Marine biological valuation of seabirds in the Belgian Part of the North Sea

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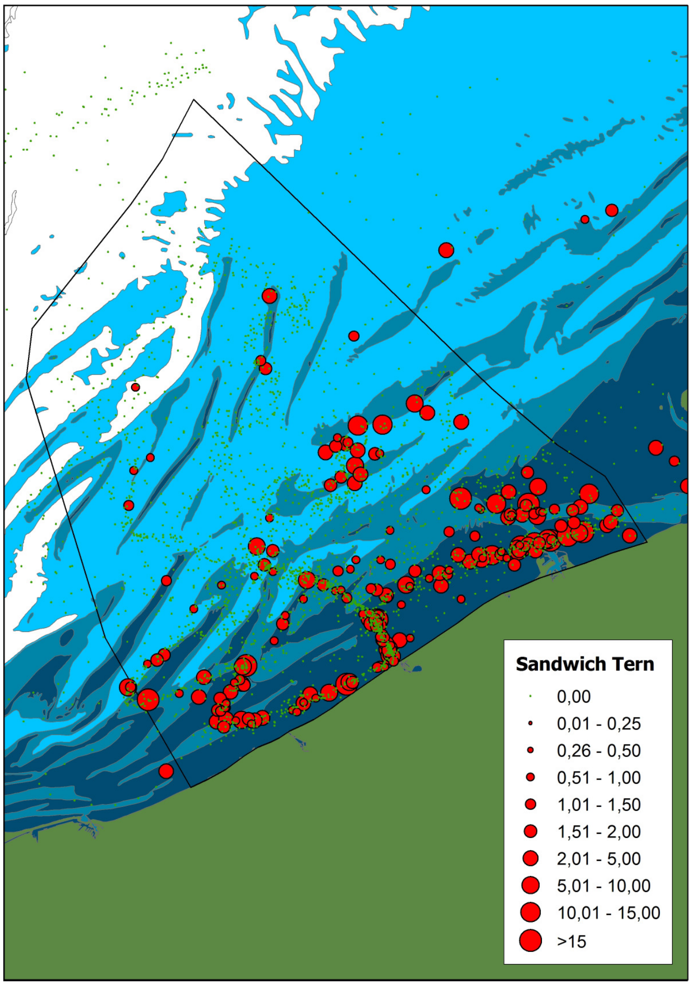

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IV. Marine biological valuation of seabirds on the BPNS

4.1. Introduction

The Belgian Part of the North Sea (BPNS) is – despite its relatively small area – a highly important area for seabirds, not only for wintering birds but also for migrants and breeding birds (e.g. Seys *et al.*, 1999; Seys, 2001; Stienen & Kuijken, 2003). Being a bottleneck area for seabirds migrating from the northern breeding areas to the southern wintering areas, more than 5% of the biogeographical population of 12 species migrates through the southern part of the North Sea (Seys, 2001; Stienen & Kuijken, 2003). Also, the BPNS functions as a major feeding area for the internationally important tern colonies in the harbour of Zeebrugge (Alvarez, 2005, Stienen *et al.*, 2005).
The importance of the BPNS was acknowledged by the designation of 3 Marine Protected Areas in 2005. The delineation of these areas was based on a selection of species, namely the species that occur on the Annex I of the Bird Directive and species regularly occurring with more than 1% of the biogeographical population (Haelters *et al.*, 2004). The study of Haelters *et al.* was very important in terms of conservation of threatened species but unlike this study did not aim to valuate the broader ornithological importance of the BPNS. In the underlying study, a biological valuation map of the BPNS is presented, that not only takes into account internationally protected species, but also non-threatened and more widely distributed species of seabirds. The final result gives a good view of the relative ornithological importance of the different zones of the BPNS.

4.2 Data collection

Seabird counts in the Belgian part of the North Sea

The Research Institute for Nature and Forest conducts standardised ship-based surveys since September 1992. Until 2001 this was mainly done from public ferries and the Belgica, but since 2001, three fixed monitoring-routes were counted each month from the research-vessel 'Zeeleeuw' (e.g. Seys, 2001). To determine the distribution, numbers and densities of seabirds in the BPNS, the data collected between September 1992 and December 2004 were analysed. Additionally, the data from the counts in 2005 were used to determine the species-diversity (see further). Thus, the compiled dataset does comprise data of standardised counts that are well distributed both temporally (both between years and within years) and spatially on the BPNS (Figure 1 in annex).

Both sitting and flying birds were counted by a standardised strip-transect-method (Tasker *et al.*, 1984). All swimming birds that are within a distance of 300 m and in an angle of 90° forward from the study-vessel were counted in intervals of 10 minutes. Flying birds were counted using a snapshot method (Komdeur *et al.*, 1992). All flying birds within a distance of 300 m and an angle of 90° forward from the study-vessel were counted every minute. In order to compensate for missed small and dark birds, the mean density of swimming birds has been multiplied with an internationally accepted correction factor (Stone *et al.*, 1995).

Figure 1. Positions of 10-minute counts on the Belgian Continental Shelf between 1992 and 2004 (in annex).

The results of these counts were transformed into densities by taking into account the speed of the research-vessel. All counts were reduced to the spatial middle points of the concerned 10-minute tracks. These midpoints are called position keys or 'poskeys' and are displayed in the dataset in degrees northern latitude and eastern longitude and hold the local densities of all species (number per square km). If the ship changed its course within a 10-minute count, the counts relate to a shorter period. To avoid that counts in very short periods of time would bias the calculation of bird densities, all poskeys in which less than 1 km was covered were omitted. Since ferry counts may result in an underestimation of the densities of certain species (e.g. alcidae and divers) because of the higher speed and the height of the observation platform, the data collected from ferries were not retained in the processed dataset. After these selections, data of 10.808 poskeys were retained. For the calculation of the number of species per 3x3 km-square all counts (also counts from ferries and those of 2005) were used (15.908 poskeys).

Selection of species

As a first step, all observations of non-seabirds were omitted from the dataset. A seabird was defined as 'a species of which at least part of the population forages at sea in a certain part of the year' (adapted from Furness & Monaghan, 1987). Between 1992 and 2005, 47 seabird-species were recorded during ship-based counts on the BPNS (Table 1 and 2 in annex). For further analysis of the data, this species-list was divided into 'common' and 'rare' seabirds. As a distinguishing criterion, a 'common' seabird was defined as a species that was observed in more than 1% of the poskeys, a 'rare' seabird as one that was seen in less than 1% of the poskeys (Table 1 in annex). Finally, 18 common seabirds were retained. This division is also defensible when the total number of birds of each species is taken into account (Table 2 in annex).

The smaller divers (notably Red- and Black-throated Diver) were grouped and analysed together as diver *sp.* since both species are not always easily distinguished at sea and a lot of the observations are noted as diver *sp.*. This elevates the precision of the final result (more observations), while it does not necessarily have consequences for the valuation since the proportion of the concerned species (Red-throated Diver) in the global group of diver *sp.* is very high (95,6% were Red-throated Divers and 4,4% Black-throated Divers, Vanermen *et al.*, 2005)[1].

Interpolation of data

Figure 1 and 2 (in annex) show that the observer effort is unevenly distributed over the BPNS. On the one hand this reflects a bias of the fixed monitoring routes of the last years, on the other hand some areas can't be reached because they are too shallow or because they are to far away to fit in a one-day schedule. Therefore, a spatial interpolation was applied to obtain maps that cover the complete BPNS. To account for confounding effects of within year fluctuations in densities and distribution of seabirds (some species occur the whole year, others only in winter or during the breeding season), an a-priori selection of the months in which a certain species occurs in the highest densities was made. This procedure is based on the supposition that the occurrence of a species in a certain density in a certain location is a reflection of the suitability of this location at that time.

Figure 2. Observer effort on 3x3 km square level (number of square kilometres surveyed) (in annex).

For each species the mean density per month was calculated (Figures 3a-c in annex). For the interpolation only the data were retained from the months in which the mean density was at least 25% of the value of the month with the maximal density (Table 3 in annex). When less than 5 months fulfilled this condition (which was especially the case in species that have a very high peak density in one or two months, e.g. Sandwich and Common Tern), the five months with the highest densities were selected.

Figure 3 a-c. Mean densities per month of each species (in annex).
Table 3. Mean density per month of each species and overview of the months retained for further analysis (in annex).

The final dataset was interpolated for each species separately using the Spatial Analyst package of ArcGis 9.0. The interpolation method used was Inverse Distance Weighting and a density-raster of 500 by 500m was created for each species. By using this algorithm, the middle point of each raster-cell got the mean density of the concerned species of the 24 poskeys closest to it, the contribution of each poskey to the final value is inversely related to the distance that poskey is from the middle point. For further analysis, these rasters were converted into a grid with cells of 3x3 km. This dimension was chosen because it matches well with the mean distance covered by boat in 10 minutes (2.98 km).

[1] In the text and the figures Red-thorated Diver is retained as the name for this group.

4.3 Application of valuation criteria on seabird data

The global underlying methodology for the valuation of the BPNS for seabirds is defined in Derous *et al.* (2007) and is based on the valuation criteria stipulated in Derous *et al.* (*in press*). Not all these questions could be answered for seabirds because of some limitations of the data available and particularities of the seabird community. There are for example no data available on the genetic structure of the seabird population on the BPNS and criteria such as 'are there habitats formed by keystone-species' are irrelevant when considering seabirds. In contrast to other ecosystem components, no great importance was attached to rare species since they do not reflect the biological value of the area. The occurrence of rare seabirds (listed in Table 1 in annex) on the BPNS does not say anything about the value of the stretch of sea where they are observed since it are only stray birds that should not really occur there (but it aren't alien species either). Only to answer the question on species richness, rare seabirds were included in the calculations.

Selecting the questions this way, four valuation criteria were retained to build the final seabird valuation map:

1) Is the subarea characterised by high counts of many species?
2) Is the abundance of a certain species very high in the subarea?
3) Is a high percentage of a species population located within the subarea?
4) Is the species richness in the subarea high?

