Gemini T-0: local seabirds

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Report number C056/15

IMARES Wageningen UR

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Cover photo: Common Guillemot *Uria aalge*, Gemini study area, 12 September 2013 (Mathias Putze)

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Summary

This report describes the results of the T-0 surveys for the monitoring of seabirds in relation to the future Offshore Wind Farm 'Gemini'. This wind farm, or rather two twin wind farms, will be built in the near future on the eastern Dutch Continental Shelf, close to the Dutch/German offshore border, at some 55 km north of the island Schiermonnikoog. In order to describe year-round seabird presence and densities and to assess which species are most likely to be affected by the future wind farm (and at which time of year), year-round, monthly seabirds surveys were carried out in and around the future wind farms.

The site is close to German waters (where other wind farms may be built) and close to a major shipping route (where surveying for seabirds is logistically difficult and where other disturbing factors are at play). Therefore, a survey design was chosen with a total survey area that was relatively narrow and which runs parallel (but outside) the shipping lane. The two wind farms are situated centrally in the study area, with three circa 15 km long stretches of reference areas in the west, centrally, and to the east of the wind farms (Figures 1 & 2).

The principal research question for these T-0 surveys is: *'How are seabirds distributed in the general area, in the absence of wind farms?'* The study aimed to map year-round seabirds' presence, numbers, and distribution of all species involved, and to identify the times of year during which different species use the area mostly or are largely absent. While we note that only one year of T-0 data cannot consider year to year variation in seabird presence, the general seasonal patterns found allow recommendations for optimal timing of future (T-1) surveys, which we think would give the best value for money.

With the exception of the Common Guillemot (*Uria aalge*), most seabirds do not reach high densities in the Gemini area, and therefore, the Gemini wind farms are unlikely to significantly impact these birds. Breeding birds, from protected colonies on Helgoland and on Dutch and German Wadden Islands, did not reach high densities during any of the spring and summer surveys. Migrant birds were not noted in high numbers.

Common Guillemots were the most numerous birds, reaching high densities during their post-breeding exodus (from UK colonies, presumably) and over the autumn and winter. As Common Guillemots are known to be displaced to some extent by offshore wind farms, the Gemini lay-out will allow for a very useful T-1 study that, together with similar T-1 studies in other offshore wind farms, will help the decision process for further offshore wind development.

1.   Introduction

Development of an offshore wind farm (OWF) in the Dutch Exclusive Economic Zone (EEZ) requires a permit under the 'Wet beheer rijkswaterstaatwerken' (Wbr). Permits for the construction of two such wind farms ('Buitengaats' and 'ZeeEnergie') have been obtained by BARD Engineering GmbH (Ministerie van Verkeer en Waterstaat, 2009a, 2009b). On 26 August 2011, these projects were obtained by Typhoon Offshore B.V. The project will hence be referred to under its new name 'Gemini'.

Construction, operation and decommissioning of offshore wind farms potentially have negative effects on the ecosystems in which they take place (Prins *et al.* 2008). Therefore, the 'Wet milieubeheer' (currently: Waterwet) prescribes that an environmental impact assessment (EIA, or, in Dutch, Milieu Effect Rapportage, MER) must be carried out. As required, such a study has been carried out as part of the permit application for both projects (Planungsgemeinschaft Umweltplanung, 2009a, 2009b). The findings in the MER led to the additional requirement of an appropriate assessment for both projects, because of possible interference of the projects with the conservation objectives of appointed Natura 2000 areas in the vicinity of the planned OWFs. These were submitted to the permit issuer as part of the Wbr permit application (Pondera 2009a, 2009b).

After completion of these studies a new configuration of the wind turbines (redesign of formation and model) as well as a new cable route were chosen. Therefore an updated EIA-procedure was carried out by Arcadis in 2013. The new permits for the wind farms 'Buitengaats' and 'ZeeEnergie' were received by December, the 4th 2013.

Based on the findings of the EIAs and the appropriate assessments, the permits for both wind farms include the obligation to submit a monitoring and evaluation plan (MEP). This MEP must be approved by the permit issuer, prior to the start of construction. A `Monitoring and evaluation plan for the ecological monitoring regarding the pre-construction phase of Gemini Offshore Wind Farm` had been developed by IMARES, in a consortium with Planungsgemeinschaft Umweltplanung Offshore Windpark (PGU[1], Bremen) in February 2012 (van Kooten *et al.* 2012). The ecological monitoring plan contained the following aspects:
1. Monitoring of harbour porpoises in relation to the OWF,
2. Monitoring of seals in relation to the OWF,
3. Monitoring of seabirds in relation to the OWF.
For these issues, it is essential to establish an understanding of the baseline situation which existed prior to the start of the Gemini OWF, because the overall aim of these studies is to elucidate the effects of construction and operation of the OWF.

Any pre-construction (T-0) monitoring must be carried out and reported prior to the start of construction. This study describes the distribution and numbers of seabirds in and around the Gemini OWF, prior to construction, based on 12 ship-based surveys (one survey in each month of the year). Clearly, one year of T-0 surveys is insufficient to understand year to year variation. Unlike the situation in e.g. Denmark or Belgium, standard practice in the Netherlands, as endorsed by the Dutch government, is to conduct just one year of T-0 studies. The results reported here therefore only provide a first impression on the avifauna in the Gemini area and are likely to be insufficient for later BACI analyses.

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[1] Planungsgemeinschaft Umweltplanung Offshore Windpark (PGU) is a long-standing collaboration between the companies Bioconsult (Bremen), planungsgruppe grün GmbH (Bremen) and IBL Umweltplanung GmbH (Oldenburg), which have been co-operating with each other since 2001.

2.   Assignment

This report describes the results of the T-0 surveys for the monitoring of seabirds in relation to the OWF Gemini (issue 3, see above). It aims to:

1. describe year-round seabird presence and densities and to assess which species are most likely to be affected by the future wind farm;
2. find any anomalies in the local seabird distribution patterns that might affect future analyses of wind farm effects;
3. find times of year when local seabird densities are so low that no real effects are to be expected during construction or operation (see timing and frequency, below).

Ad 1: future surveys may specifically target those species that are most vulnerable. Should the occurrence of these species be limited to specific seasons, the emphasis of future T(1) surveys could be directed to these seasons.

Ad 2: This may appear a theoretical problem, but should there be an area within the Gemini study site where seabird numbers are always different from the surroundings, and should a wind farm be built right there, T-1 surveys will find an "effect" that without good T-0 data will be attributed to wind farm presence.

Ad 3: There may be certain times of year when bird densities in the Gemini area are very low, for all species, such as the breeding season (should the Gemini site be out of reach of most breeders). If this can be established, it might be an option not to conduct further surveys in such periods.

Note, however, that just one year of T-0 data may be insufficient to firmly establish periods for which future surveys will not be needed.

The principal research question for the T-0 surveys is: *'How are seabirds distributed in the general area, in the absence of wind farms?'* The study aims to map year-round seabirds' presence, numbers, and distribution of all species involved. This is done by taking monthly, three-day snapshots of the birds present in the study area over one year, in order to get an overall impression of seabird presence and densities. The study further aims to identify the times of year during which different species use the area mostly or are largely absent.

3. Materials and Methods

The location of the survey area for the two OWFs `Gemini´ is about 55 km north of the island Schiermonnikoog, in the Dutch EEZ at the Dutch-German border (Figure 1-A).

Timing and frequency

The Dutch authorities require monthly surveys for one year before construction or monthly surveys from April through October plus two mid-winter surveys in January and February. Either schedule can possibly be reduced for post-construction surveys if months can be identified without significant seabird presence in the study area. Therefore, the T-0 monitoring was carried out monthly for one year as a basis to evaluate the optimal survey effort during the construction and operational phases. An important goal of the T-0 surveys was the identification and justification of necessary survey months. Condensing survey effort in the months with the highest densities of vulnerable seabirds might then be an option. As noted earlier, however, there is a risk of overlooking important times of year, with limited T-0 effort available, such as in this study, so some caution is needed to identify times of year with either very high or very low seabird presence.

Survey design

The Dutch authorities had stipulated that besides the wind farm itself, an area extending 15 km beyond the wind farm perimeters needs to be surveyed. As the wind farm borders a major shipping line (situated to its north, Figure 1-B), it was decided that an area extending from 15 km west of GEMINI to 15 km east of GEMINI (extending into German waters) was to be surveyed. The T-0 survey design comprises nine circa 45 km long transects running ESE-WNW (1 to 9, see Figure 1-B) parallel to the shipping lane (and also roughly parallel to the isobaths and the coastline) through the GEMINI wind farms. These transect lines are equidistant (1.2 km apart) and were designed to get more or less equal survey effort within the future 'impact area' (GEMINI E and GEMINI W, the CENTER (the future empty space between the wind farms)) and two directly comparable reference areas EAST and WEST on either side (see Figure 2a). Seven of the nine lines run through the wind farms, lines 1 and 9 run just north and south of the wind farm perimeters Figure 2a). At the time of designing these T-0 surveys, it was not yet clear whether a wind farm would be built just across the Dutch/German border, in the proposed easterly reference area. Should that be the case (Figure 2b), this will clearly impact future T-1 surveys.
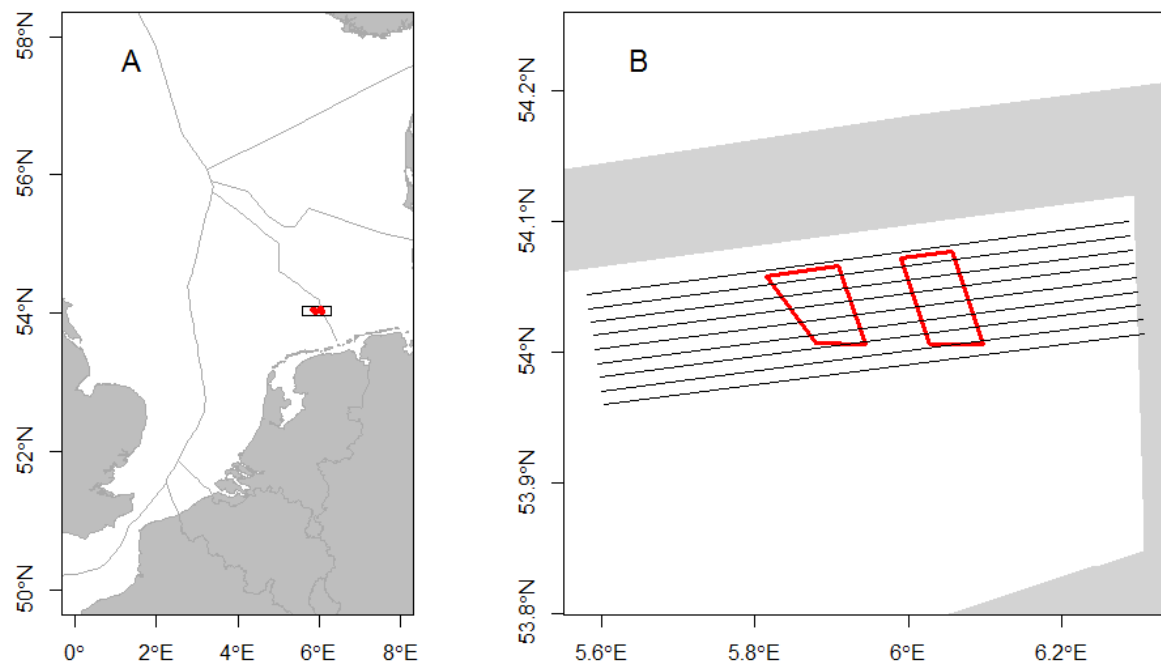
Figure 1. (A) Position of study area in the Dutch North Sea. (B) Configuration of the transect lines (WSW-ENE black lines) in relation to the future wind farms (red borders) and shipping clearways (grey areas).
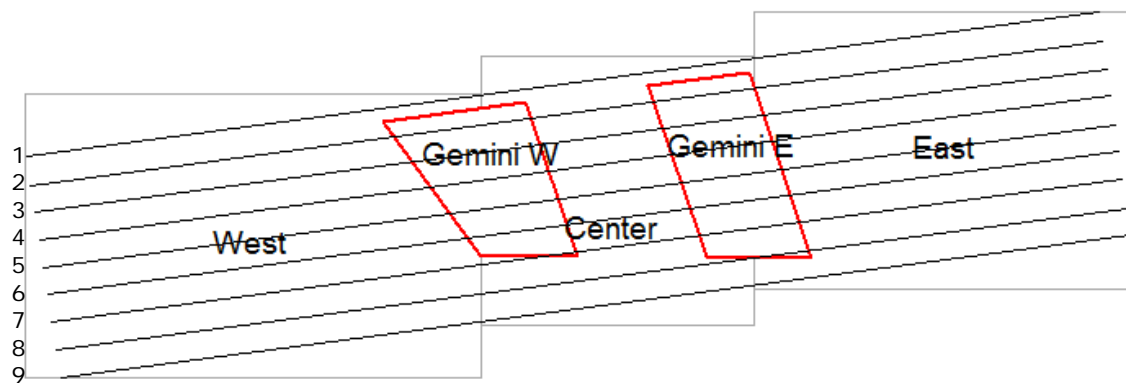
Figure 2a. Split of study area in five blocks: 1) 'West', running from the westernmost point to halfway the western wind farm; 2) 'Gemini W', the western wind farm; 3) 'Center', the area between and north and south of the two wind farms; 4) 'Gemini E', the eastern wind farm and 5) 'East', the area east of the eastern wind farm. Nine equidistant transect lines (1-9) were used to cover this area.

