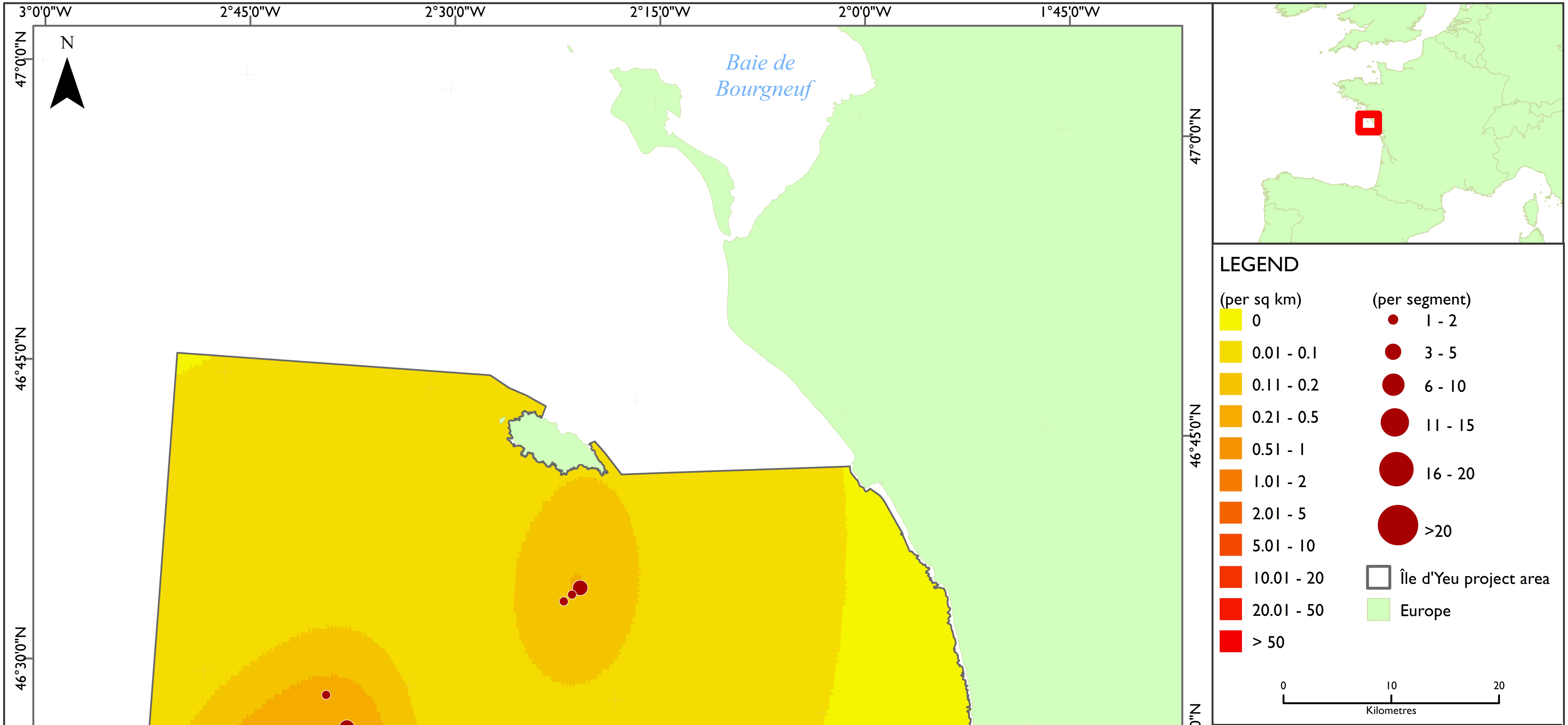
SCALE	PLOT SIZE
1:500,000	A4

DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef
AERIAL SURVEYING LIMITED

3.4.17 Distribution maps for bottle-nose dolphin

81 A distribution map for bottle-nose dolphin is presented as Figure 18.



CLIENT: AAMP

PROJECT: HP00070 - Île d'Yeu

DRAWING TITLE: Figure 18 - Density of bottlenose dolphin (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER: HP00070-701-013