4.3.1 Answer to question: Is the subarea characterised by high counts of many species?

The cells of the extrapolated density-rasters of each species were divided in 10 classes using the quantile classification-method in ArcGis 9.0. By doing this, each class contains the same number of raster-cells. These classes got values of 1 (lowest densities) to 10 (highest densities). Raster-cells in which a given species was not observed got a value of 0. Next, for each raster-cell the values of all species were summed up (Figure 4 in annex). Then, for each grid-cell of the 3x3 km-grid, the mean value of the enclosed raster-cells was calculated. Finally, these values were divided into 5 classes, again using the quantile classification-method, so that all classes contain an equal number of grid-cells (Figure 5 in annex).

4.3.2 Answer to question: Is the abundance of a certain species very high in the subarea?

Based on the interpolated density-rasters, the mean number of each common species present on the BPNS was calculated (Table 4). Subsequently, for each species, the mean density and the mean number of birds was calculated for each 3x3 km-gridcell. Based on these figures, a map was created showing the proportional importance of a given subarea for each species (Figure 6 in annex).
Some species obviously occur very aggregated and locally reach very high densities, whereas others occur more evenly distributed over the BNPS. To account for this difference, an 'aggregation-coefficient' was calculated by dividing the total percentage of the 5% of grid-cells with the highest densities by the total number of grid-cells in which the species was recorded (Table 4). For each species, an 'aggregation-map' was created by multiplying the proportional importance of each grid-cell (given in Figure 6 in annex) by it's aggregation-coefficient. Finally the values of the 18 species were summed for each grid-cell to obtain a single aggregation map (Figure 7 in annex).

Species	Number of birds on the BPNS	Percentage of the biogeographical population occurring on the BPNS	Total percentage of birds occurring in the 5% most important 3x3 km-grid-cells	Number of 3x3 km-grid-cells with presence of the species	Aggregationco
Red-throated Diver-	594	0,1	32	348	0,09
Great Crested Grebe	904	0,2	46	173	0,26
Northern Fulmar	884	0	35	338	0,1
Northern Gannet	2117	0,2	26	397	0,07
Great Cormorant	66	0	84	73	1,16
Common Scoter	4444	0,3	92	113	0,81
Great Skua	120	0,3	32	282	0,11
Little Gull	1038	1,2	33	342	0,1
Black-headed Gull	916	0	91	115	0,79
Common Gull	3875	0,2	43	431	0,1
Kittiwake	5697	0,1	37	441	0,08
Herring Gull	4963	0,5	48	430	0,11
Great Black-backed Gull	2840	0,6	43	440	0,1
Lesser Black-backed Gull	5105	1	38	440	0,09
Sandwich Tern	751	0,4	52	292	0,18
Common Tern	1883	1	72	232	0,31
Common Guillemot	9008	0,1	15	438	0,03
Razorbill	1673	0,1	22	400	0,06

Table 4. Mean number of each species present in the BPNS, percentage of the biogeographical population, total percentage occurring in the most important 5% of the 3x3 km-grid-cells, number of grid-cells with presence and aggregation coefficient.

4.3.3 Answer to question: Is a high percentage of a species' population located within the subarea?

For each species, the percentage of the biogeographical population occurring in each cell of the 3x3 km-grid was calculated. The biogeographical populations of the species were derived from Delany & Scott (2005) and from Burfield & Van Bommel (2004). Based on these values, biopopulation-maps were created for each species (Figure 8 in annex). Figure 9 (in annex) gives the aggregated 'biopopulation-map'. This map was created by multiplying the value of each grid-cell of the biopopulation-maps of each species by it's aggregation-coefficient and by summing up the resulting values for the 18 species for each grid-cell.

4.3.4 Answer to question: Is the species richness in the subarea high?

For each grid-cell, the number of seabird species observed in the field was determined (Figure 10 in annex). Given the difference in observer effort (number of km^2 surveyed per grid-cell, Figure 2 in annex) between the grid-cells, this is not a realistic representation of the situation. Therefore, the observed number of species was corrected by applying a logistic regression analysis in which besides the variable 'number of kilometres surveyed', also 'distance to the coast' and 'mean depth' in each grid-cell was taken into account. The last two variables were taken into account to correct for possible differences in species richness between coastal and non-costal grid-cells as well as for possible relations between species' occurrences and sandbanks. Because 'distance to the coast' and 'mean depth' were strongly correlated and given the fact that 'distance to the coast' explained more of the variance than 'mean depth', only 'distance to the coast' was finally retained in the regression. The regression equation is as follows (Equation 1):

Equation 1: $N\ species^{exp} = 1{,}817 + 7{,}898 * \log(n\ km) – 0{,}1405 * \text{distance to coast} + 0{,}0012 * (\text{distance to coast})^2$

Figure 11 (in annex) gives the modelled number of species per 3x3 km-grid-cell.

As a last step, the deviation of the modelled expected value relative to the number of species actually observed in the field was calculated for each grid-cell (proportional deviation, Equation 2). Next, for each grid-cell the expected number of species for a fixed distance of 400 km monitored was corrected with this value to obtain the final biodiversity (Equation 3) per grid-cell:

Equation 2: $\text{Proportional deviation} = [(N\ \text{species}^{obs} - N\ \text{species}^{exp}) / N\ \text{species}^{exp}] * 100$

Equation 3: $\text{Biodiversity} = N\ \text{species}^{exp(400\ km)} + [(N\ \text{species}^{exp(400\ km)} / 100) * \text{proportional deviation}]$

Figure 12 (in annex) gives the final biodiversity-map.

4.4 Marine biological valuation map of seabirds of the BPNS

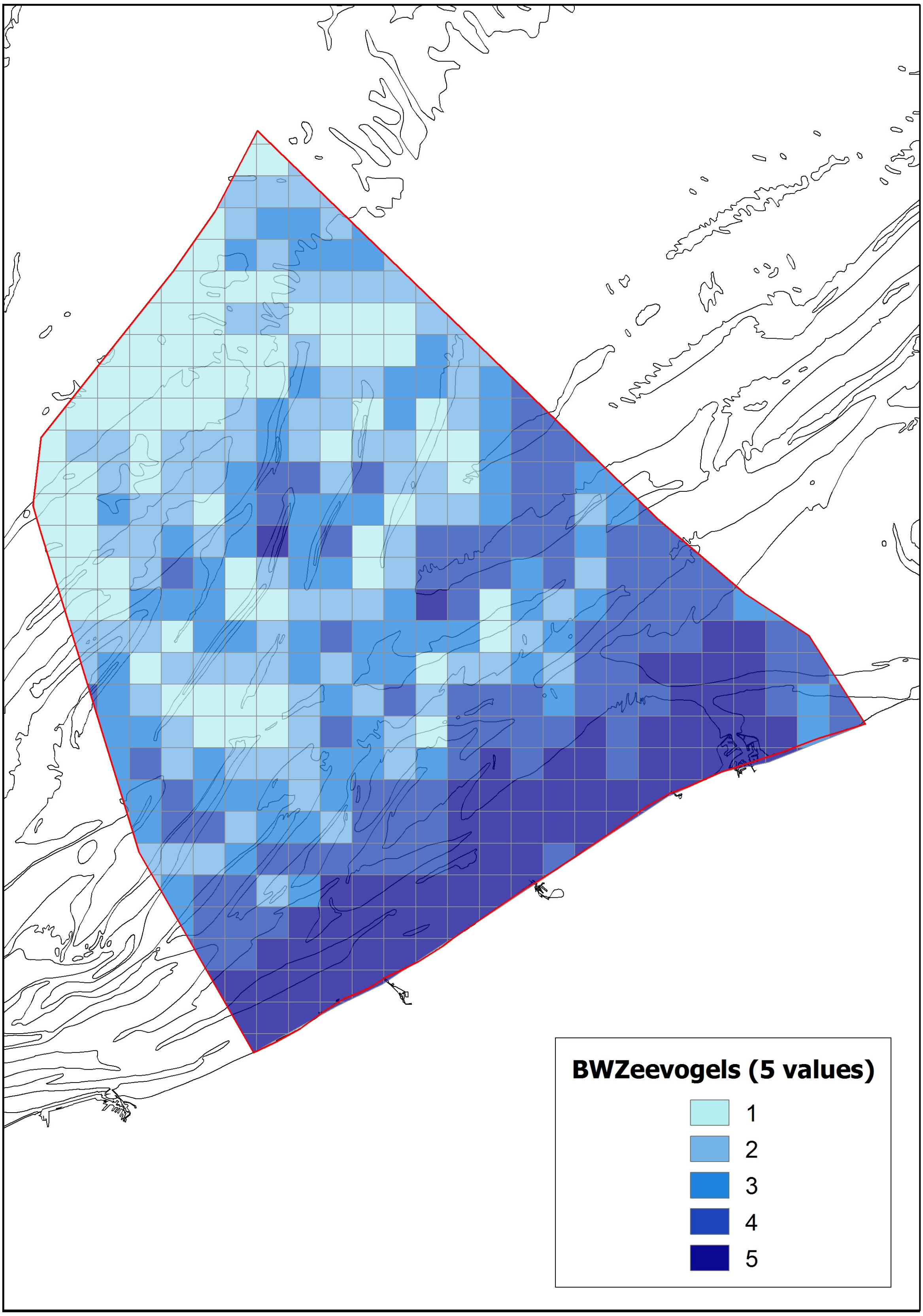

Figure 13. Marine biological valuation map of seabirds of the BPNS.

4.5 Reliability of results

As a direct consequence of the uneven distribution of the datapoints on the BPNS, this due to differences in observer effort (Figure 1 & 2 in annex), the data for the different grid-cells are not equally reliable. In less well sampled areas the interpolation made use of datapoints quite far from the midpoint and in those areas it is thus possible that the values do not accurately reflect the actual situation. This is especially the case for the borders of the BPNS that were, despite an effort to count more often in these areas during the last two years, less well sampled compared to the rest of the BPNS. Therefore, a reliability score was given to each grid cell, ranging from 1 (least reliable, < 10 km^2 surveyed) to 3 (most reliable, > 30 km^2 surveyed). As a rule, one can expect grid-cells with scores 2 and 3 (more than 10 km^2 surveyed) to be sufficiently reliable.