Figure 3b. The Gemini study site in an international setting. "Gemini-E'(ast) is situated right at the Dutch/German border and there are several wind farms being planned and constructed in close proximity. Particularly wind farms in the eastern part of the Gemini study area (now in the proposed reference area) will influence future surveys and, possibly, bird densities. Wind farms at greater distances were not yet operational during the Gemini T-0 surveys, and no reactions of seabirds to distant construction works were noted, but could not be excluded either.

Seabird counting techniques

Data on bird presence and bird densities were collected at sea, using ship-based strip-census techniques (Tasker *et al.* 1984). In summary, birds were counted in one or (mostly) two, 300 m wide strips on either side of the survey vessel, by two separate teams of two observers. This doubled the effort compared to a single side count, and made that a large relative surface area was studied compared to the total study area. Although considerable numbers of seabirds were also seen beyond the 300 m limits, or at closer range but outside the snap-shots used in the strip counts (Tasker *et al.* 1984), only birds seen 'in transect' (also see below)' were used for modelling purposes. These birds were always seen within 300 m perpendicular distance to the ship's transect line and in the case of flying birds, at the right snapshot moments and forward distance (see Tasker *et al.* 1984).

Birds were recorded in real time, but for analysis, transect lines were broken up into 1 minute (time) stretches and birds seen 'in transect' in each individual 1 minute count were pooled (from t=0 to t=5 mins and for portside and starboard). At t=1 min, the next count commenced, from t=1 min to t=2 mins, etc. Densities were calculated as numbers seen in transect, divided by area surveyed. Area surveyed is the way length covered in that particular 1 minute period (depending on sailing speed, which was continuously monitored but kept close to 10 knots or 18.5 km/h) and strip width (300 or 600 m), corrected for the proportion of birds that were missed by the observers (see next section: distance sampling). The location of each count was taken as the mid-position between the positions at t=0 and t=1 min, for each count, on the ship's transect line.

Due to movement of flying birds and the fact that they usually fly much faster than the sailing speed of the ship, the density of flying birds is easily overestimated. To account for this overestimation, flying birds were counted by the so-called snap-shot method (Tasker *et al.* 1984). This method prescribes that all birds flying above the transect should be recorded as 'in transect' at fixed time intervals and only to a fixed distance ahead. Here, we used a 1-minute interval. The distance travelled within one time interval determines the forward distance that is regarded as 'in transect'. For example, at a speed of 10 kt, the distance travelled in one minute is circa 300 m, and consequently, all birds flying above the 300 x 300 m rectangle at whole minutes are noted as within the transect.

Flying heights

Flying heights of birds were routinely noted for all birds that were seen in the air (as opposed to swimming, on the water), in several categories (meters above sea level, m asl). Flying heights in the lower air space could be judged against known altitudes, particularly known deck heights and the known elevation of the observers (eye height) above sea level. Birds seen more than an estimated ship length above sea level were more difficult to categorise precisely, and for this reason the flying height categories became broader at higher altitudes.

Flying heights were classed as: 1 (0-2 m asl); 2 (2-10); 3 (10-25); 4 (25-50); 5 (50-100), 6 (100-200) or 7 (>200 m asl). An overview of the collected data, per species, per altitude class is given in Appendix 3.

Detailed analysis of Common Guillemot data

For Common Guillemot, a detailed data analysis was carried out to investigate whether bird densities showed anomalies at wind farm locations that might wrongfully impact future assessments of wind farm presence. This analysis consists of a distance analysis to account for imperfect detection and a statistical

analysis to estimate the effect of the wind farm locations on bird densities. In the statistical analysis, only data from surveys was used with sufficient numbers of birds present: the surveys for the months May, June and August were excluded (see below). Note that July was included as during the July survey surprisingly high numbers of Common Guillemots were encountered, that is: much higher densities than in June and August.

Distance analysis

Birds swimming or floating on the water surface (as opposed to birds in flight) may be hard to detect. Detection probability is determined by several factors, such as colour, shape and behaviour of the bird, but especially the distance from the transect line (i.e. the observer). Perpendicular distance is a major determinant of detection probability. The technique of distance sampling (Buckland *et al.* 2001) was used to infer the relationship between detectability and distance. Therefore, all (groups of) birds on the water were assigned to a particular distance class, perpendicular to the ship's track line: 0-50 m (A), 50-100 m (B), 100-200 m (C), 200-300 m (D) and more than 300 m (E). Flying birds (see above) were noted as in distance class F, and were considered to be always detected when in transect. Only the numbers of birds on the water had thus to be corrected for birds missed by the observers. From the numbers of individuals counted in bands A-D, detection functions were estimated, from which the so-called effective strip width (ESW_{swim}) for swimming birds was obtained. The ESW_{swim} represents the width within which the expected number of detected objects would be the same as the numbers actually detected within the full width of 300 m (Buckland *et al.* 2001). ESW for all birds, swimming and flying, was calculated by taking the average of ESW_{swim} and ESW_{fly} (300 m), weighted for the respected numbers of swimming and flying birds seen in transect.

Detection functions were created using the software package Distance (v6.0) (Thomas *et al.* 2009). This software offers several model 'key' functions that are fitted to the counts per distance band. Models can include covariates and 'series adjustment terms' (the latter allow extra flexibility, but were limited to one here because of the limited number of distance bands). The half-normal and the hazard-rate key functions with a cosine series adjustment function were used in the analyses. As detection probabilities may vary with weather conditions and between observer teams, seastate and survey number were included as continuous and factor covariates, respectively. All combinations of model functions and covariates were fitted. Subsequently, the model with the lowest AIC (Akaike's Information Criterion; Akaike 1973; see: Buckland et al. 2001) was selected. Due to the low number of observations of Common Guillemots in the surveys of June 2012 and May and August 2013, these were excluded from these and further analyses.

Note that it is implicitly assumed in the modelling that all swimming birds will be detected if they swim on the track line, or in the case of sub-bands within a wider strip, within the first band (A). However, detection probability on the track line (the so-called g(0), Buckland *et al.* 2001) is unlikely to be perfect, for example due to escape diving by alcids. There is however no correction factor available for an imperfect g(0). Observations using 'double-platforms' (Hammond *et al.* 2002) would be needed to assess the fraction of birds seen on the trackline.

In distance analyses, detection probability of clusters of individuals is modelled. This means that the resulting density represents the density of clusters of individuals. To arrive at a density of individuals, the density of clusters needs to be multiplied by the average group size. However, detection probability may depend on cluster size. To correct for such a bias, we used the expected cluster size on the transect line (i.e. at perpendicular distance 0). This value is obtained from the intercept of a regression line of cluster size against distance from the transect line.

Statistical analysis

Statistical analysis of seabird density data is often hampered by two statistical problems. First, there is often a large number of zeros in the data ('zero inflation'). Second, the number of birds often shows large variation, with many small values and few (very) large values. Data exploration showed that this dataset has the aforementioned properties. That is, zero inflation and substantial variation in distribution patterns between surveys. Therefore, we applied a modified version of the model used for the analysis of the OWEZ/PAWP dataset (Leopold *et al.* 2013a). This is a Zero Inflated Generalized Additive Mixed Model (ZIP GAMM) with the response variable (the number of Common Guillemots noted per 1-minute count) assumed to follow a Poisson distribution.

This model can be described as follows.

$$Y_{ijk} \sim ZIP(\mu_{ijk}, \pi_{ijk})$$
$$\text{logit}(\pi_{ijk}) = \gamma_k$$
$$\log(\mu_{ijk}) = \beta_1 \times I_{WEST} + \beta_2 \times I_{EAST} + f_k(x_{ijk}, z_{ijk}) + a_{jk} + s_{ijk}$$

$$I_{west} = \begin{cases} 1 & \text{if observation } ijk \text{ is made in Gemini - West} \\ 0 & \text{else} \end{cases} \tag{1}$$

$$I_{east} = \begin{cases} 1 & \text{if observation } ijk \text{ is made in Gemini - East} \\ 0 & \text{else} \end{cases}$$

$$a_{jk} \sim N(0, \sigma^2_{Hour})$$

This model includes parameters β_1 and β_2 for the effect on bird densities in the western and eastern Gemini wind farm, respectively. Moreover, it has a two dimensional smoother for each survey, which were modelled using a radial basis spline (Ngo & Wand 2004). Each 2-D smoother contains an intercept allowing for different mean values per survey.

To account for small temporal and some spatial autocorrelation, a random effect *a* per transect line *j* per survey *k* was included. The effectively surveyed area per 1-minute count s_{ijk} is included as an offset.

Markov Chain Monte Carlo (MCMC) was used to estimate the posterior distribution of the parameters. Calculations were carried out in JAGS (Plummer 2003) using the R package R2jags (Su & Yajima 2012) in R (R Development Core Team 2011). A burn-in of 100,000 iterations was used and 100,000 iterations were carried out using a thinning rate of 100, with 3 chains, resulting in 3000 iterations for each posterior distribution. Diffuse priors were used for all parameters. The random effect a_{jk} imposes a correlation on all observations made within the same hour and captures small-scale temporal and spatial correlation.

4.   Results

Effort

In total, 12 surveys were carried out, using four ships and a team of 11 observers from IMARES and IBL Umweltplanung (Table 1; Appendix B). Surveys lasted three days, with January 2013 being the only exception with four days due to snowy conditions. Trip reports of these surveys have been published earlier, see Table 1 for references.

The August and September surveys, which were planned initially for 2012, were postponed to 2013. This leads to a disrupted time series, with two-month gaps in 2012 (August/September) and in 2013 (June/July).

Over 12 surveys, a total of 4 898 km was sailed, in nearly 640 observation hours. With a strip width of 300 m at (mostly) each side of the ship corresponds to a surveyed area of 2,938 km^2 (Table 2). All nine planned transect lines could be surveyed during most surveys (Figure 4), with the exception of the southernmost line, which was not surveyed in October 2012 and only partly surveyed in December 2012, due to bad weather conditions. Weather conditions were generally good to moderate. The seastate during the surveys was mostly not higher than 4. During the surveys in July 2012, March 2013 and August-September 2013, the majority of effort was realized in seastates <6 (Table 2, Figure 3).

Table 1. Ships and observers per survey.