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE	PROJECTION	DATUM
1:500,000	A4	Lambert-93 (EPSG 2154)	RGF93

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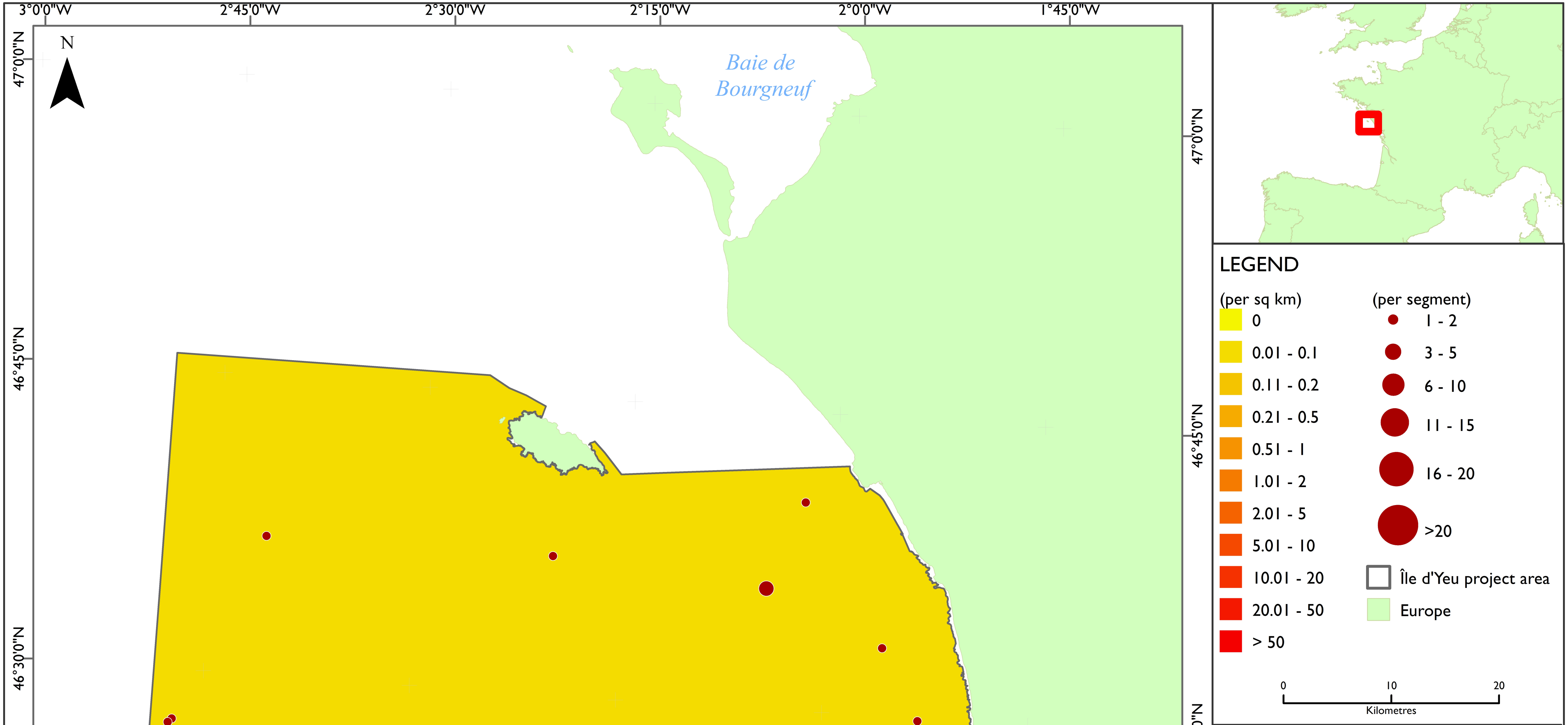
3.4.18 Distribution maps for harbour porpoise

82 A distribution map for harbour porpoise is presented as Figure 19.



CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 19 - Density of harbour porpoise (number/km²) and number of detections per segment on 11 August 2016