4.6 Discussion of maps

The ultimate valuation map (Figure 13) clearly shows the high ornithological value of the coastal zone (Vlaamse Banken, Zeelandbanken, Vlakte van de Raan). This zone has since long been recognised as being important for seabirds on the BPNS both as foraging area for breeding birds and for wintering birds (e.g. Seys *et al.*, 1999; Seys, 2001; Stienen & Kuijken, 2003; Haelters *et al.*, 2004). The map, however, throws a new light on the value of more offshore regions. Where earlier studies failed to identify these areas as particularly important for seabirds, the valuation method used in this study clearly pinpoints the higher ornithological value of the Thorntonbank, the waters north of the Vlakte van de Raan and parts of Hinderbanken.

A word of caution regarding the numbers of seabirds occurring on the BPNS calculated to create the aggregation maps and the biopopulation-map has to be put. These numbers are to be regarded as the mean number of birds that are present in the selected months, not as maxima, nor as the total number of birds present any one time. The numbers presented here are very useful for biological valuation, but do not reflect the real seabird densities, since peak numbers are often levelled off. Also, these numbers do not take into account the turnover rate of migrating seabirds. For example: 40 to 100% of the biogeographical population of Little Gull is crossing the BPNS, both during spring and autumn (Seys, 2001; Stienen & Kuijken, 2003), but interpolated values presented here only concern 1,2% of the biogeographical population.

4.7 Literature

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4.8 Annexes

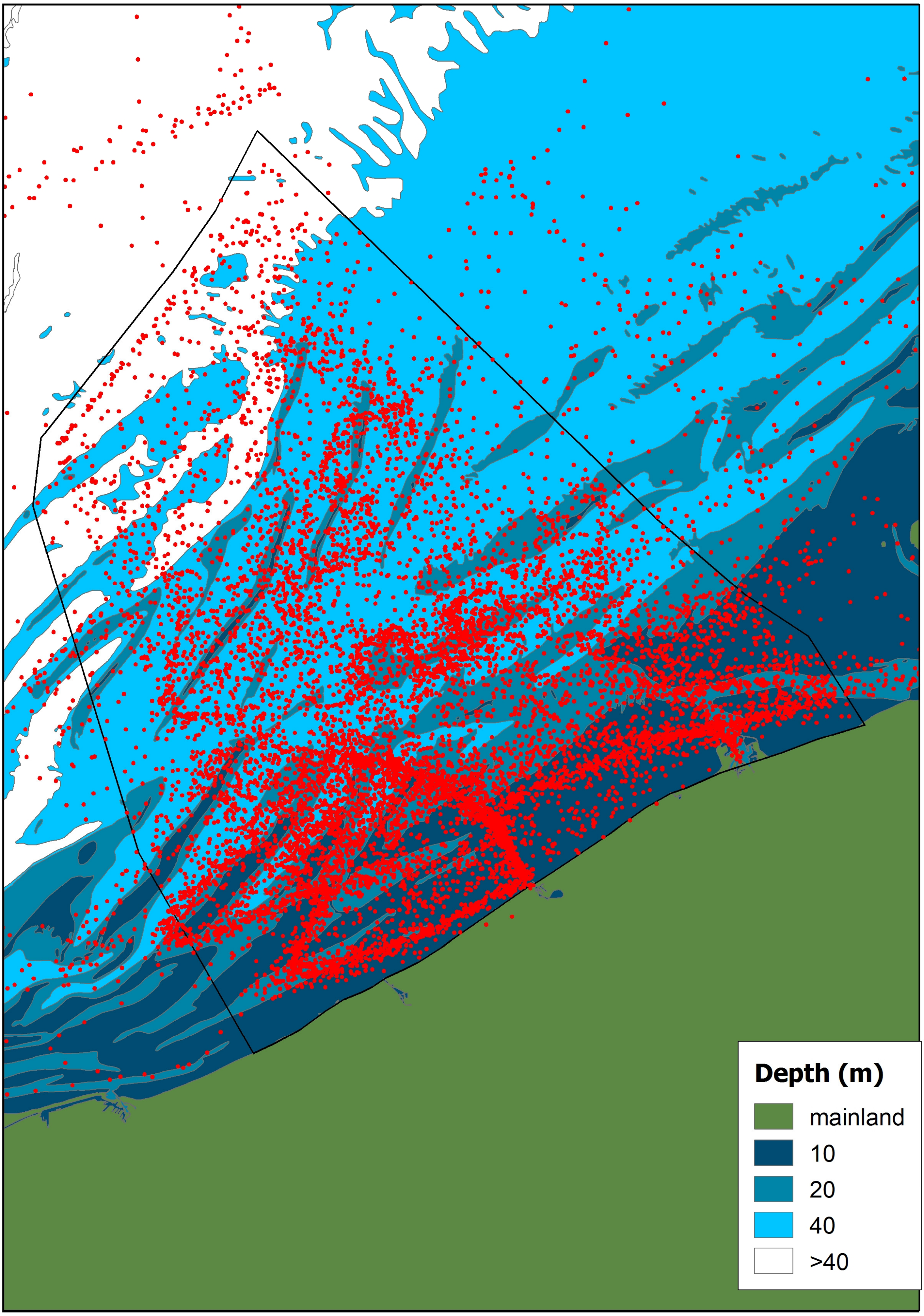

Figure 1. Positions of 10-minute counts in the Belgian Part of the North Sea between 1992 and 2005.

Table 1. Number of poskeys in which a species was observed (on a total of 15.908). The species selected for density calculations ('common' species) are indicated in blue.

Species	Number of poskeys
Lesser Black-backed Gull	5187
Herring Gull	4837
Great Black-backed Gull	4726
Kittiwake	4592
Common Guillemot	4316
Common Gull	3925
Northern Gannet	3705
Little Gull	2175
Northern Fulmar	1361
Razorbill	1287
Red-throated Diver	1245
Sandwich Tern	1225
Black-headed Gull	1185
Common Tern	1089
Great Crested Grebe	983
Common Scoter	869
Great Cormorant	516
Great Skua	430
Arctic Skua	137
Black-throated Diver	88
Common Eider	81
Pomarine Skua	46
Sooty Shearwater	43
Black Tern	42
Arctic Tern	35
Velvet Scooter	33
Mediterranean Gull	30
Yellow-legged Gull	24
Little Tern	24
Red-breasted Merganser	23
Leach's Storm-petrel	17
Puffin	10
Manx Shearwater	8
Red-necked Grebe	7
European Storm-Petrel	6
Shag	6
Greater Scaup	4
Long-tailed Skua	3
Sabine's Gull	3
Black-necked Grebe	2
Gull-billed Tern	2
Little Auk	2
Great Northern Diver	1
Cory's Shearwater	1
Mediterranean Shearwater	1
Iceland Gull	1
Black Guillemot	1

Table 2. Total number of birds observed of each species. The species selected for density calculations ('common' species) are indicated in blue.

Species	Number of birds
Lesser Black-backed Gull	82215
Herring Gull	66341
Common Scoter	47178
Common Gull	40667
Kittiwake	33096
Great Black-backed Gull	31385
Common Guillemot	20149
Black-headed Gull	17769
Northern Gannet	16855
Common Tern	12933
Little Gull	12320
Northern Fulmar	8639
Sandwich Tern	5379
Great Crested Grebe	4369
Razorbill	3359
Red-throated Diver	3357
Common Eider	2436
Great Cormorant	2241
Great Skua	526
Velvet Scooter	383
Arctic Skua	194
Black Tern	117
Greater Scaup	114
Red-breasted Merganser	103
Black-throated Diver	94
Arctic Tern	85
Sooty Shearwater	60
Little Tern	57
Pomarine Skua	48
Mediterranean Gull	33
Yellow-legged Gull	26
Leach's Storm-petrel	19
Little Auk	13
Red-necked Grebe	10
Puffin	10
Manx Shearwater	9
European Storm-Petrel	6
Shag	6
Black-necked Grebe	3
Long-tailed Skua	3
Sabine's Gull	3
Gull-billed Tern	2
Great Northern Diver	1
Cory's Shearwater	1
Mediterranean Shearwater	1
Iceland Gull	1
Black Guillemot	1