Year	Month	Days	Ship	Observers[*]	Reference
2012	June	19-21	Reykjanes	ML , SG, AR, NS	Leopold et al 2012
2012	July	22-24	Reykjanes	ML, HV, AR, NS	Leopold et al 2013b
2012	October	23-25	Hydrograf	SG, HV, NS, MP	Geelhoed et al 2013a
2012	November	14-16	Hydrograf	NS, AR, SP, VB	Stöber et al 2013a
2012	December	17-19	Hydrograf	SP, RN, VB, SK	Stöber et al 2013b
2013	January	11-14	Hydrograf	SG, HV, VB, AR	Geelhoed et al 2013b
2013	February	17-19	Hydrograf	SP, RN, VB, NS	Stöber et al 2013c
2013	March	12-14	Sverdrupson	ML, SK, NS, SP	Leopold et al 2013c
2013	April	15-17	Cecilie	ML, RB, NS, AR	Leopold et al 2013d
2013	May	11-13	Cecilie	SP, MP, AR, NS	Stöber et al 2013d
2013	August	6-8	Hydrograf	SG, HV, SP, MP	Geelhoed et al 2013c
2013	September	10-12	Hydrograf	ML, RB, NS, MP	Leopold et al 2013e

[*] AR = Annegret Rausch[2], HV = Hans Verdaat[1], ML = Mardik Leopold[1], MP = Mathias Putze[2], NS = Nicole Stöber[2], RB = Rob van Bemmelen[1], RN = Roland Neumann[2], SG = Steve Geelhoed[1], SK = Susanne Kühn[1], SP = Stefan Pfützke[2], VB = Verena Blum[2].
[1]: IMARES; [2]: IBL Umweltplanung

Table 2. Effort per survey.

| Yr/month survey	# 1-min. counts	Distance covered (km)	Surveyed area (km²) per Beaufort wind force (Bft)						
			1 Bft	2 Bft	3 Bft	4 Bft	5 Bft	6 Bft	total
201206	1 348	415	88.0	22.6	104.2	34.2	0.0	0.0	249.1
201207	1 264	392	0.0	27.6	13.6	150.1	43.6	0.0	234.9
201210	1 091	371	35.8	61.3	92.8	22.7	9.9	0.0	222.5
201211	1 268	417	42.1	31.6	141.2	35.5	0.0	0.0	250.3
201212	1 177	378	0.0	27.1	49.7	133.7	15.9	0.0	226.5
201301	1 298	419	13.7	34.7	150.5	52.7	0.0	0.0	251.6
201302	1 289	417	62.9	131.5	0.0	47.0	8.6	0.0	250.0
201303	1 278	417	34.3	50.9	56.6	73.4	9.7	25.0	250.0
201304	1 274	418	0.0	6.4	122.9	79.8	39.9	1.6	250.7
201305	1 343	420	0.0	0.0	76.8	175.1	0.0	0.0	251.9
201308	1 364	419	0.0	0.0	41.5	134.6	75.4	0.0	251.6
201309	1 356	416	27.8	58.2	41.3	66.5	0.0	27.8	221.6
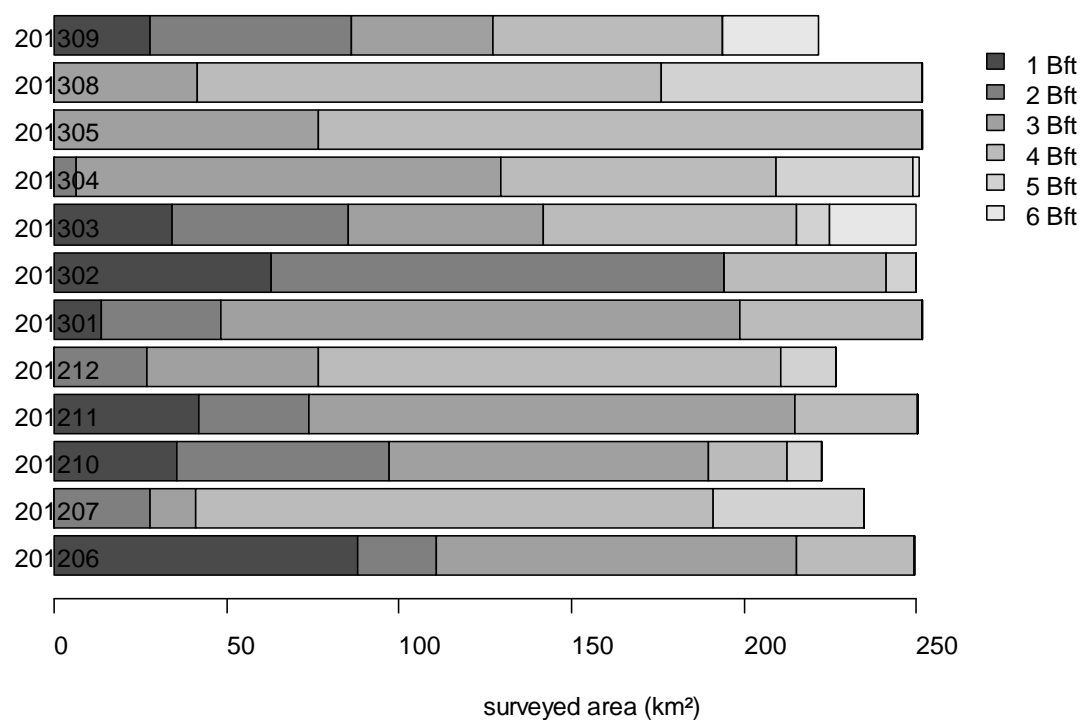
Figure 4. Distribution of seastates over the realized effort (expressed in surveyed area, km²) per survey.
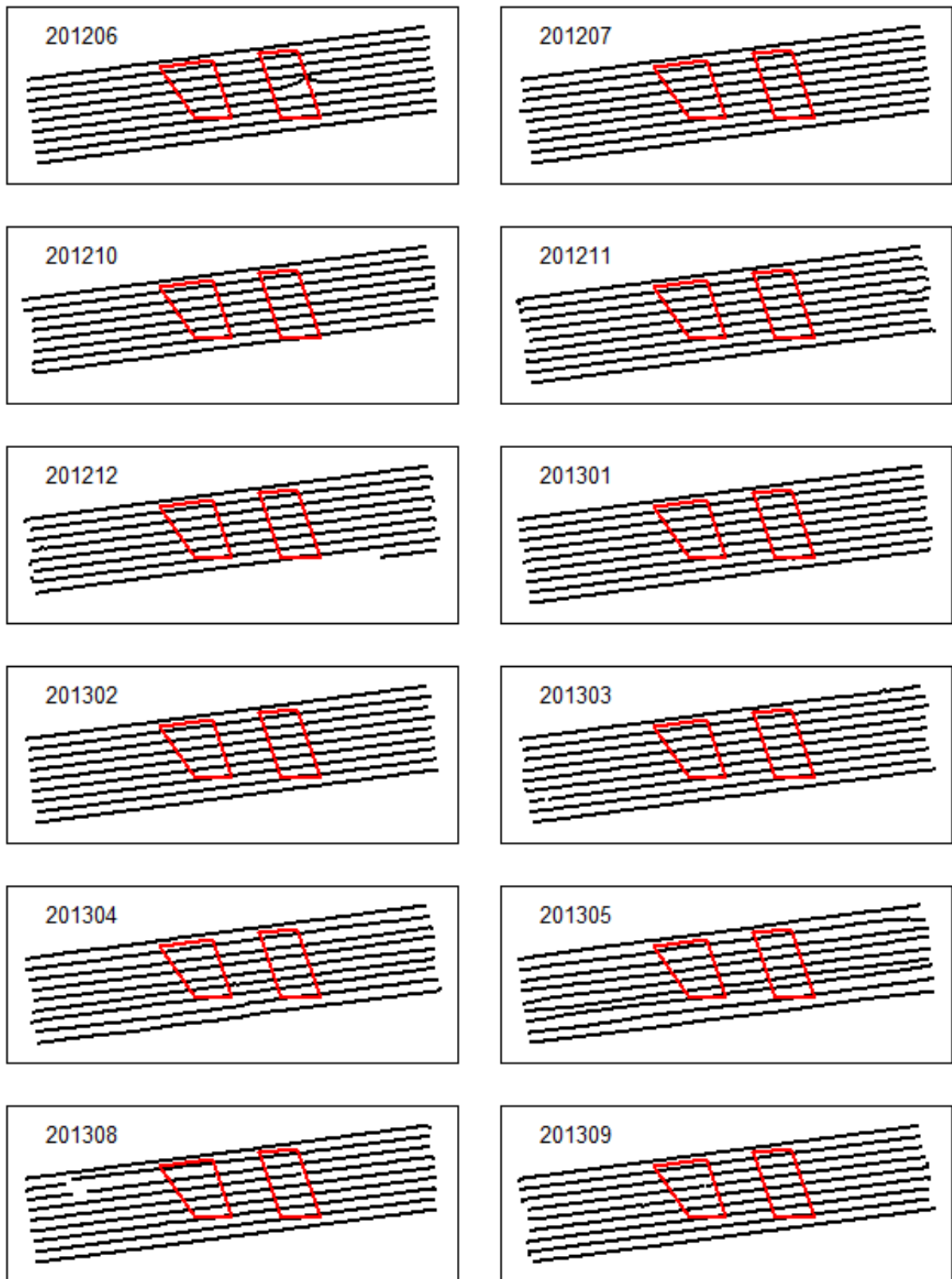
Figure 5. Sailed transect lines per survey. Note that the southernmost line was skipped entirely in October 2012 and for the most part in December 2012. The slight anomaly in June was due to another survey ship (with divers in the water) anchored right on one of the pre-determined survey lines. This position had to be given a wide berth.

Species composition

In total, 16,202 individuals of 75 bird species were recorded. Of these, 10,021 individuals of 51 species were recorded as 'in transect' and can therefore be included in further density analyses. A complete species list with total numbers per survey is provided in Appendix A. For the 20 most abundant species, the total numbers of birds recorded 'in transect', are listed in Table 3. From these, Common Guillemot is by far the most abundant species. Not only is the total number of individuals much higher than for other species, the number of surveys with at least 20 individuals (limit based on data exploration, but still a fairly arbitrary threshold) is also the largest. Razorbill, Black-legged Kittiwake, Lesser Black-backed Gull, Northern Gannet, Common Gull and Little Gull all have at least five surveys with more than 20 recorded individuals. The remaining species either have a peaked occurrence (see: Species accounts) or occurred always in low numbers.

Table 3. List of the 20 most abundant species in terms of total number of individuals observed within the counting strip. Species with at least 50 individuals recorded are discussed in detail. Next to the 6311 identified auks (Common Guillemots and Razorbills), rather large numbers of these auks could not be identified by some observers (392 birds in total, mostly in October (65), November (157), December (63) and February (92)). Likewise, relatively large numbers of divers were left unidentified, mostly in March (7) and April (14) and so were some terns in summer. These are not included in density estimates for either species (in parentheses). For subsequent analyses unidentified auks were not considered a problem, as these "birds" were seen both inside and outside the future wind farm sites, irrespective of their location. Red- and Black-throated Divers and terns were analysed as groups anyway.

Species	Total number of individuals	Range, ± SD	N surveys with >20 individuals
Common Guillemot	4,947	(3-1045, ± 319.7)	10
Razorbill	1,364	(0-517, ± 159.6)	7
(Guillemot/Razorbill)	392	(0-157, ± 51.0)	4
Black-legged Kittiwake	785	(0-215, ± 68)	8
Lesser Black-backed Gull	674	(0-299, ± 90.4)	5
Northern Gannet	430	(6-100, ± 29.7)	7
Common Starling	339	(0-294, ± 84.1)	3
Common Gull	216	(0-41, ± 17.7)	5
Great Black-backed Gull	193	(0-55, ± 21)	3
Little Gull	179	(0-35, ± 13.3)	5
Arctic Tern	133	(0-83, ± 24.7)	2
(Arctic/Common Tern)	15	(0-6, ± 2.1)	0
Northern Fulmar	109	(0-43, ± 12.6)	2
Herring Gull	102	(0-38, ± 13.3)	2
Common Scoter	89	(0-62, ± 18)	1
Red-throated Diver	50	(0-17, ± 5.2)	0
(Red/Black-throated Diver)	28	(0-14, ± 4.3)	0
Greylag Goose	49	(0-30, ± 9.8)	1
Eurasian Wigeon	25	(0-24, ± 6.9)	1
Black-headed Gull	24	(0-15, ± 4.3)	0
Greater White-fronted Goose	21	(0-21, ± 6.1)	1
Common Tern	18	(0-13, ± 3.7)	0
Great Cormorant	18	(0-9, ± 3.1)	0

Both the number of species and the total number of birds showed a seasonal pattern (Figure 5). The total number of species seen within the transect bands fluctuated between 7 and 18. Several rare species were only seen outside the transect bands or outside snapshot moments, and the total number of species seen was therefore slightly higher, fluctuating between 9 in June and 37 in October and 33 in April, respectively. The total numbers of birds recorded peaked in October (n=2,334) and November (n=2,992) and gradually decreased to less than 500 birds in May-June. During the July survey numbers increased again, but in August the lowest number during the twelve surveys was recorded.