DRAWING NUMBER
HP00070-701-015

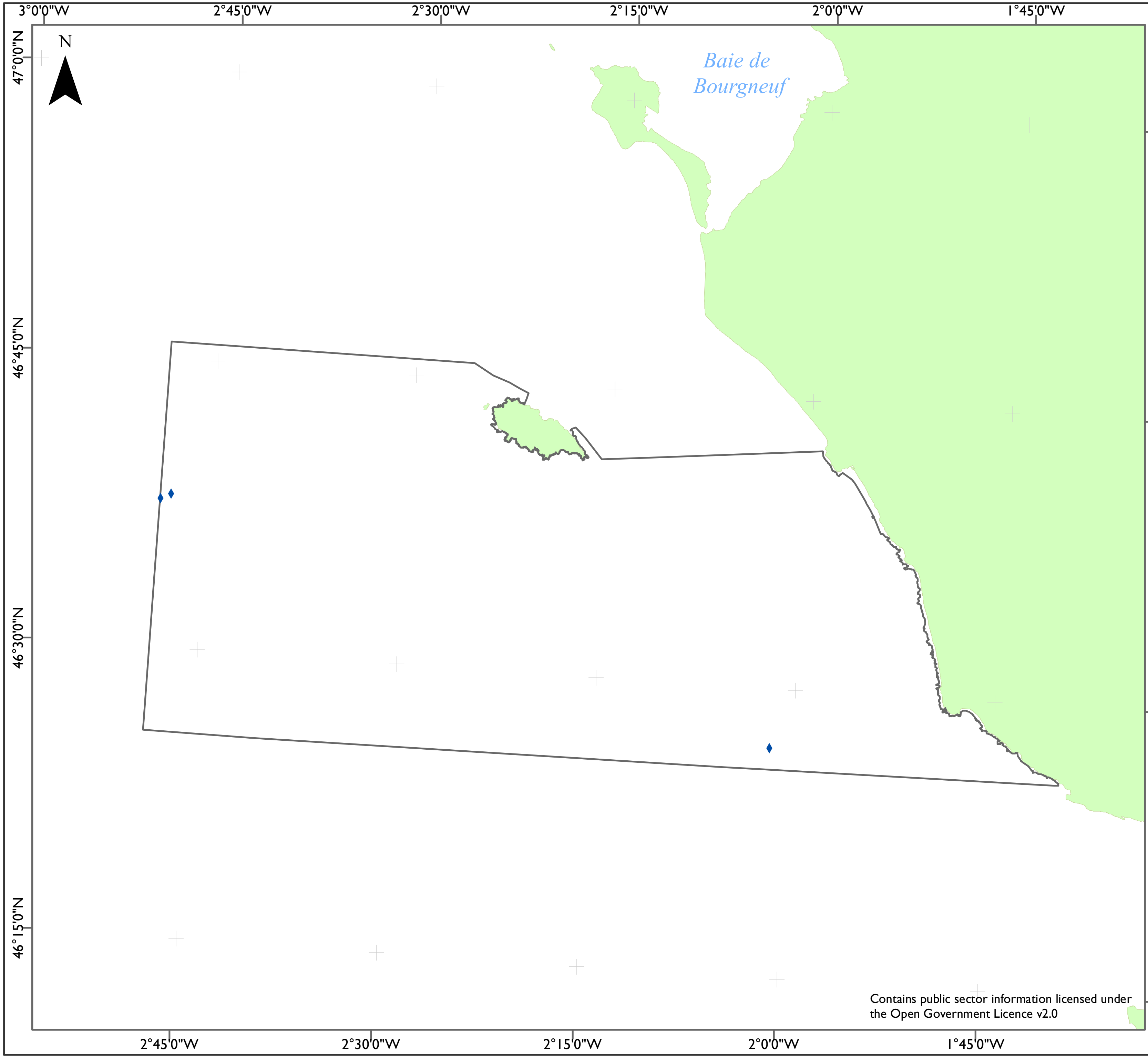
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