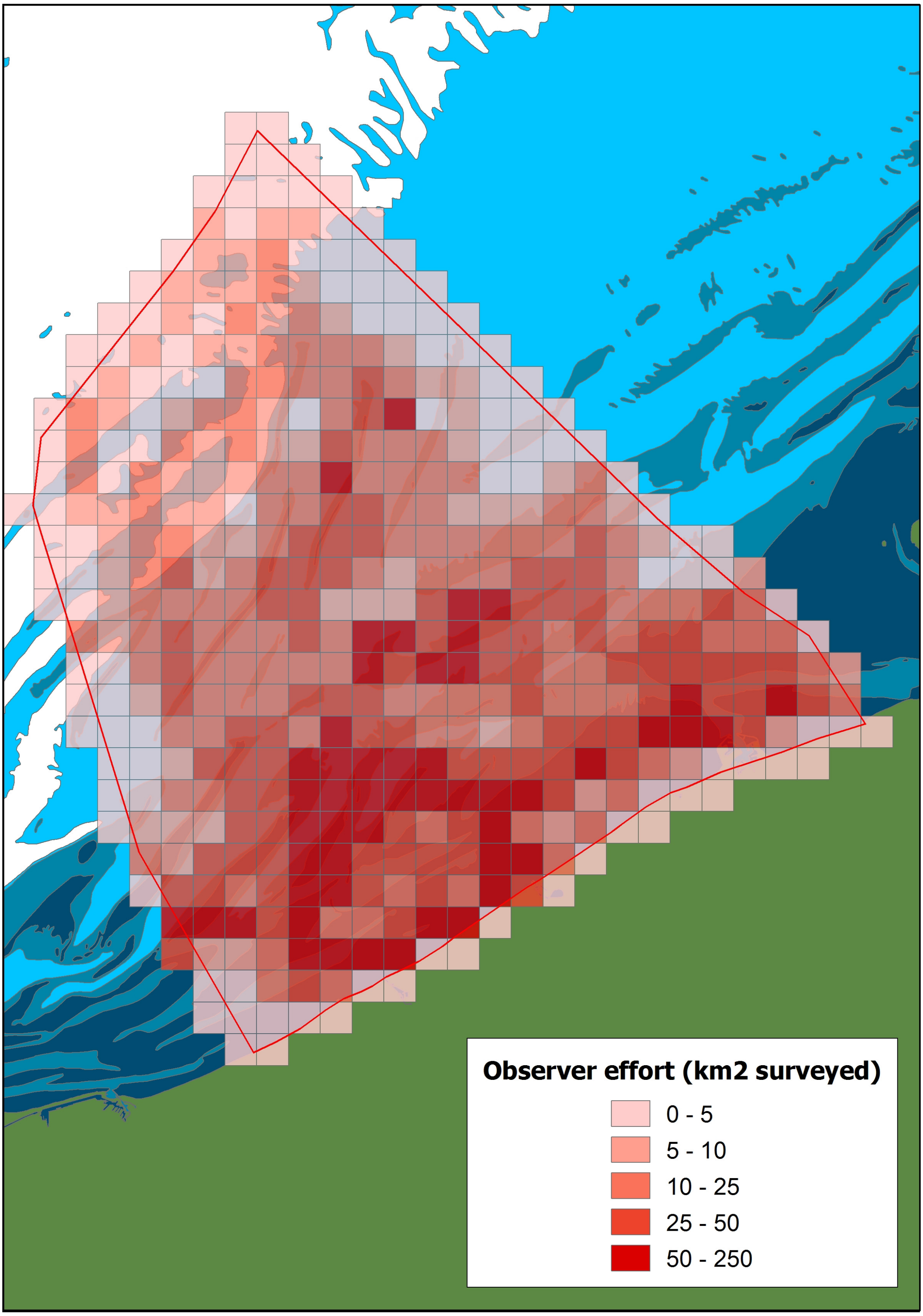

Figure 2. Observer effort on 3x3 km square level (number of square kilometres surveyed).

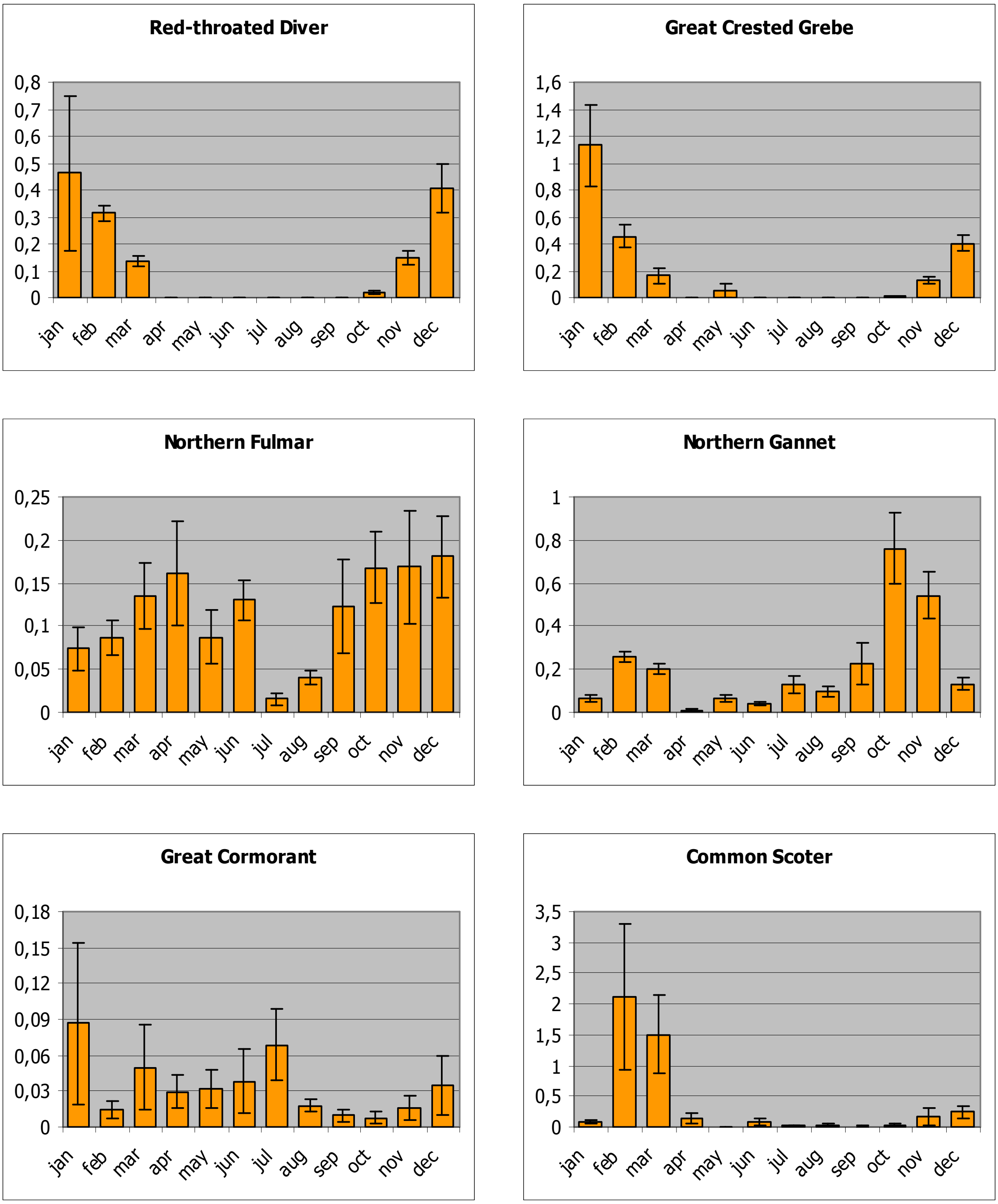

Figure 3 a. Mean densities per month of each species.

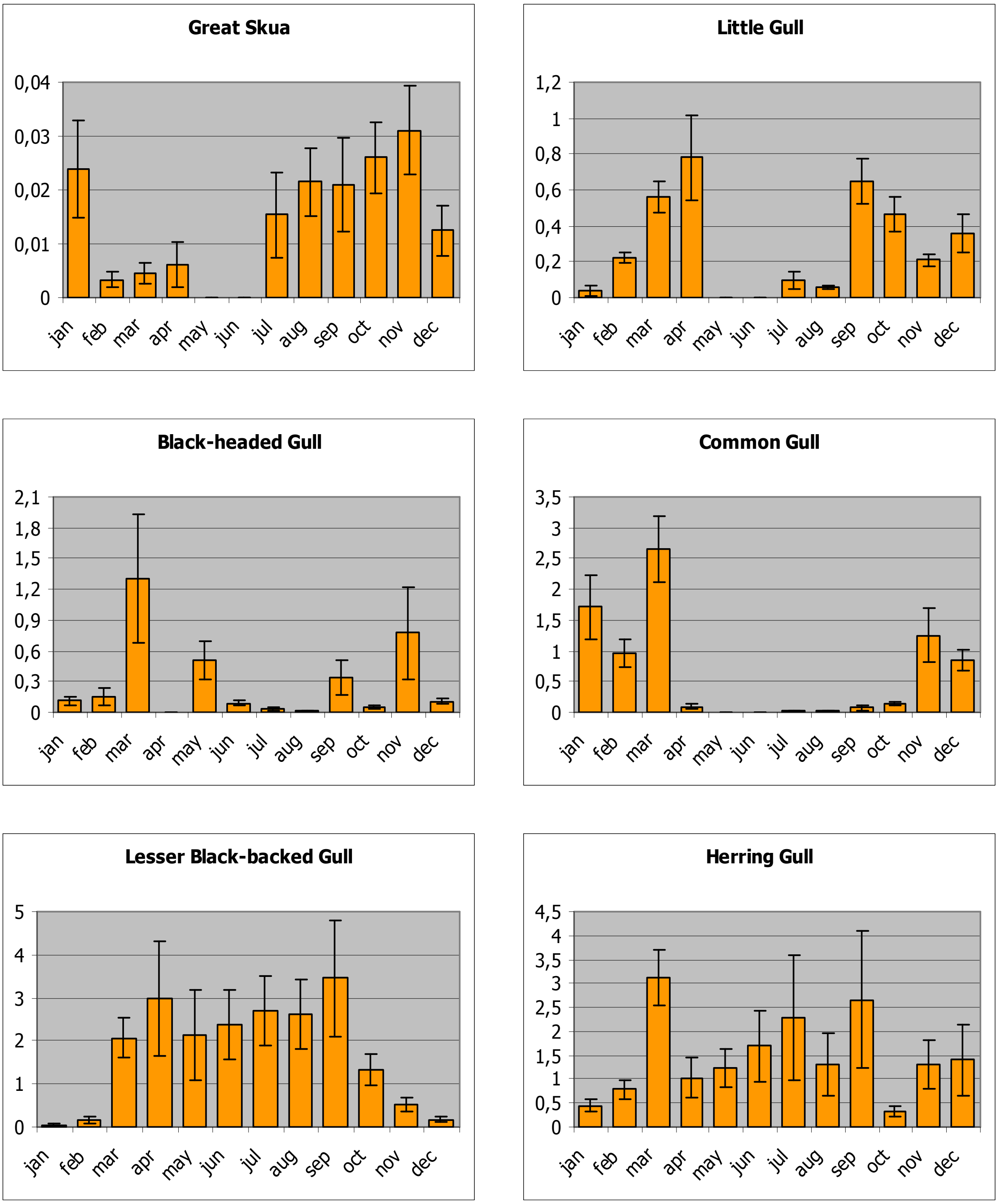

Figure 3 b. Mean densities per month of each species.