Figure 6 shows the species composition, with the five most abundant species highlighted against the remaining species. Common Guillemot made up nearly 40% or more during most of the surveys. From October to April, Razorbill made up 6-29% of the individuals seen 'in transect'. In the summer months, up to 43% of the birds were Lesser Black-backed Gulls and during midwinter, about 20% were Black-legged Kittiwakes. The remaining species made up about 25% on average, with higher percentages (41-46%) in May, June and October, when either 'common seabirds', in particular alcids, were missing (May-June) or when many migrating songbirds, wildfowl and waders (May and October) were noted.
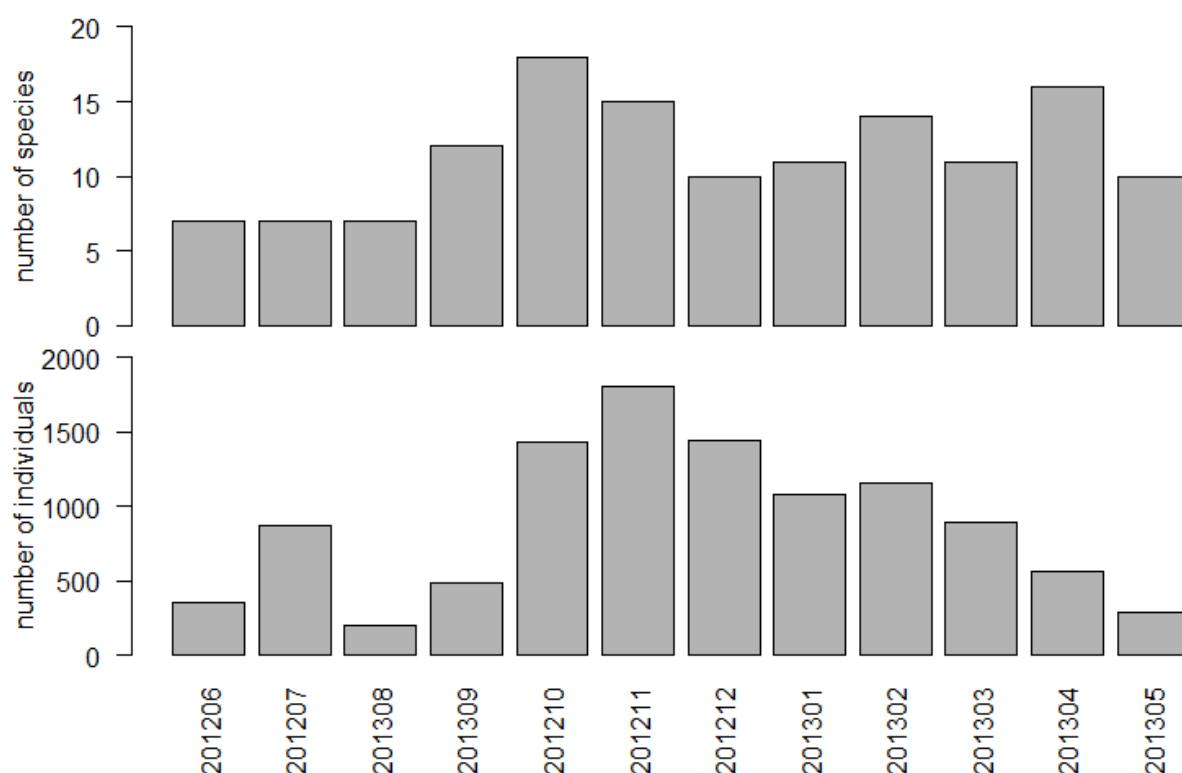

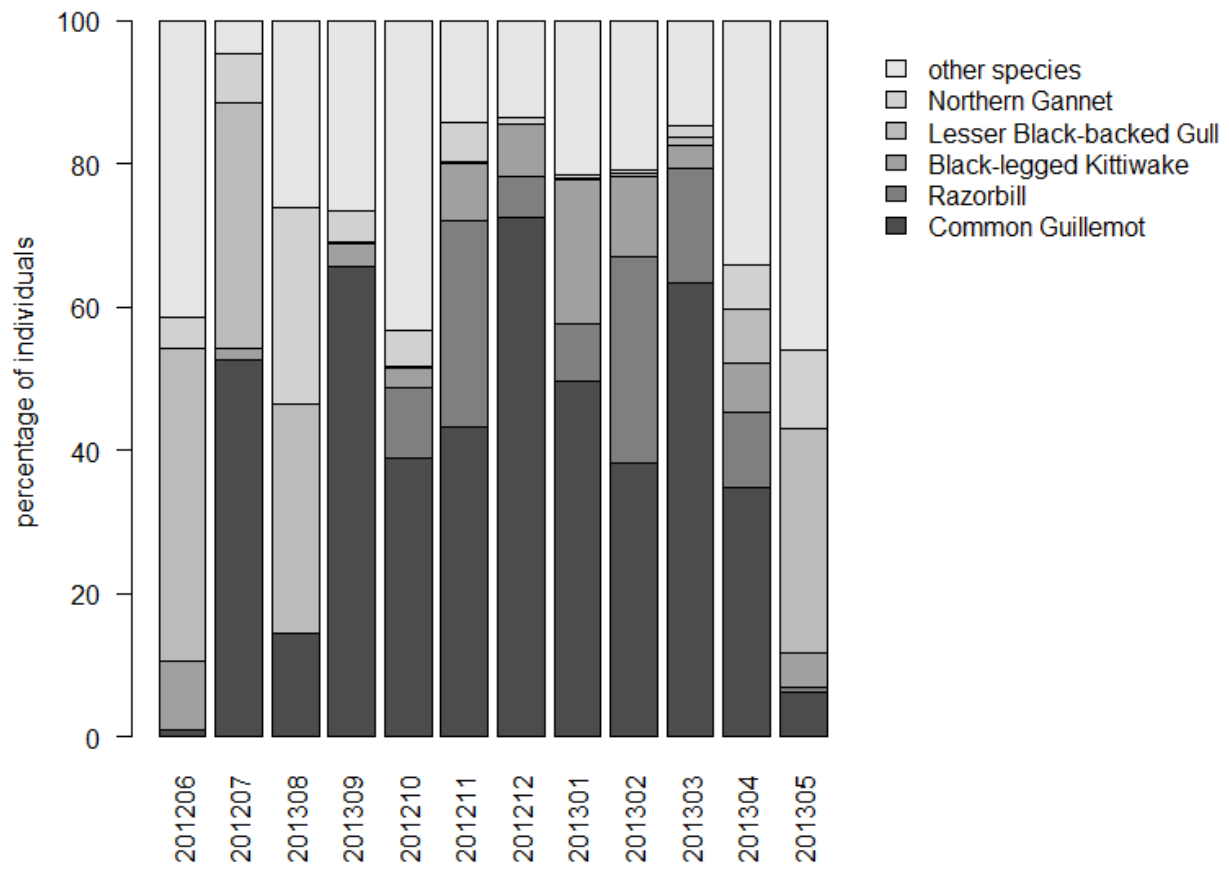Figure 6. Number of species (top) and number of individuals (bottom) recorded 'in transect', per survey.

Figure 7. Species composition, showing the percentage of the five most numerous species in the total counts (within transect) per survey. Note that during the majority of surveys, nearly 40% or more of the individual birds comprised Common Guillemots.

Species accounts: phenology and distribution

In this chapter species with at least 50 individuals recorded are discussed in more detail. For each species the spatial and seasonal pattern within the study area is described. The seasonal pattern is visualized in a bar plot showing mean monthly density for all birds within the counting strip, as well as in maps of all sightings (in and outside the counting strip combined) for each survey. Moreover, a figure is presented showing the density for all birds within the counting strip per survey per area to see how the study area is split into five areas. This should give a rough idea of any anomalies present in seabird densities at the wind farm locations compared to the adjacent areas. As the focus is on comparisons between sub-areas, the densities presented here are not corrected for incomplete detection or for birds not identified to species.

The phenology and distribution of seabirds in the study area is compared to the spatial and seasonal pattern in other parts of the North Sea. To this end, patterns in bird distribution and phenology found in the single surveys (one for each month of the year) are compared to other survey data, for the Southern and German Bights of the North Sea, and on a larger scale for the North Sea at large. Sources are given in the appropriate species accounts.

Red-throated and Black-throated Diver

Red-throated and Black-throated Diver can be difficult to identify to species level when they are seen under less than optimal observation conditions, especially in winter plumage and at large distances (e.g. flying away from the approaching survey vessel). Divers are easily disturbed and dive or fly off at great distances to avoid shipping, which makes them difficult birds to survey (Schwemmer et al. 2011). The same characteristic makes divers probably highly vulnerable to disturbance by wind turbines (Dierschke et al. 2006).

Both Red- and Black-throated Divers are mainly wintering birds, which migrate into and through the German Bight in autumn and spring, and most have left the area again by May (Mendel et al. 2008). Both diver species are mainly found in coastal waters, shallower than 20 m in the Southern Bight and shallower than 30 m in the German Bight (Skov et al. 1995, Stone et al. 1995). The vast majority of divers wintering in the eastern North Sea are Red-throated Divers (Camphuysen & Leopold 1994, Mendel et al. 2008), but there is a migration peak in Spring of Black-throated Divers moving through the area, best known from seawatching data (Camphuysen & van Dijk 1983; Platteeuw et al. 1994; www.trektellen.nl). Divers are largely absent from the North Sea in summer.

During the surveys 119 small divers (i.e. Red- or Black-throated Divers) were seen both within and outside the counting strip, of which 72.3% (n=119) could be identified to species level. The majority of these was Red-throated Diver (91.9%, n=86). Divers were seen between October and May. Their occurrence showed two distinct seasonal peaks. A smaller one that builds up from early autumn to December, followed by a dip in January and a higher peak in February-May, with a maximum in April. The latter may be related to a stop-over migration pattern with individuals migrating through the area in a relatively narrow time window. Overall, densities are still relatively low, also in April.

Most individuals were seen flying by (n=78, 65.5% of all divers recorded); 90% of these were recorded to fly lower than 25 m above sea level, below the rotor swept areas, possibly indicating that mostly local birds, and local movements were involved.

The distribution showed diffuse patterns without (consistently) higher density areas (Figure 8). The January dip in the study area is remarkable, but a reason for this could not be guessed.
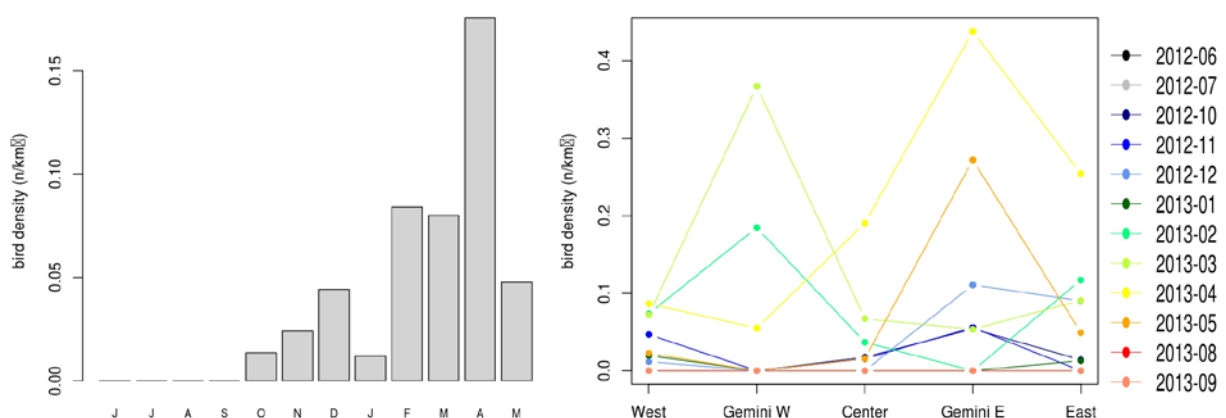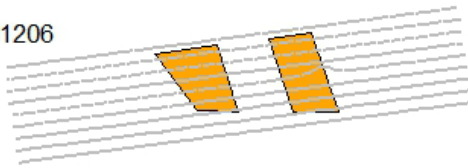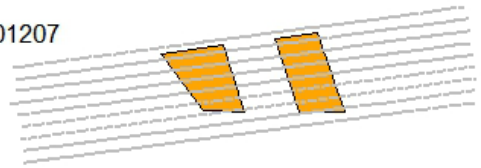