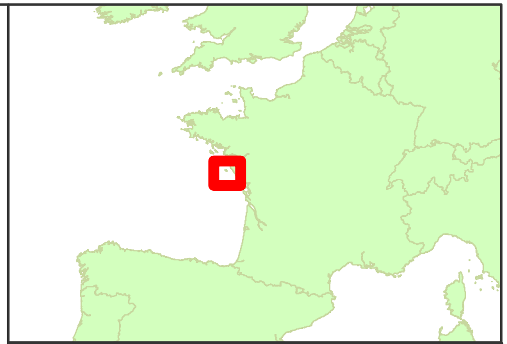
SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

HiDef AERIAL SURVEYING LIMITED

3.4.19 Distribution maps for less abundant non-avian animal species

83 A distribution map for less abundant, non-avian animals is presented as Figure 20.





LEGEND

Species

- Blue shark
- Île d'Yeu project area
- Europe

0 10 20
Kilometres

CLIENT	AAMP
PROJECT	HP00070 - Île d'Yeu
DRAWING TITLE	Figure 20 - Detections of less abundant non-avian animal species (number/km²) on 11 August 2016
DRAWING NUMBER	HP00070-701-018

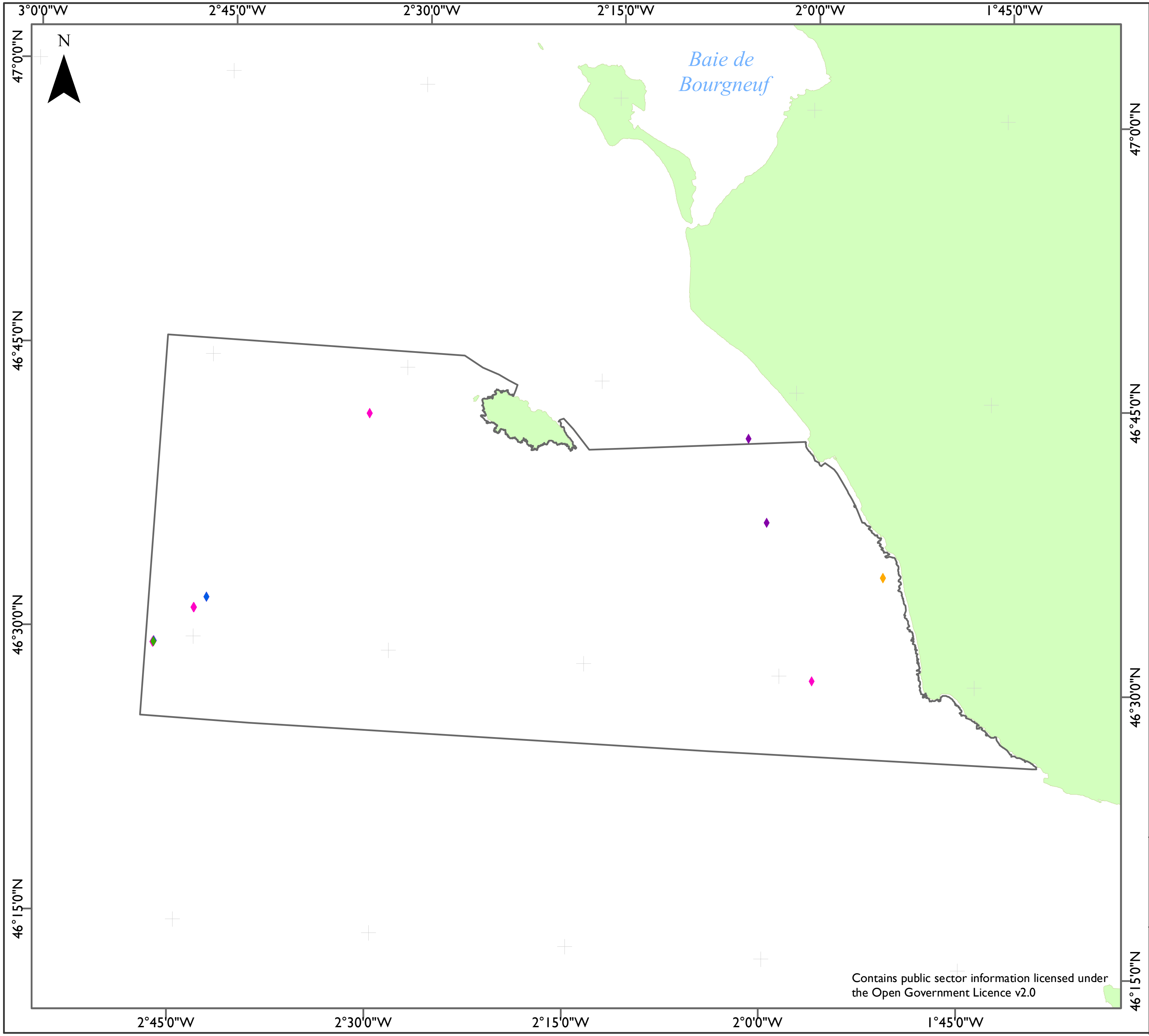
VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	**PROJECTION**
RGF93	Lambert-93 (EPSG 2154)