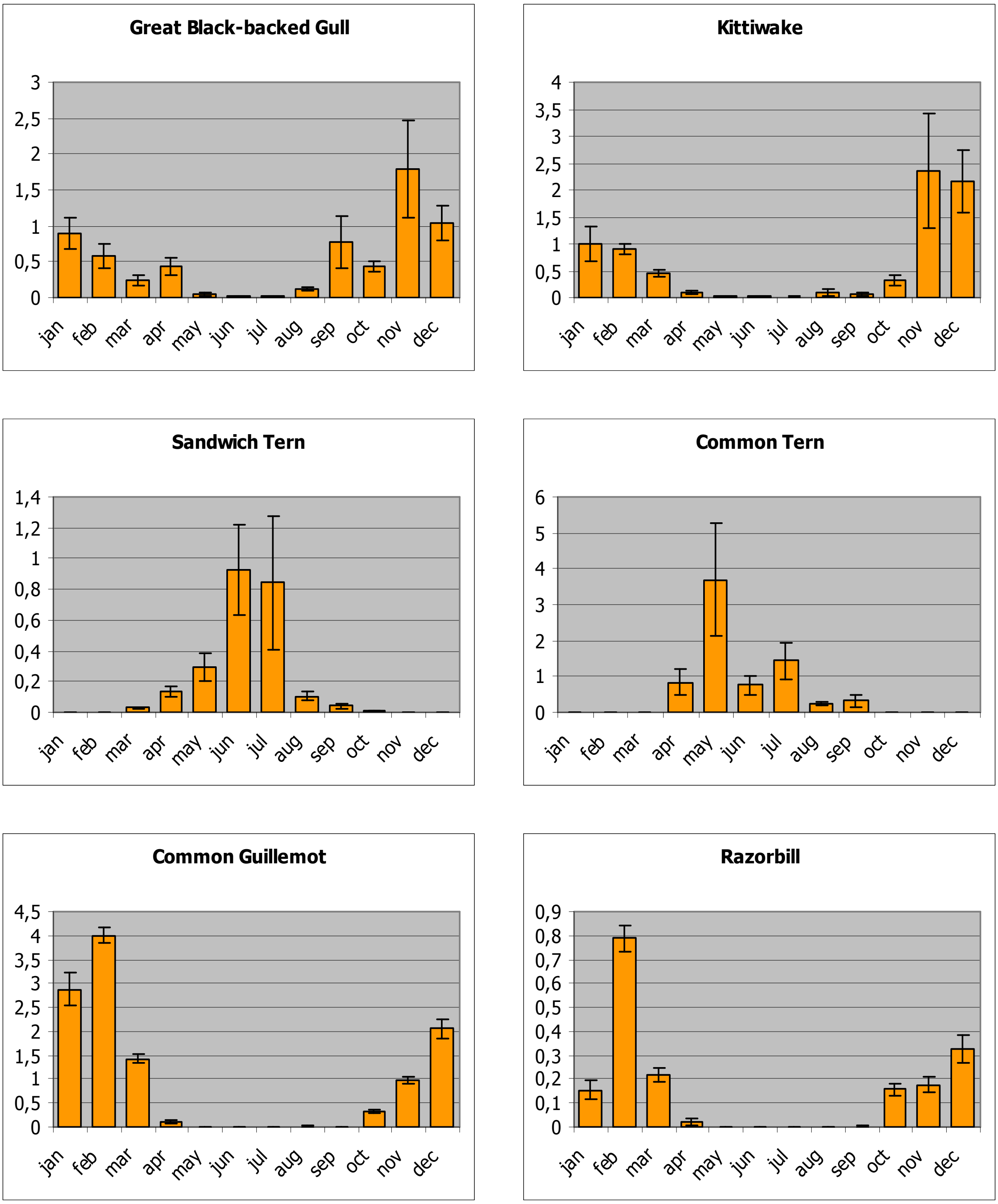

Figure 3 c. Mean densities per month of each species.

Month	Red-throated Diver	Great Crested Grebe	Northern Fulmar	Northern Gannet	Great Cormorant	Common Scoter	Great Skua	Little Gull	Black-headed Gull	Common Gull
jan	0,462	1,135	0,074	0,065	0,087	0,090	0,024	0,038	0,110	1,711
feb	0,314	0,458	0,086	0,258	0,014	2,123	0,003	0,220	0,159	0,967
mar	0,134	0,162	0,135	0,202	0,050	1,509	0,005	0,559	1,306	2,661
apr	0,000	0,000	0,162	0,012	0,030	0,144	0,006	0,782	0,004	0,095
may	0,000	0,055	0,087	0,065	0,032	0,000	0,000	0,000	0,505	0,004
jun	0,000	0,000	0,130	0,039	0,038	0,081	0,000	0,000	0,093	0,003
jul	0,000	0,000	0,016	0,129	0,069	0,017	0,015	0,096	0,035	0,017
aug	0,000	0,000	0,041	0,096	0,018	0,033	0,021	0,058	0,013	0,015
sep	0,000	0,000	0,123	0,223	0,010	0,009	0,021	0,649	0,335	0,071
okt	0,017	0,008	0,167	0,759	0,008	0,040	0,026	0,461	0,044	0,146
nov	0,146	0,129	0,169	0,544	0,016	0,168	0,031	0,209	0,772	1,251
dec	0,406	0,405	0,180	0,132	0,034	0,243	0,012	0,356	0,106	0,834

Month	Lesser Black-backed Gull	Herring Gull	Great Black-backed Gull	Kittiwake	Sandwich Tern	Common Tern	Common Guillemot	Razorbill
jan	0,054	0,448	0,887	1,002	0,000	0,000	2,870	0,154
feb	0,175	0,790	0,581	0,903	0,000	0,000	4,005	0,789
mar	2,075	3,115	0,237	0,448	0,029	0,001	1,423	0,216
apr	2,979	1,019	0,440	0,092	0,134	0,834	0,118	0,021
may	2,156	1,230	0,045	0,020	0,293	3,692	0,003	0,000
jun	2,364	1,692	0,019	0,023	0,929	0,767	0,005	0,000
jul	2,699	2,288	0,016	0,012	0,843	1,436	0,000	0,000
aug	2,630	1,308	0,118	0,098	0,102	0,228	0,016	0,000
sep	3,459	2,658	0,785	0,057	0,044	0,326	0,000	0,002
okt	1,318	0,335	0,439	0,323	0,008	0,015	0,335	0,158
nov	0,519	1,308	1,784	2,353	0,000	0,000	0,981	0,175
dec	0,180	1,404	1,040	2,157	0,000	0,000	2,054	0,326

Table 3. Mean density per month of each species and overview of the months retained for further analysis (indicated in green).

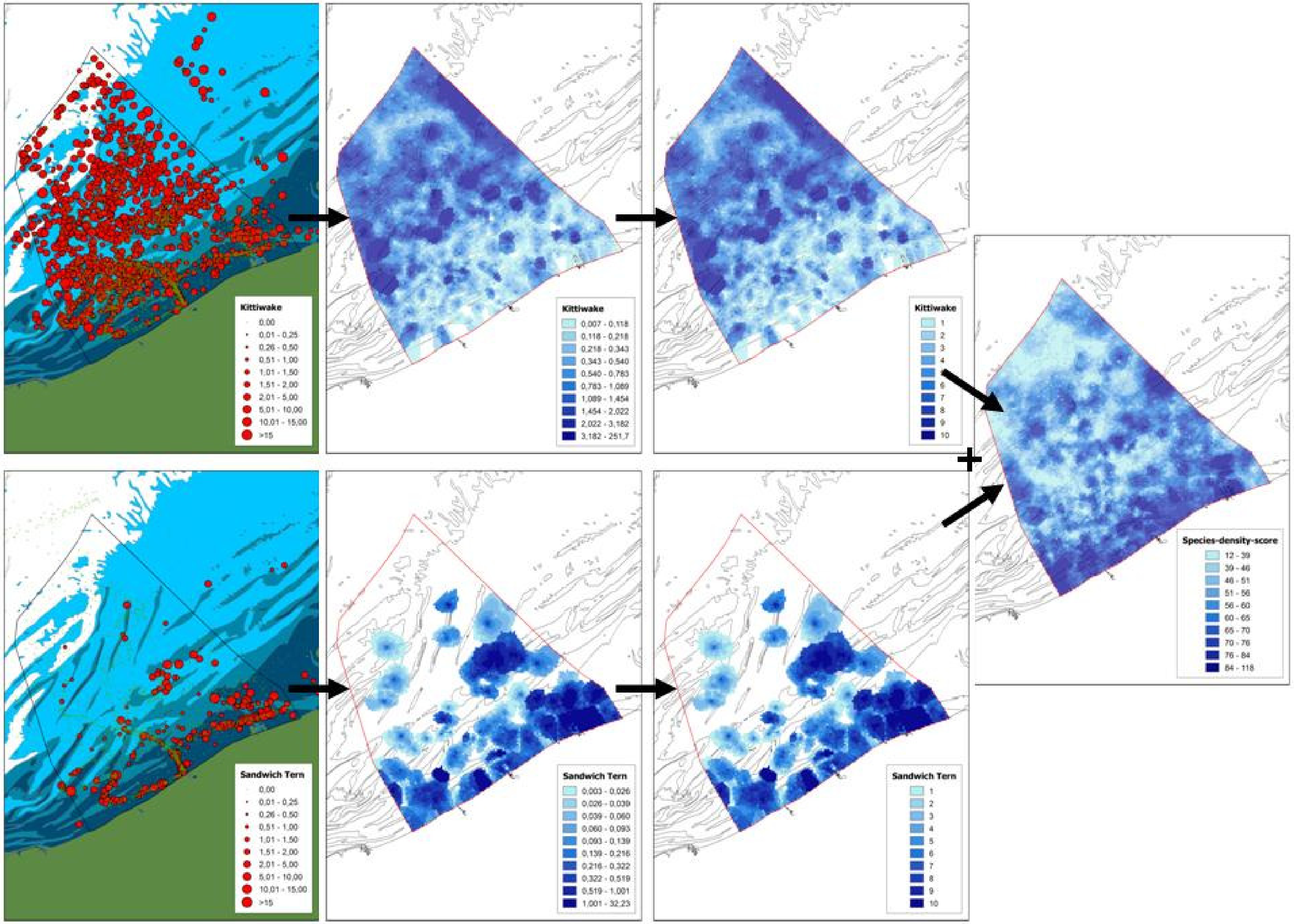

Figure 4. Methodology to answer the question 'Is the subarea characterised by high counts of many species?'.