Figure 8. Divers (Red-throated and Black-throated Diver combined). Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right). The wind farms are 'Gemini W' and 'Gemini E'.
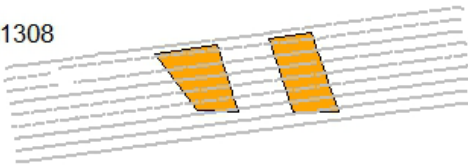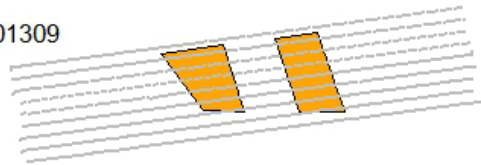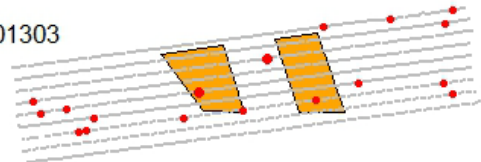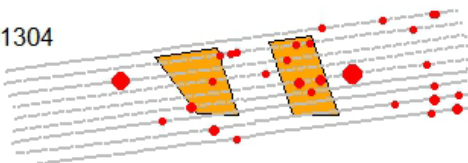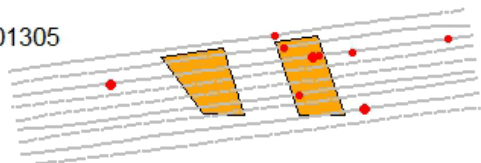
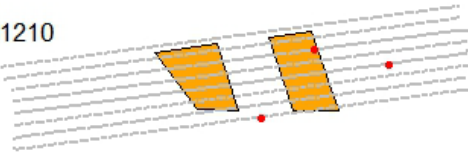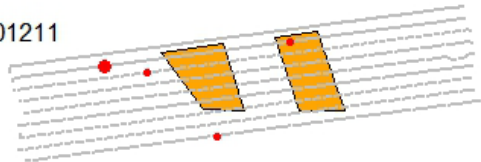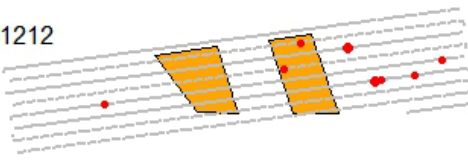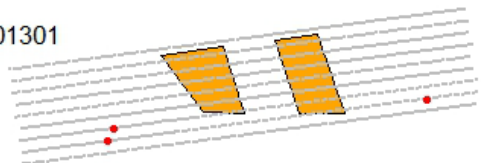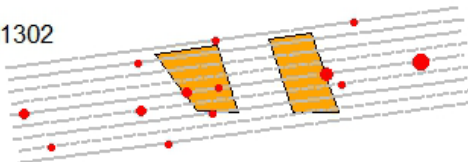Figure 9. Divers. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute. Red-throated (n=79), Black-throated (n=7) and unidentified Divers (n=33) are combined here.

Northern Fulmar

Northern Fulmars are by far the most numerous bird in the group of "tubenoses" in the general area. Their occurrence is mostly concentrated in the offshore areas of the German and Southern Bights of the North Sea, with very few nearshore observations (Baptist & Wolf 1993; Camphuysen & Leopold 1994; Stone et al. 1995; Berrevoets & Arts 2001; Mendel et al. 2008; van Bemmelen et al. 2011; Poot et al. 2011; Leopold et al. 2013a). Increasing numbers breed on Helgoland; the current population size has passed 100 breeding pairs (Mendel et al. 2008; Dierschke et al. 2011).

A total of 109 Northern Fulmars were seen within the counting strip. Fulmars were seen in all months except November with highest densities in September and January (Figure 9). Fulmars often showed no clear distribution patterns, but tended to be most numerous in the westernmost parts of the study area. This is conform a pattern found earlier in the German Bight, when Northern Fulmars were found to reach the highest densities in more westerly, and more saline waters (Mendel et al. 2008).

Figure 10. Northern Fulmar. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
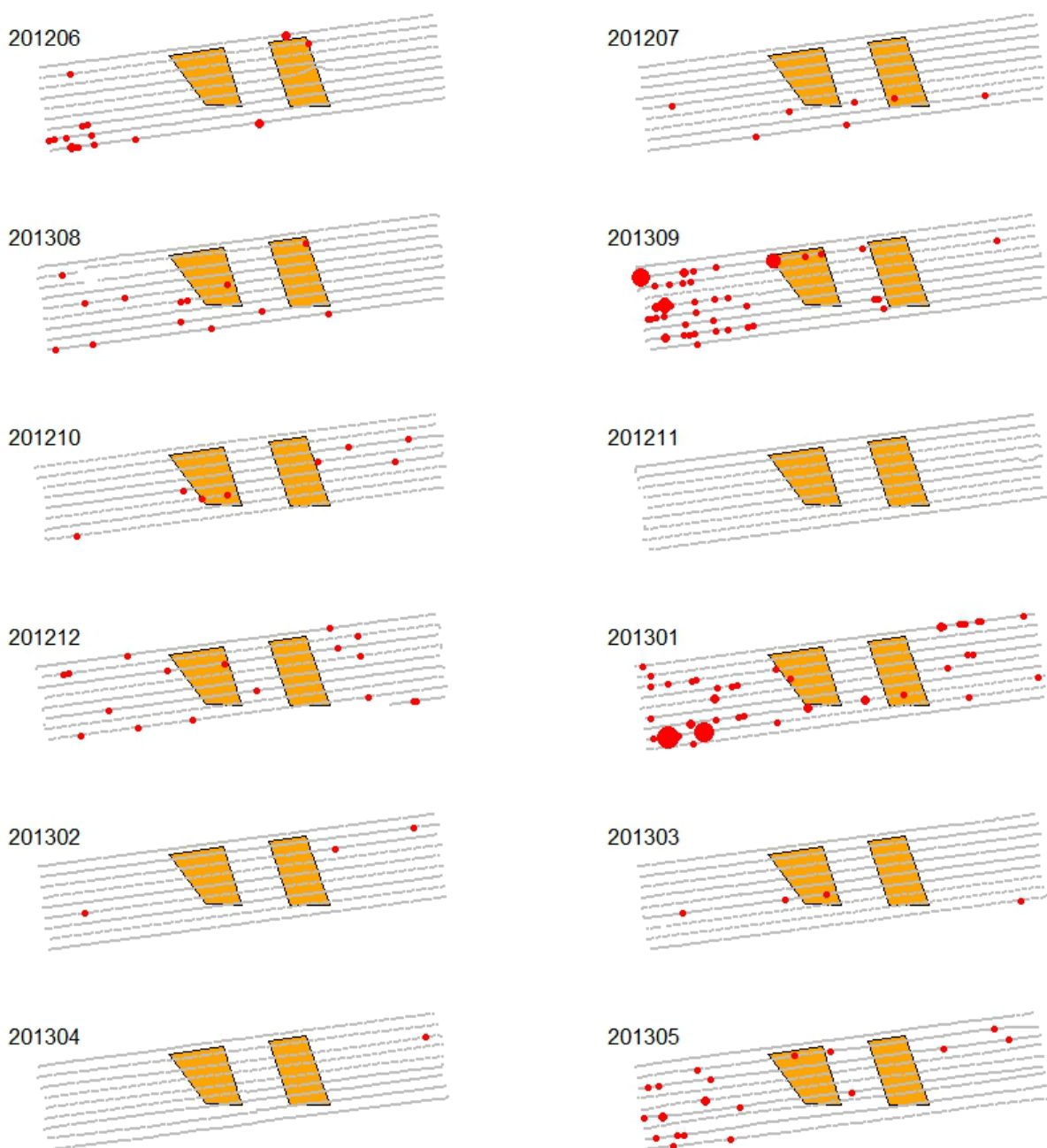
Figure 11. Northern Fulmar. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Northern Gannet

Northern Gannets are present year-round in the Southern and German Bights of the North Sea and occur here mostly widely dispersed and in low densities. An autumn peak in numbers is noticeable in large-scale survey data in the general area (Mendel et al. 2008; Arts 2012), as well is in small scale survey data and seawatching data (Camphuysen & van Dijk 1983; Leopold & Platteeuw 1987; Platteeuw et al. 1994; www.trektellen.nl; this study). Gannets often show a patchy distribution, which is often probably related to the distribution of preferred prey species, pelagic fish species such as mackerel, sprat and herring. Owing to their pelagic foraging behaviour (Garthe et al. 2014), Northern Gannets can travel long distances to obtain prey and may occur far offshore even during the breeding period (Hamer et al. 2007). Large breeding colonies are found in the UK, which holds almost 70% of the world's breeding population (BirdLife International 2004). In Germany, the only colony site is located on Helgoland, with a still growing population of >400 pairs (Dierschke et al. 2011; 489 pairs in 2012, Grave 2013). Outside the breeding season, Northern Gannets disperse offshore and tracking studies have shown that at least some individuals migrate to wintering grounds located in the Atlantic off West Africa (Garthe et al. 2012). The North Sea, however, is also used for over-wintering, both by juveniles, subadults and adult birds (Mendel et al. 2008).

The current study shows a year round presence in the Gemini area, with a slight summer peak in densities, followed by a higher autumn peak (October/November, Figure 11). Winter numbers are low, spring migration was noticeable, but far less marked than the autumn passage. Northern Gannets were found throughout the study area without clear hot spots, although birds tended to be slightly more numerous along the western halves of the transect lines (Figure 13).
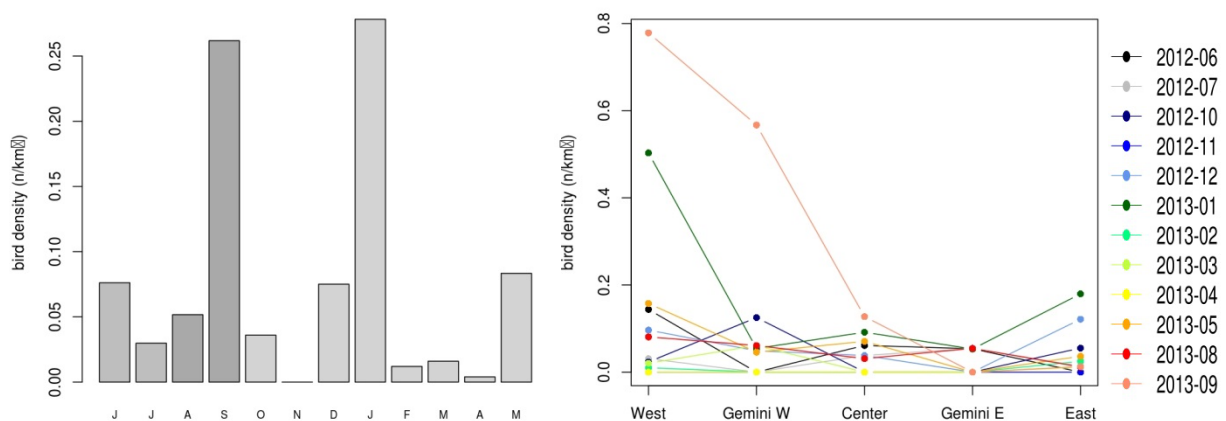

Figure 12. Northern Gannet. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.

The monthly age distribution (Figure 12) shows a predominance of adult birds in the study area from autumn to spring (November-May), while immatures (2-5 year olds) were most numerous from July-September. Only one juvenile (a bird that was born in that same year) was seen, in September.
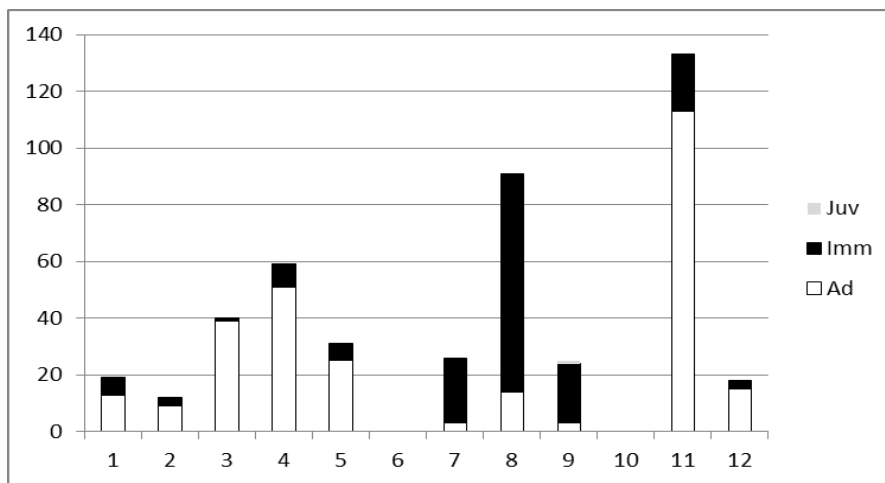
Figure 13. Northern Gannet. Age distribution per survey. Juveniles: birds in their first year (only one seen, in September, not visible. Immatures: birds that were probably between 2 and 5 years old, based on plumage characteristics. Adults: birds in full adult plumage, probably 6 years old, or older.