HiDef AERIAL SURVEYING LIMITED

3.4.20 Distribution maps for unidentified non-avian animals

84 A distribution map for unidentified non-avian animals is presented as Figure 21.



LEGEND

No ID
- Cetacean species
- Dolphin species
- Fish species
- Seal / small cetacean species
- Squid
- Île d'Yeu project area
- Europe

0 10 20
Kilometres

CLIENT
AAMP

PROJECT
HP00070 - Île d'Yeu

DRAWING TITLE
Figure 21 - Detections of unidentified non-avian animal species (number/km²) on 11 August 2016

DRAWING NUMBER
HP00070-701-019

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

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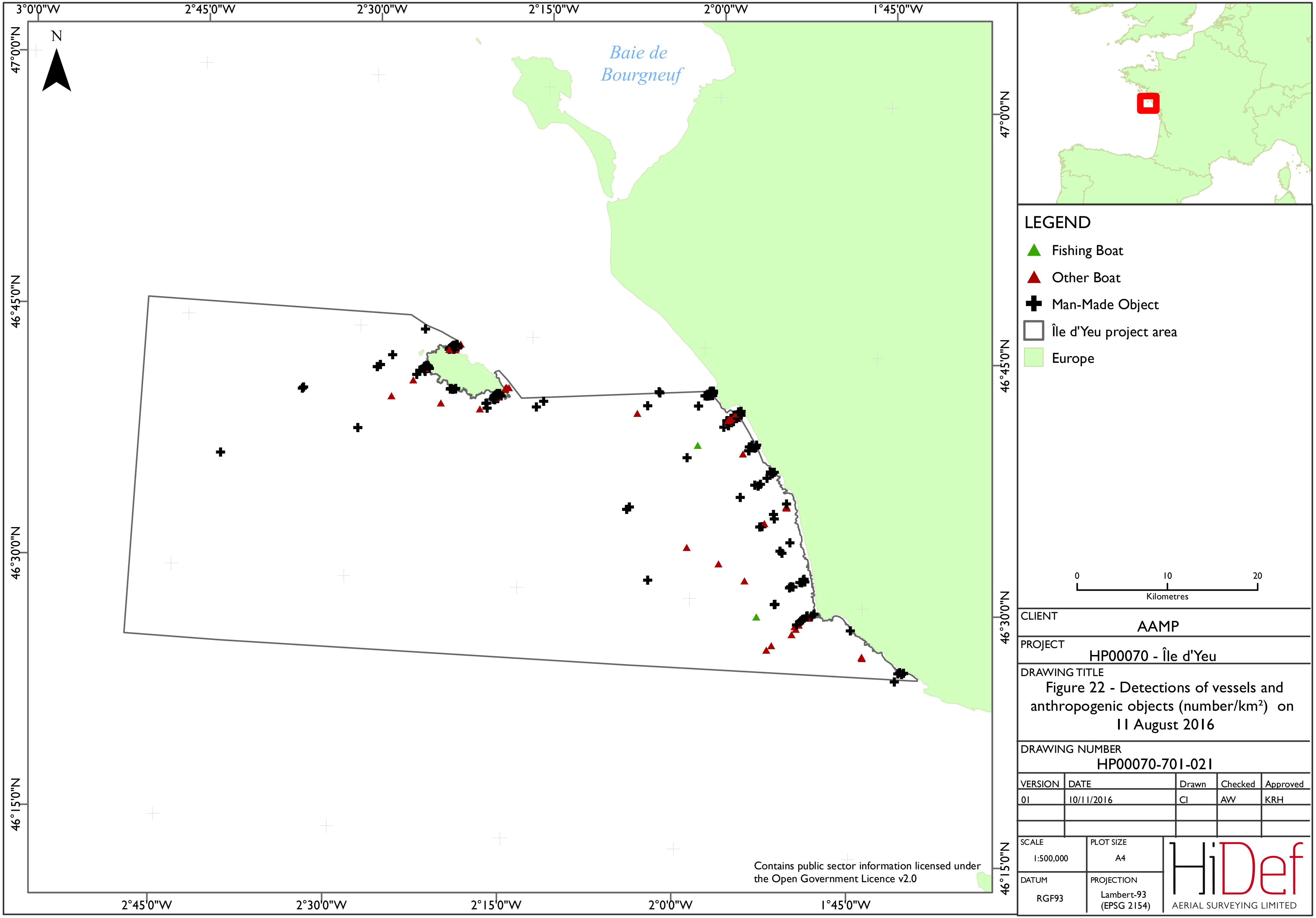
3.4.21 Distribution maps for anthropogenic activity