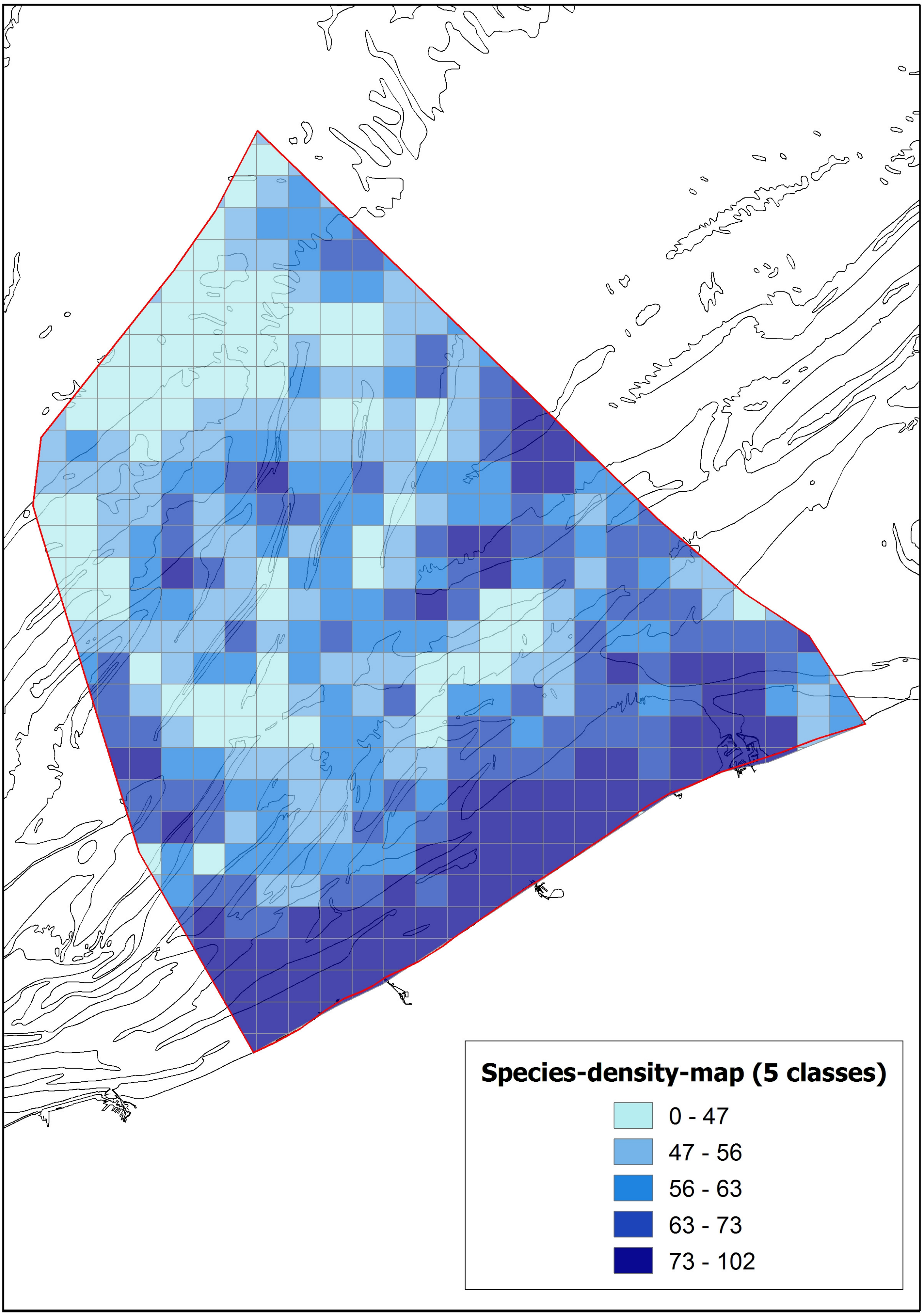

Figure 5. Species-density map.

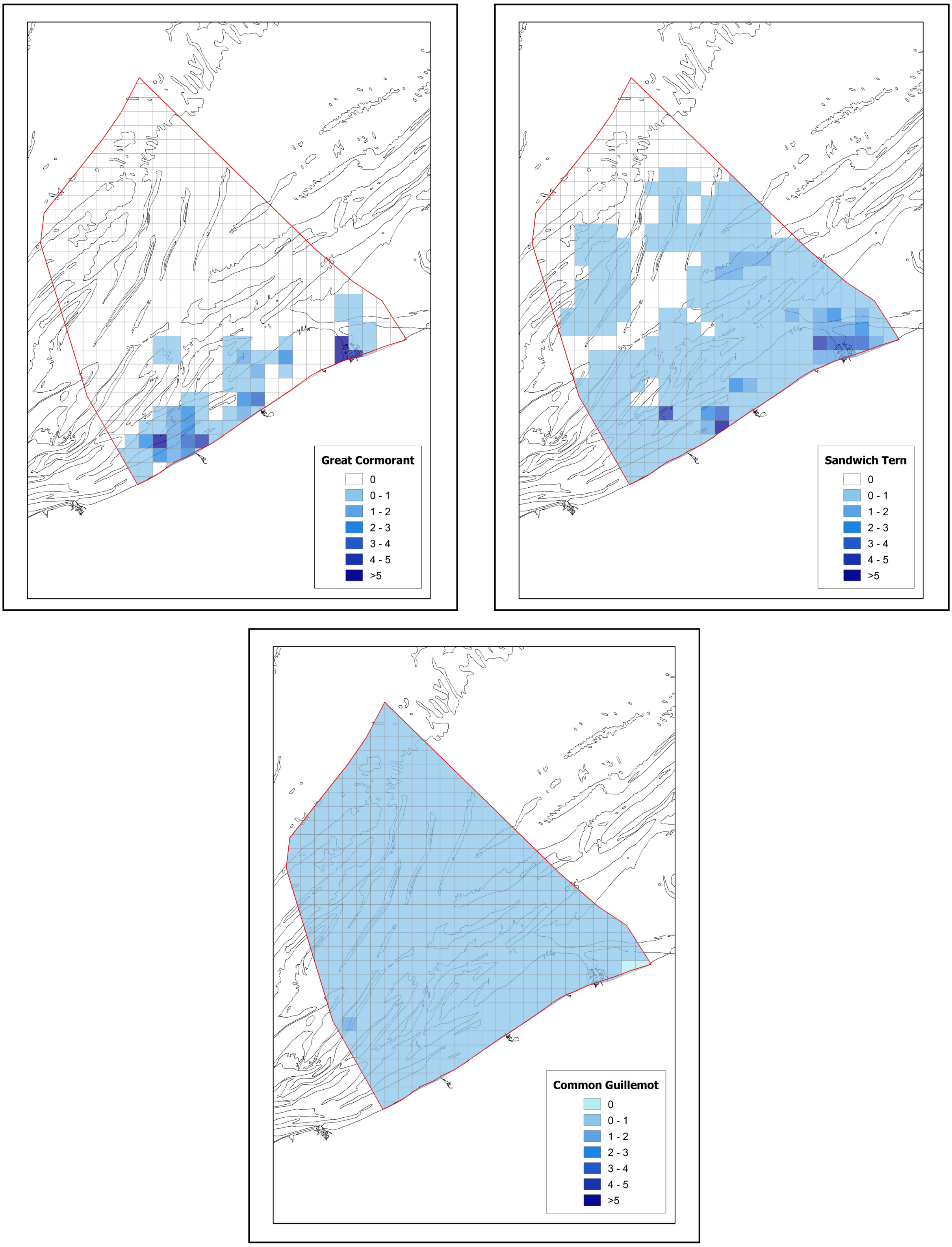

Figure 6. Examples of aggregation-maps of Great Cormorant (very aggregated), Sandwich Tern (moderately aggregated) and Common Guillemot (not aggregated).

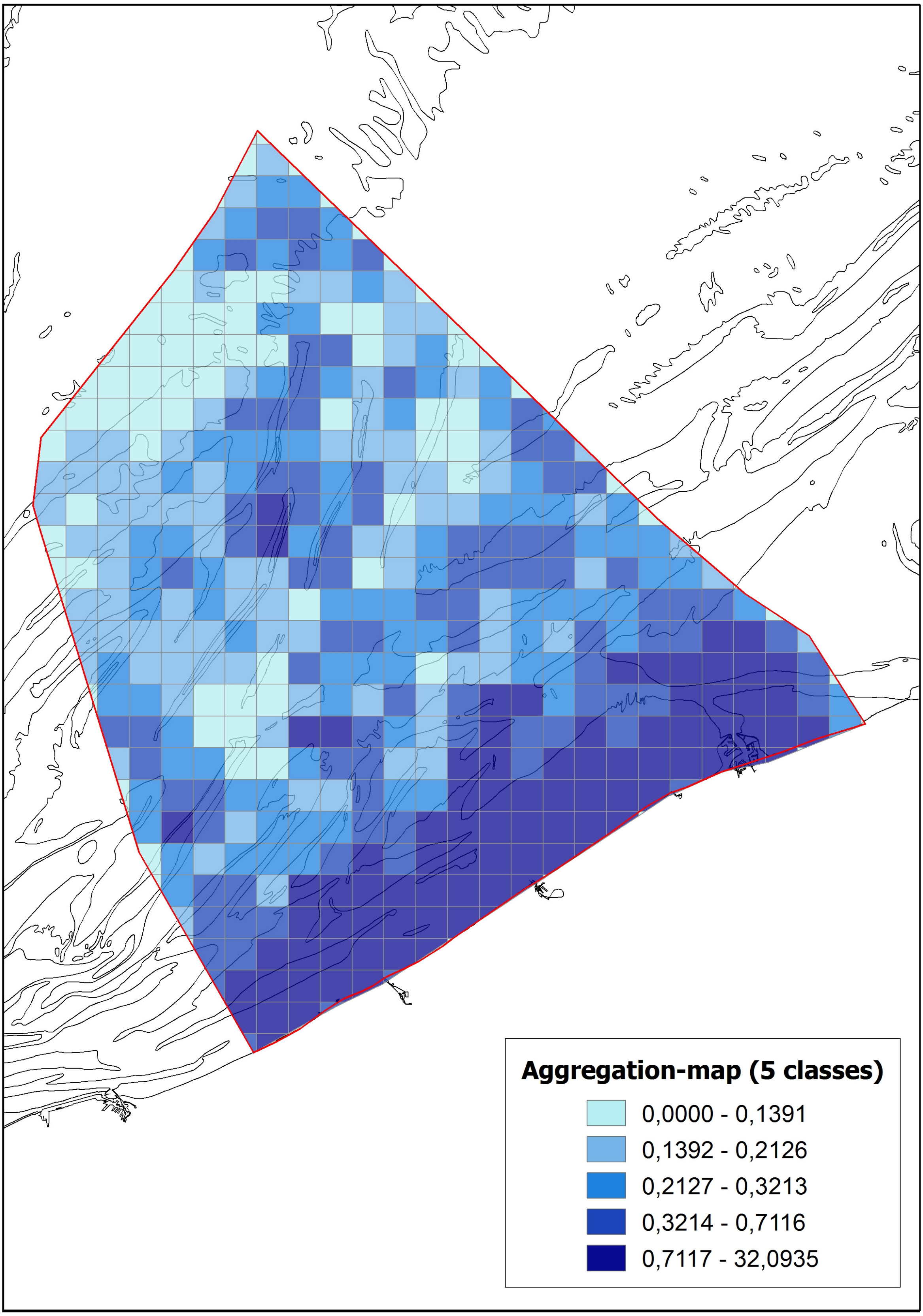

Figure 7. The aggregation-map.