Figure 14. Northern Gannet. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Common Scoter

Common Scoters do not breed along the Dutch and German North Sea coasts and occur mainly during winter along the eastern North Sea shores. This species generally prefers shallow coastal waters during the non-breeding season and the spatial distribution within these sites is related to prey abundance and environmental and anthropogenic variables that may affect foraging efficiency. Indeed, high numbers of Common Scoters have been shown to coincide with sites that had a high abundance and biomass of various bivalve prey species in shallow coastal waters (Leopold et al. 1995; Aulert & Sylvand 1997; Degraer et al. 1999; Fox 2003; Kaiser et al. 2006). Only during migration, Common Scoters can be observed further offshore, crossing the North Sea, and usually in small flocks (Offringa 1993). Although scoter numbers in the eastern North Sea are usually highest during winter, in some areas Common Scoters can occur in considerable densities in late summer during moult. Important moulting areas have been identified along the German coastline, particularly off the North and East Frisian Islands (Deppe 2005; Garthe et al. 2007; Mendel et al. 2008). Moulting sites, however, like wintering sites are always situated in shallow waters, and never so far offshore as the Gemini site.

During the Gemini surveys, Common Scoters were seen in all months, always in low numbers, but with a considerable peak in October (Figure 14), indicating migration across the North Sea. Most (96%) Common Scoters were recorded as flying, crossing the North Sea. 96% of all scoters seen flying, were lower than 25 m above sea level; only 3 birds were seen between 25 and 50 m above sea level (asl). Distribution shows no clear pattern. With exception of the Gemini W area scoters were seen everywhere in the area (Figure 15).
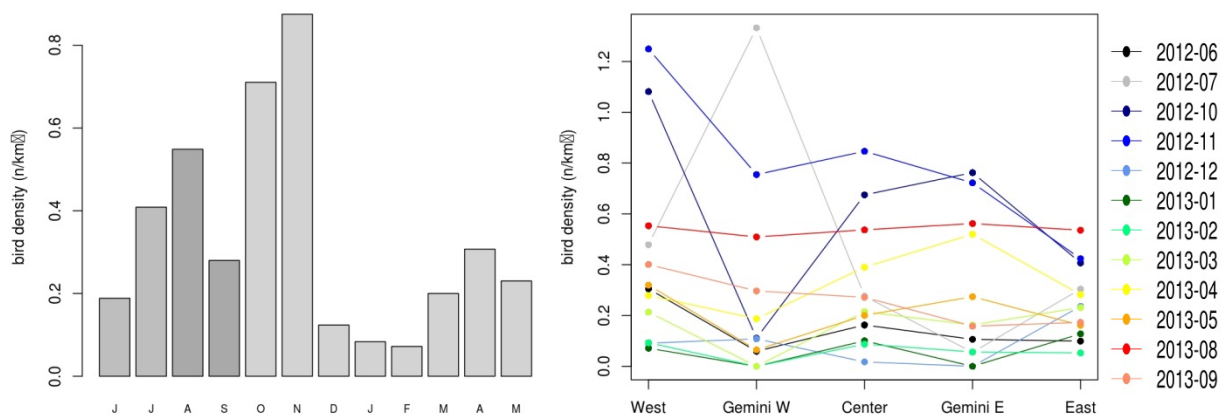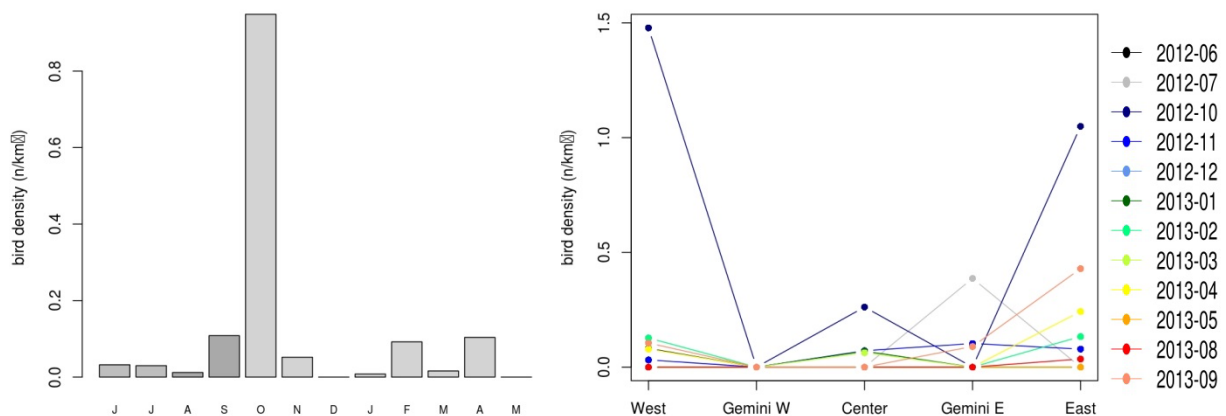

Figure 15. Common Scoter. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.

Figure 16. Common Scoter. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Little Gull

A major part of the European breeding population passes the North Sea during migration. It is estimated, that annually 52,000 individuals passes the island of Helgoland alone, which is more than half of the biogeographic population (Dierschke et al. 2011). Spring migration starts in the end of March, culminates in the last week of April and first week of May and stops immediately in mid May. Hotspots of occurrence in the German part of the North Sea are waters riddled with tidal fronts, south and east of Helgoland and in the Eider estuary, Schleswig-Holstein, i.e. away from the Gemini site (Schwemmer & Garthe 2006; Mendel et al. 2008). Autumn migration takes place between end of September and beginning of November and is more restricted to coastal areas. An important area in the German North Sea at that time is the outer Elbe estuary (Mendel et al. 2008). Small numbers of Little Gull winter in the North Sea far off the coast, while the main part of the European population has their wintering grounds further south. Also in the Dutch parts of the North Sea offshore winter observations were restricted to November and February (Van Bemmelen et al. 2011; Poot et al. 2011).

Little Gulls were seen in all surveys from September through April, with the usual autumn and migration peaks clearly marked (Figure 16). Most birds were just seen flying by (76%), but 24% were seen foraging briefly (by dipping or shallow plunging from flight) or at least looking for feeding possibilities (looking down into the water from flight). Important feeding concentrations were not observed although the birds tended to be loosely concentrated at times: e.g., in the west of the study area (February) or in the east (September): Figure 17. 95% of all Little Gulls in flight were seen passing by at altitudes lower than 10 m above sea level (the remainder at 10-25 m).