85 A distribution map of anthropogenic activity is presented as Figure 22.



CLIENT	AAMP
PROJECT	HP00070 - Île d'Yeu
DRAWING TITLE	Figure 22 - Detections of vessels and anthropogenic objects (number/km²) on 11 August 2016
DRAWING NUMBER	HP00070-701-021

VERSION	DATE	Drawn	Checked	Approved
01	10/11/2016	CI	AW	KRH

SCALE	PLOT SIZE
1:500,000	A4
DATUM	PROJECTION
RGF93	Lambert-93 (EPSG 2154)

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3.5 Behaviours of seabirds and non-avian animals

86 The behaviour of seabirds has been categorised as flying or sitting. The number of each observed is presented in Table 7.

87 In addition, the surfacing behaviour for all non-avian animals is presented in Table 8. Snapshot surfacing indicates where the head of a seal or dorsal fin of a cetacean are clear of the water surface in the middle frame of the sequence in which the animal is present.

Table 7 Summary of seabird behaviours during Survey 1 on 11 August 2016

Species	Number recorded flying	Number recorded sitting	Number recorded taking off	% Flying	Total
Fulmar	1	1	0	50%	2
Balearic shearwater	23	421	2	5%	446
European storm-petrel	12	0	0	100%	12
Gannet	17	8	1	65%	26
Redshank	4	0	0	100%	4
Black-headed gull	0	1	0	0%	1
Mediterranean gull	2	0	0	100%	2
Lesser black-backed gull	118	171	2	41%	291
Herring gull	3	5	0	38%	8
Herring gull complex	84	138	1	38%	223
Great black-backed gull	9	31	0	23%	40
Sandwich tern	31	0	0	100%	31
Common tern	14	0	0	100%	14
Guillemot	0	47	0	0%	47
Puffin	0	1	0	0%	1
No ID					
Small gull species	1	2	0	33%	3
Large gull species	2	96	0	2%	98
Gull species	0	18	0	0%	18

Species	Number recorded flying	Number recorded sitting	Number recorded taking off	% Flying	Total
Tern / small gull	1	0	0	100%	1
Auk / shearwater species	0	1	0	0%	1
Total	**322**	**941**	**6**	**25%**	**1269**

Table 8 Summary of surfacing behaviour for non-avian animals during Survey 1 on 11 August 2016