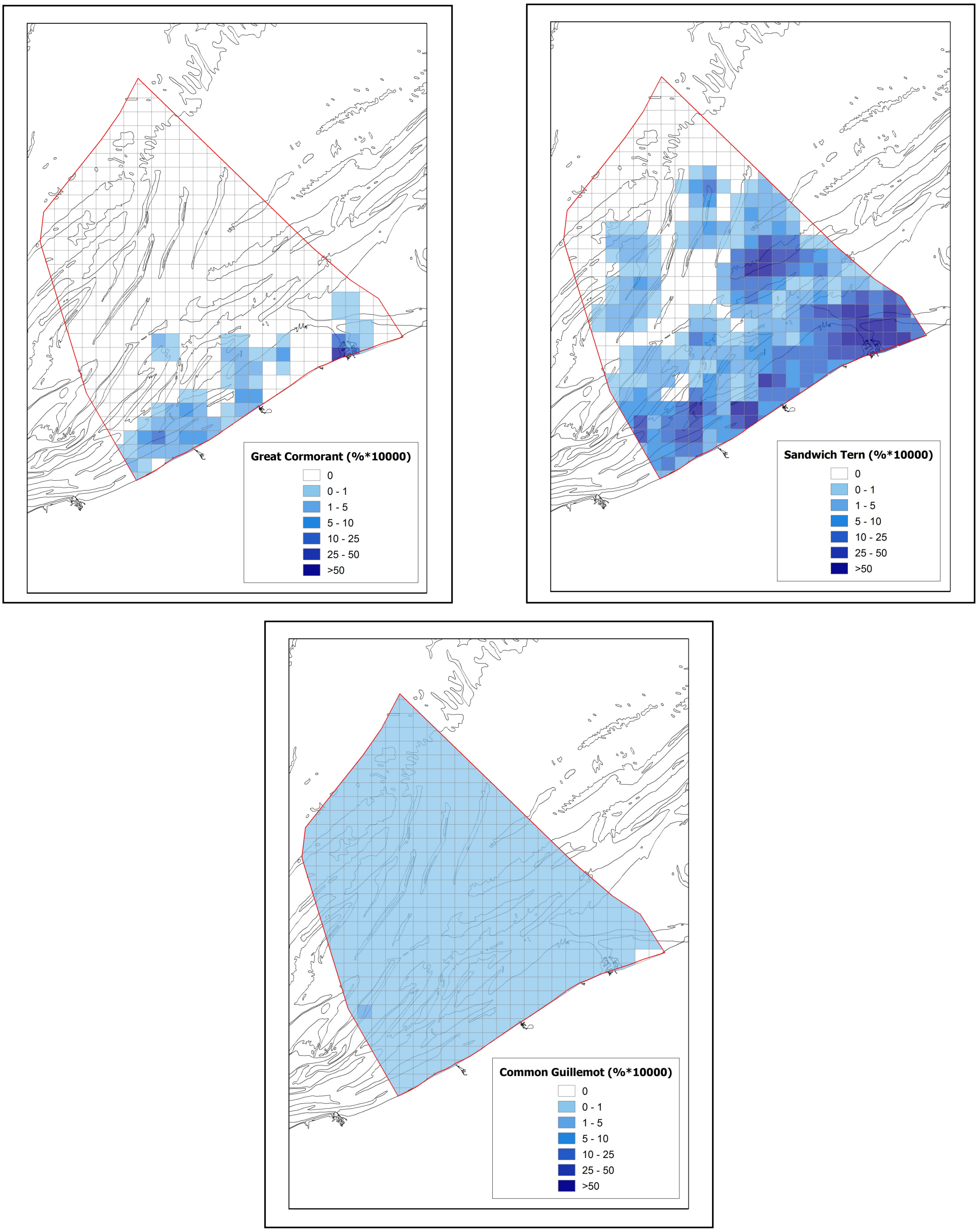

Figure 8. Examples of biopopulation maps of Great Cormorant, Sandwich Tern and Common Guillemot.

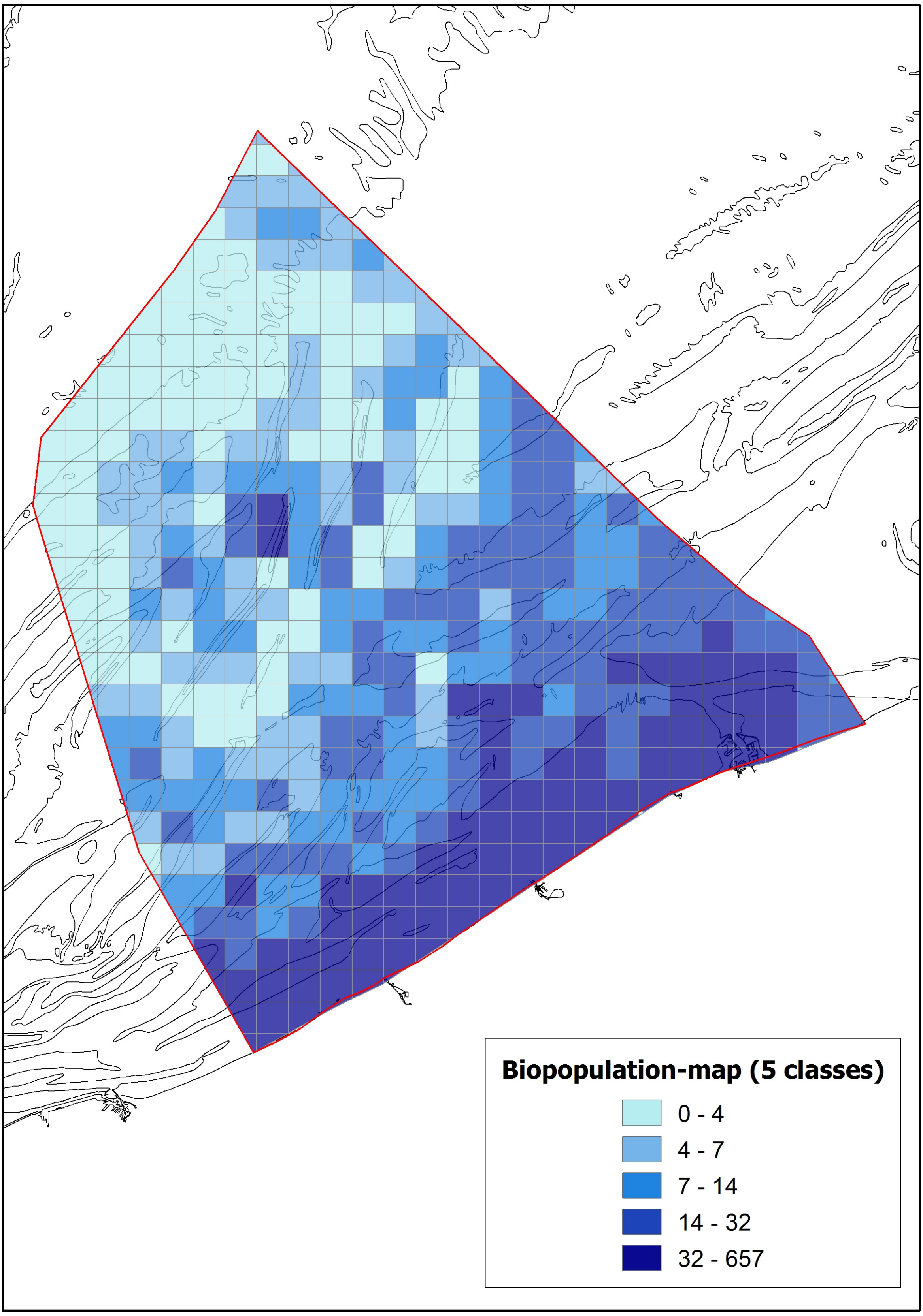

Figure 9. The biopopulation-map.