Figure 17. Little Gull. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
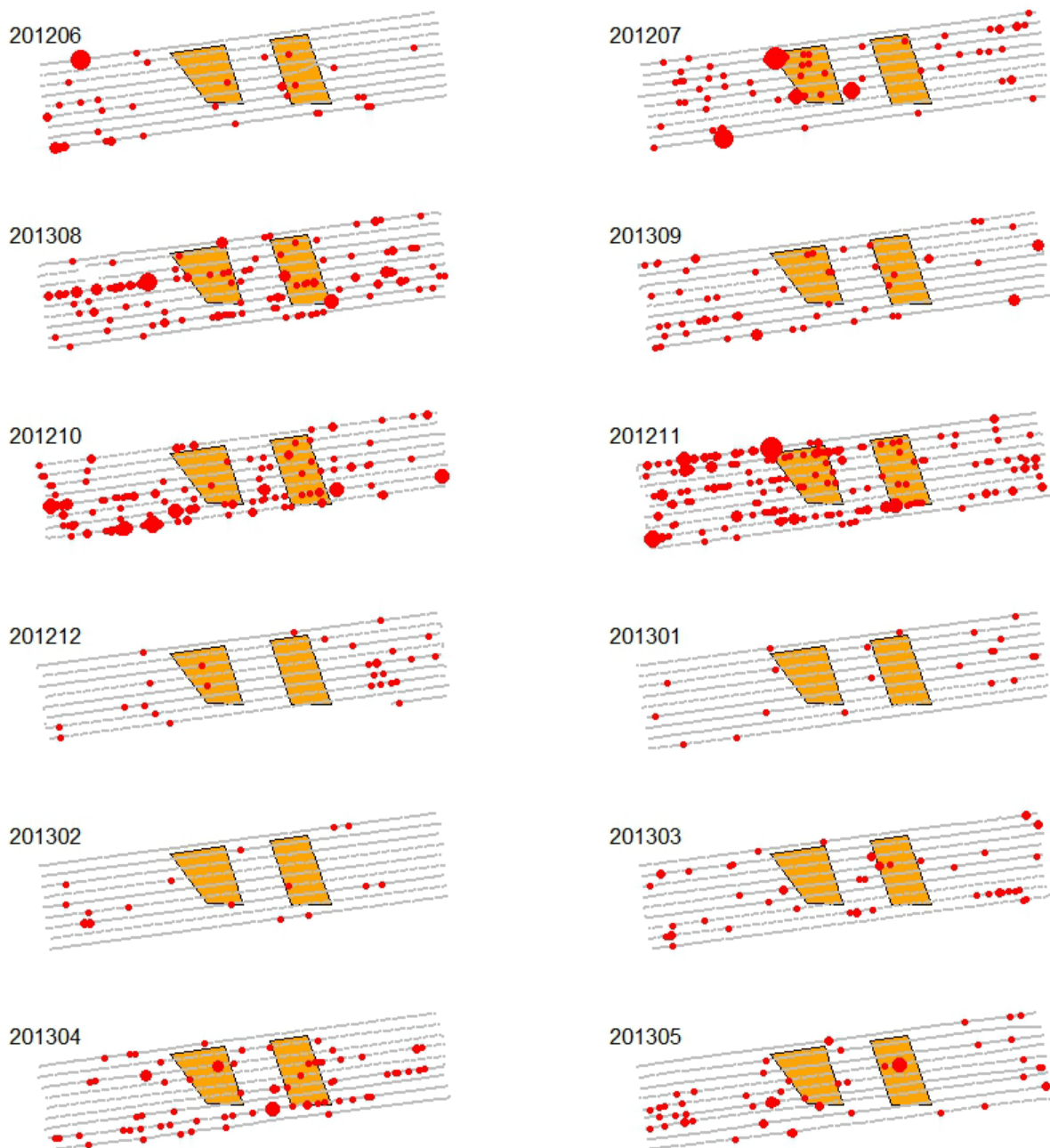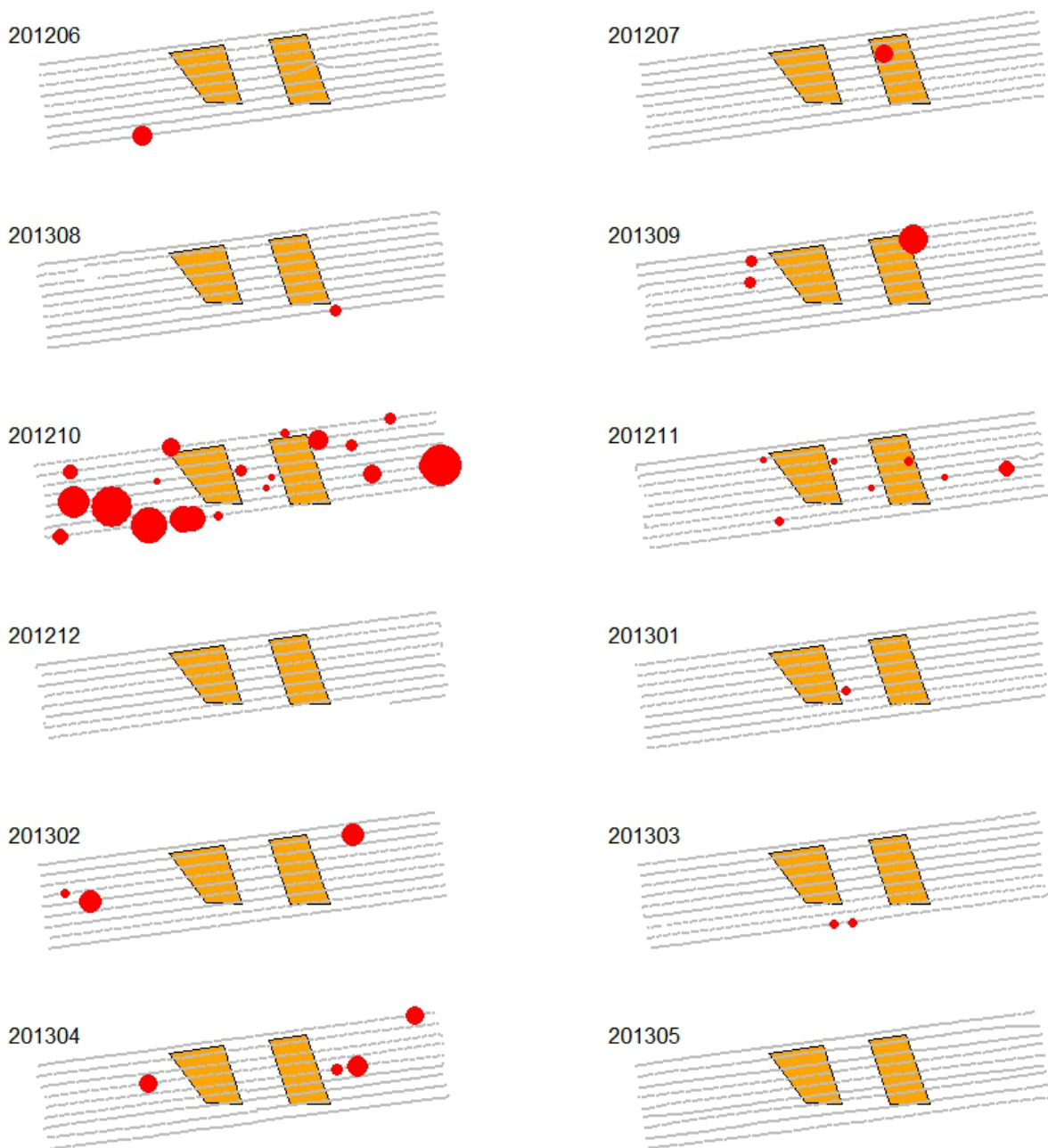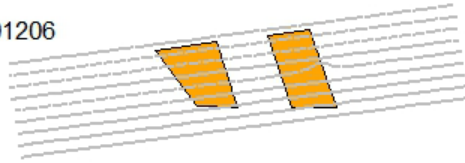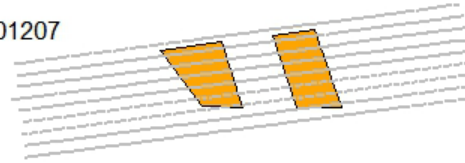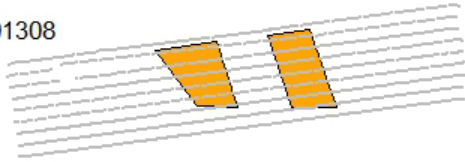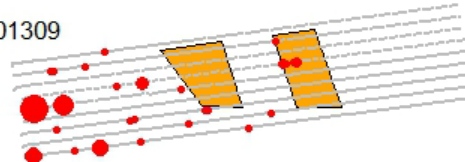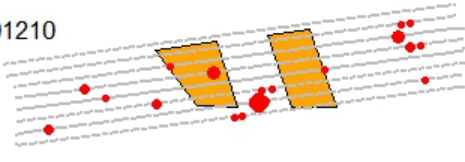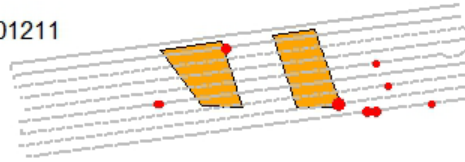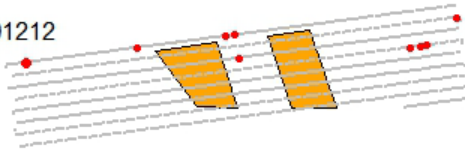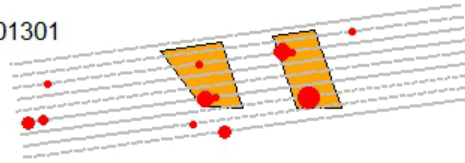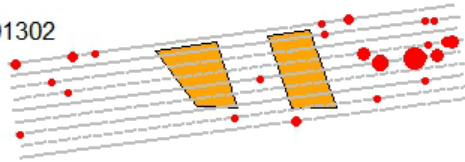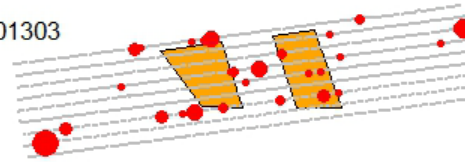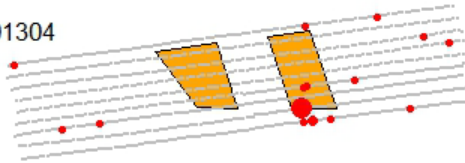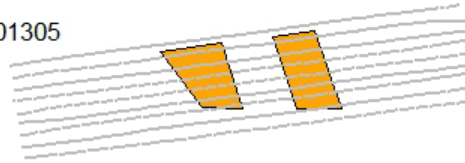
Figure 18. Little Gull. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Common Gull

The Common Gull is a common breeding bird and year-round visitor in the area. Tens of thousands of birds spend the winter in the North Sea, while the summer population in the German part is estimated a number of 4,200 individuals (Garthe et al. 2007) and 55,000 in the Dutch part (Camphuysen & Leopold 1994). Common Gulls are both present in coastal and in offshore areas, but densities in the latter ones are in all seasons much lower (Skov et al. 1995; Mendel et al. 2008).

Breeding birds do not venture far offshore and summer densities in the Gemini area were very low. A large winter influx of more easterly and northerly breeding birds boosts numbers in winter. However, most Common Gulls prefer more nearshore waters and peak densities during the winter (from October to March) densities in the Gemini area were only about 0.3 birds per km^2 (Figure 18). Birds occurred throughout the study area, without any clear patterns (Figure 19).
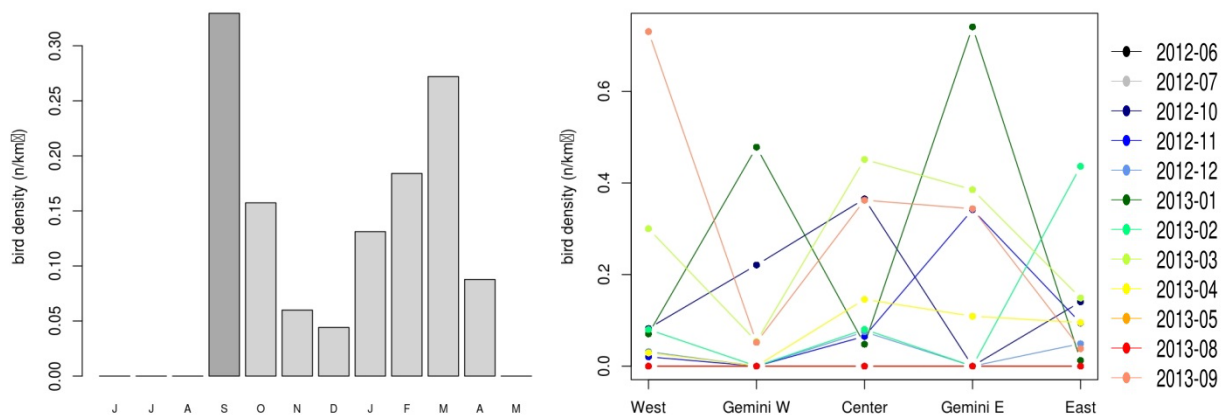

Figure 19. Common Gull. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.

Figure 20. Common Gull. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Lesser Black-backed Gull

The Lesser Black-backed Gull is a common seabird in the eastern North Sea, with tens of thousands of pairs breeding along the Dutch, Danish and German coastline. From early March the birds return to the North Sea, from their wintering sites in southern Europe and western Africa. Of all the breeding gulls in the area, the Lesser Black-backed Gull is the most 'offshore species'; the species easily travels dozens of kilometres offshore on feeding trips from its colonies (Garthe et al. 2004; Ens 2007; Exo et al. 2008; Camphuysen 2013). Hence, Lesser Black-backed Gulls occur during the breeding season both in coastal and in offshore areas and the Gemini site should just be in reach of breeders from the Frisian Islands, provided that feeding would be attractive here. However, the Gemini area proved to be a rather uniform part of the North Sea, without clear frontal activity or other features attracting many birds, and also the numbers of active fishing vessels (providing alternative food in the form of discards and offal; Walter et al. 1995; Garthe et al. 1996; Mendel et al. 2010) were low in the area.

Lesser Black-backed Gulls were most numerous during the summer surveys, from April through August (Figure 20), reaching the highest densities, of over 3 birds per km^2, in July. Even though 95% of all Lesser Black-backed Gulls seen were aged as "adults", at that time, which coincides with the end of the breeding season, most birds in the area appeared to be loafing, non-breeding birds that had no clear connection to any colony as we never observed early morning arrival or evening departures towards land. Such birds are likely either near-adult prospectors, or adults that skipped breeding during this particular year, or unsuccessful breeders that lost their clutch/brood early. We point out that these assumptions are speculative and could not be supported by data obtained from transect counts alone. Without marked, GPS-logged birds it is not possible to be certain whether breeding birds from adjacent colonies (e.g. Schiermonnikoog) do reach the Gemini area, but from our observations it would appear that breeding birds did not reach the Gemini area in any significant numbers. Other (tracking) techniques will be necessary to study this problem. Birds occurred throughout the study area (Figure 21), without any clear patterns. High concentrations of Lesser Black-backed gulls are related to fishing vessels.


Figure 21. Lesser Black-backed Gull. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
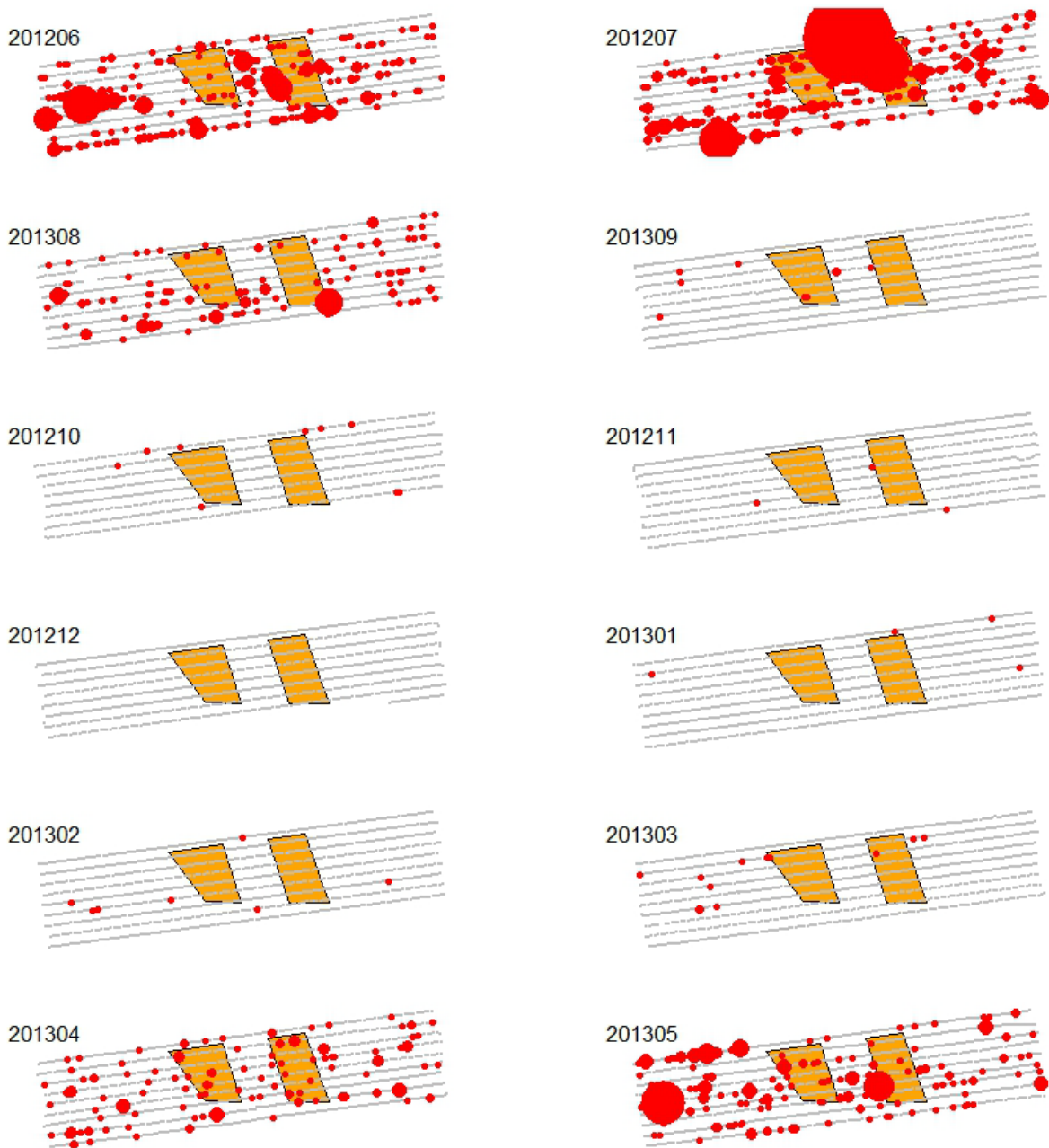
Figure 22. Lesser Black-backed Gull. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Herring Gull