Species	Submerged	Surfacing	Snapshot surfacing	% Surfacing	Total
Ocean sunfish	13	0	1	7%	14
Blue shark	3	0	0	0%	3
Common dolphin	90	3	1	4%	94
Bottle-nosed dolphin	7	4	2	46%	13
Harbour porpoise	8	2	1	27%	11
Squid	1	1	0	50%	2
No ID					
Fish species	4	0	0	0%	4
Dolphin species	27	0	0	0%	27
Cetacean species	2	0	0	0%	2
Seal / small cetacean species	1	0	0	0%	1
Total	**156**	**10**	**5**	**9%**	**171**

4 Discussion

88 The survey was highly successful in characterising the bird and mammal species present in the Île d'Yeu survey area, recording a total of 1148 birds of 14 different species.

89 In addition, the survey recorded 135 marine mammals of six species. A further 157 animals were recorded which were not assigned to a species.

90 Balearic shearwater were the most abundant species recorded with a density of 1.79 birds/km² equating to an estimated 4401 (± 95% CI 158 – 13596) individuals across the study area. This species was primarily distributed towards the east and south-east of the survey area.

91 This abundance estimate compares favourably with the citation for the SPA of 2500 – 4000 individuals (European Environment Agency 2016), but caution should be used when comparing these population estimates because of the wide confidence intervals. It is expected that the primary cause of the wide CI was the highly clumped nature of this species' distribution. The precision may be improved in future through the use of density surface modelling ("DSM") or a different survey design.

92 Low number of European storm-petrel were recorded during the survey with density estimates of 0.05 birds/km², equating to 120 birds (± 95 % CI 8 – 315) in total. These numbers were lower than originally expected from the survey and compare to the estimate used for classification of the SPA of 1000 – 2000 (European Environment Agency 2016).

93 Herring gull were recorded in low numbers with a density estimate of 0.03 birds/km². However, herring gull complex had much higher densities with estimates of 0.86 birds/km². This was because of the difficulty to distinguish between lesser black-backed, herring and yellow legged gull species although during the summer the number of yellow legged gulls would be low in comparison to herring gull.

94 Common dolphins were the most abundant marine mammals. The relative density was recorded at 0.38 animals/km² which equated to 941 individuals (± 95% CI 407 – 1627) in the whole study area. This species was observed in the west, north east and south east of the survey area. The majority of common dolphins were submerged which indicates a good identification rate for this species while underwater.

5 Conclusions

95 The majority of bird species were located towards the east of the survey area close to the shoreline. The most abundant bird species recorded was Balearic shearwater, while the most abundant non-avian species was common dolphin.

96 Balearic shearwater was a key target species for this survey and the abundance estimate provided by this survey demonstrates that the HiDef digital video technique is highly effective at generating an unbiased abundance estimate for this species.

97 The survey method proved effective for detecting a range of other seabird, marine mammal and fish species, many of which would be very difficult to survey using other techniques (such as boat-based or digital stills) owing to the high proportion of animals that would be submerged.

98 Population estimates of non-avian animals should be treated as relative abundance, because a proportion of the animals present in the study area would be submerged and too deep to be detected from the aircraft. Simple corrections are possible when information on the depth distribution of the animals is available.

99 European storm-petrel was probably under-recorded during this survey, due to its small size and dark plumage. It is likely that if surveys were carried out at a lower camera resolution (such as 1cm or 0.5cm, which is easily achievable with the HiDef GEN II system) then a larger number of this species would be recorded. However, this would be at the expense of transect width, requiring a greater number of transects to achieve the same percentage coverage.

100 The wide confidence intervals for Balearic shearwater and many other inshore species can be attributed to their highly clumped distribution. This could be controlled better by adopting a stratified random sampling campaign with narrower-spaced transects in the high density area for this species, and more widely-spaced transects further offshore than in the transect design used for this survey. If this were combined with a density surface modelling method for data analysis (in which habitat co-variates could be used to help explain the distribution patterns), then this would be likely to improve the precision of the density and abundance estimates.

6 References

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