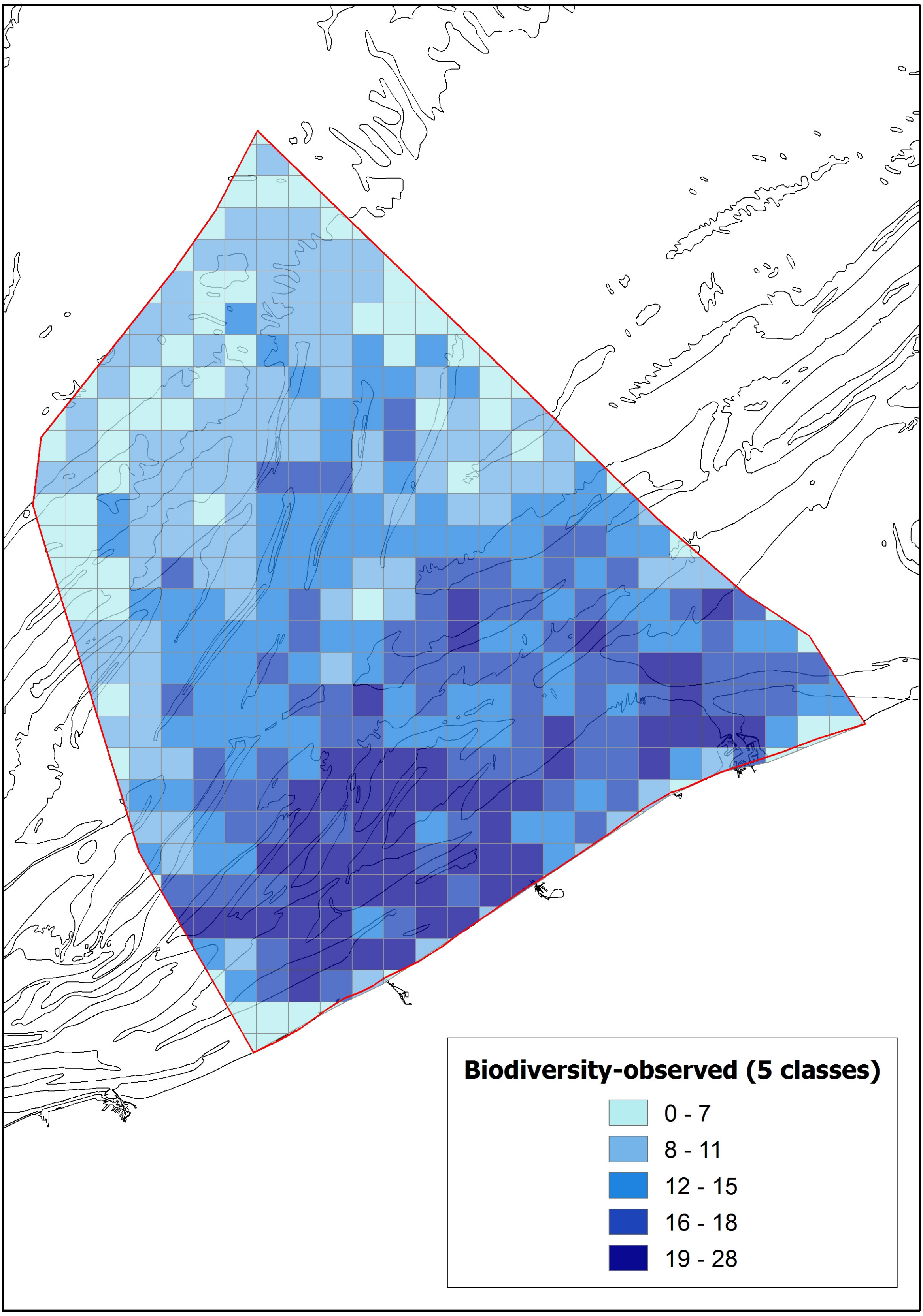

Figure 10. Observed number of species in 3x3 km-gridcells.

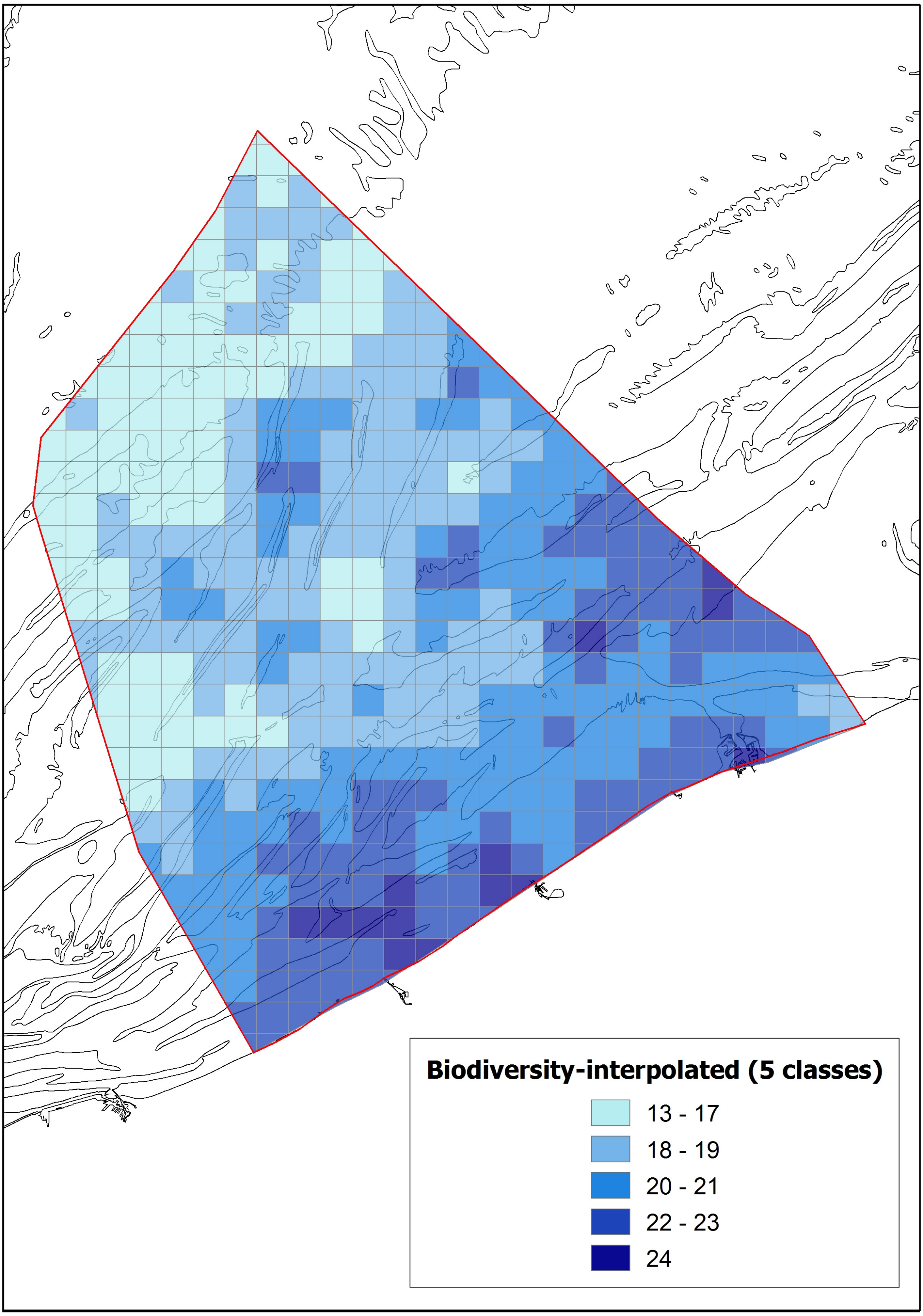

Figure 11. Modelled number of species in 3x3 km-gridcells.

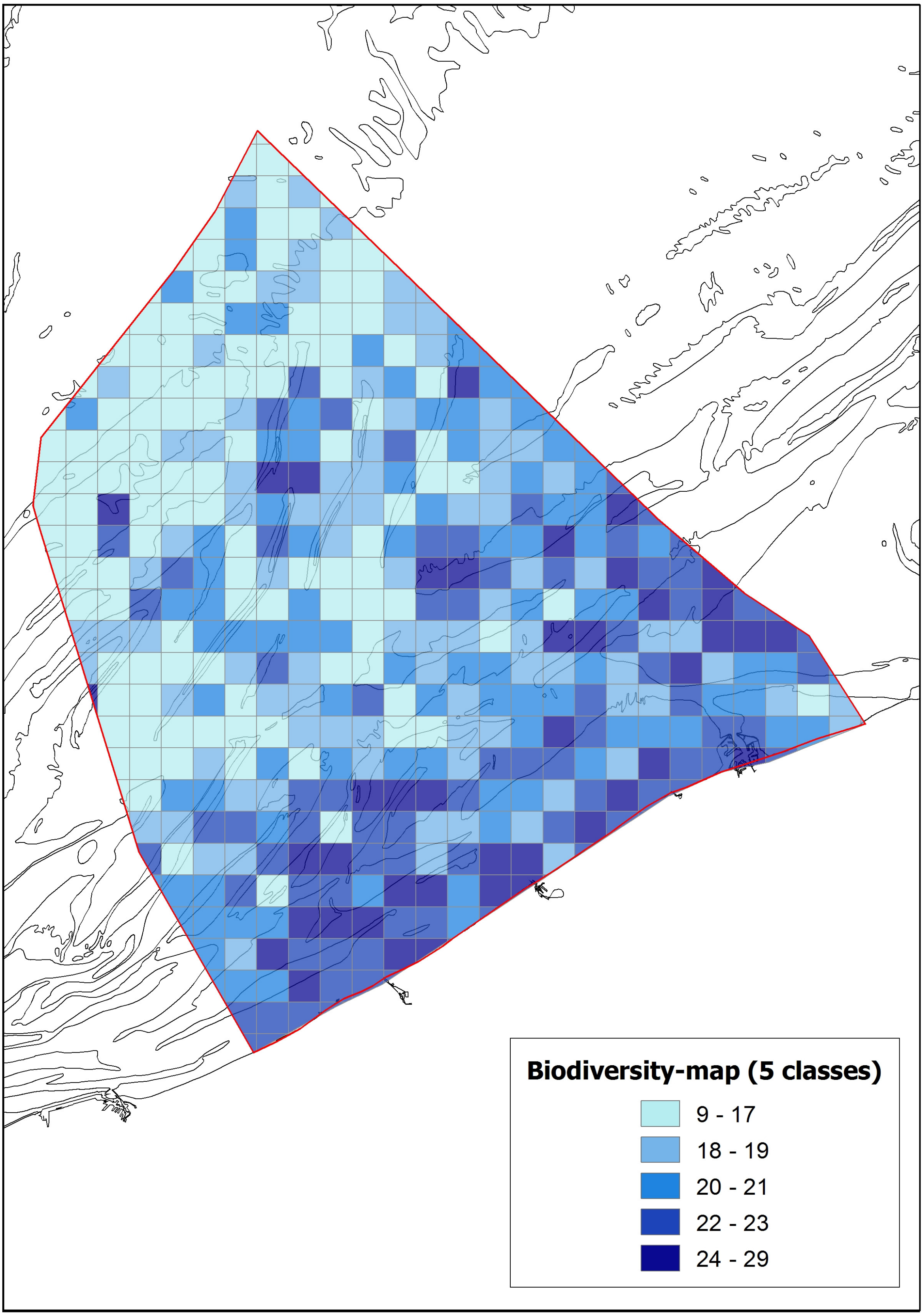

Figure 12. The biodiversity-map.