Like the Lesser Black-backed Gull, the Herring Gull is a common breeding species along the entire North Sea coast. Colonies with many thousands of pairs are found on several Frisian Islands, on Helgoland and at the mainland coast. Compared to Lesser Black-backed Gulls, Herring Gulls are much more restricted to coastal waters in the breeding season and shortly thereafter when they undergo their post-breeding moult (Camphuysen & Leopold 1994; Mendel et al. 2008). From autumn onwards, birds disperse, however, into offshore waters, their numbers strengthened by birds from more northern countries. Winter birds reside and forage throughout the entire North Sea (Carter et al. 1993; Mendel et al. 2008). Unlike Lesser Black-backed Gull almost the entire North Sea breeding population of Herring Gull winters within its breeding range. Generally the densities in German and Dutch offshore waters are highly fluctuating and birds flock in large numbers on (human) fishing grounds (Garthe et al. 1996; Camphuysen 2013). Peak numbers of Herring Gull are reached both in December/January and in March/April, when migrants of breeding sites further north and mix with local birds.

In the Gemini area, Herring Gulls were present from September through March and largely absent in the other months (Figure 22), signifying that breeding birds do not reach the area. Peak-densities were found in December, at around 0.35 birds per km^2. Only 15 birds were noted from April through July, 12 of these were in adult plumage.

The Herring Gulls occurred throughout the Gemini area, without clear pattern (Figure 23).
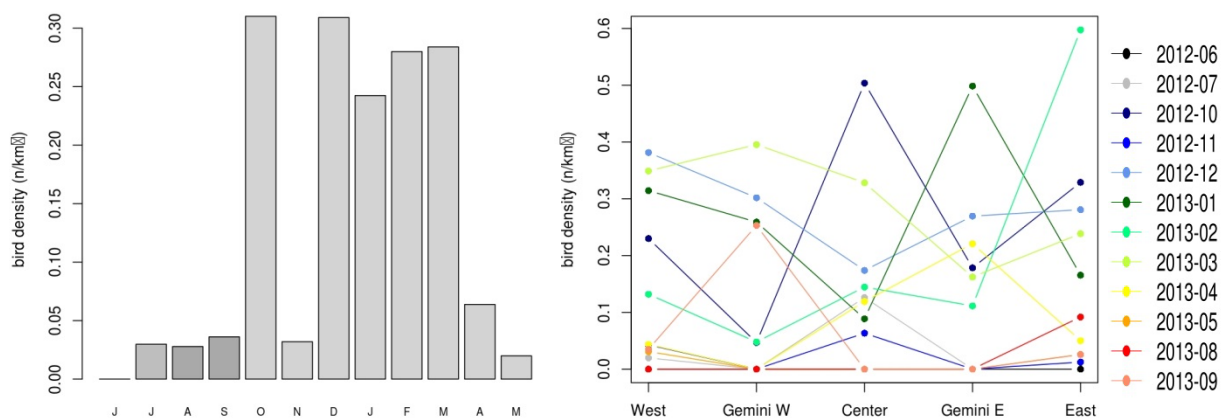

Figure 23. Herring Gull. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
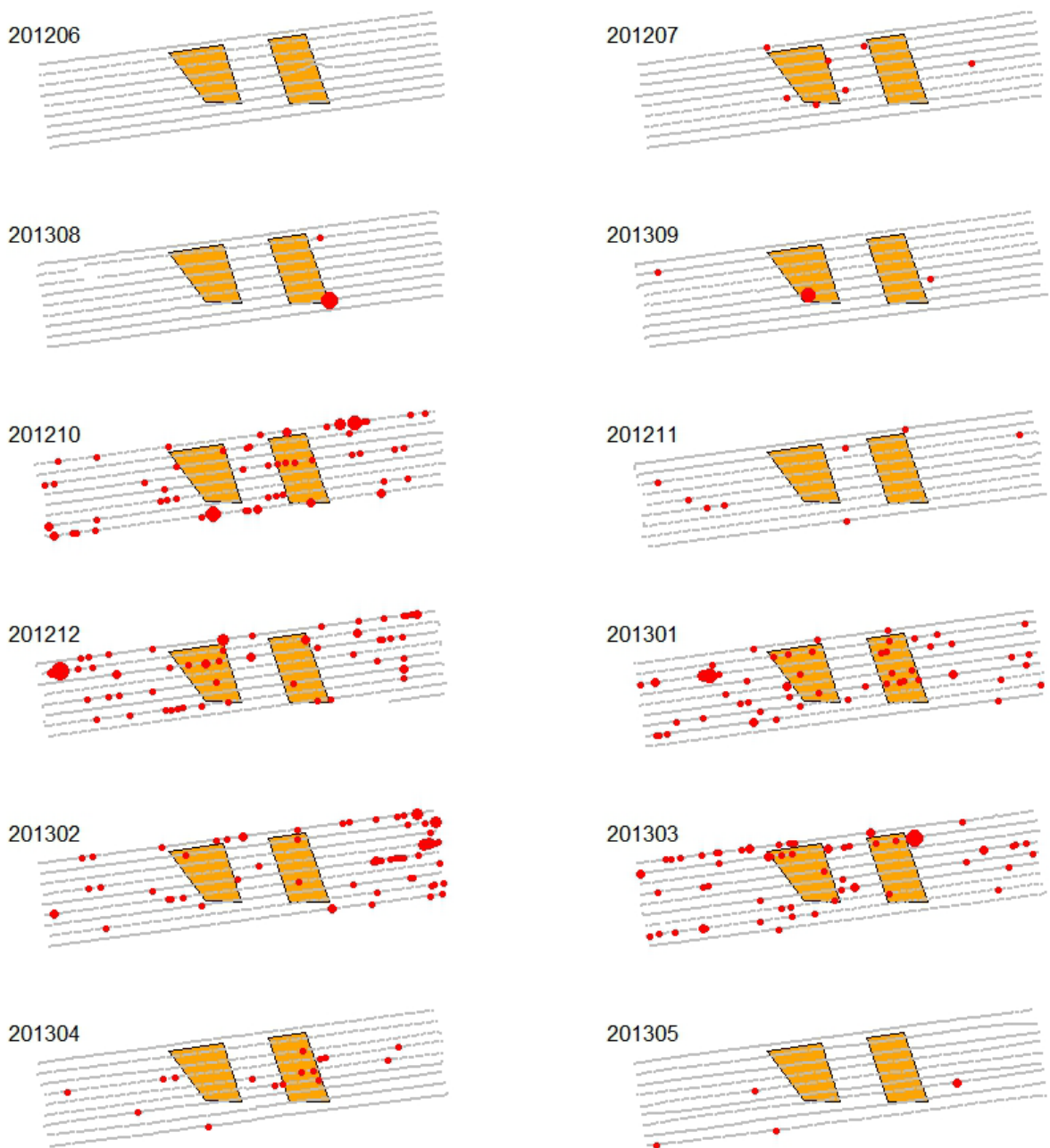
Figure 24. Herring Gull. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Great Black-backed Gull

Great Black-backed Gulls are rare breeding birds at the North Sea coast, but reach offshore densities in winter similar to those of Herring Gulls (Figure 23). The species ranges over the southern North Sea with no clear spatial pattern (Camphuysen & Leopold 1994). Mendel et al. (2008) mention a hot spot around Helgoland in summer concerning mainly immature individuals. Like other gull-species, Great Black-backed Gulls feed around fishing vessels but their numbers were often lower than those of other species in the associated flocks (Camphuysen et al. 1993). Dierschke et al. (2011) assume, that declining numbers of Great Black-backed Gull on Helgoland correlate with decreasing commercial fishing activity in the vicinity of the island in recent years.

During the Gemini surveys, Great Black-backed Gulls were seen in all months but June, but mostly from November through January, with densities reaching nearly 1 bird per 2 km^2 (Figure 24). Like other gulls, Great Black-backed Gulls occurred throughout the study area, without clear patterns (Figure 25).
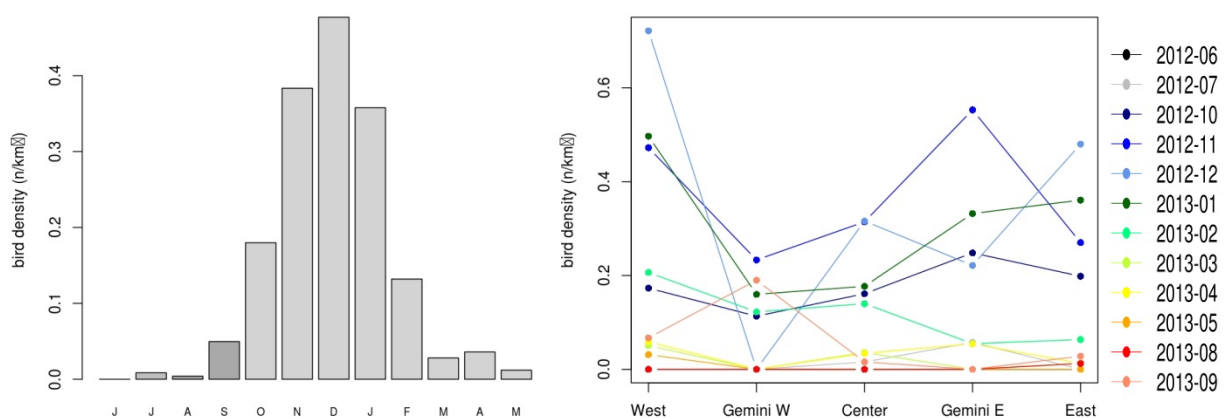
Figure 25. Great Black-legged Gull. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
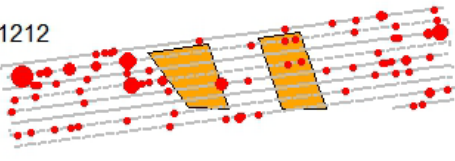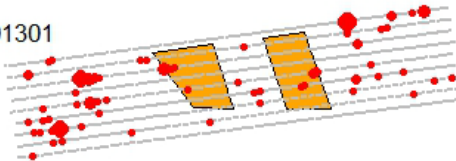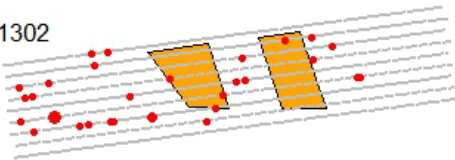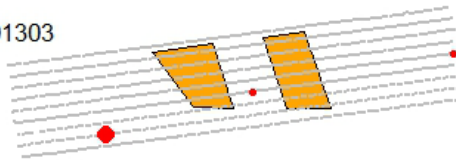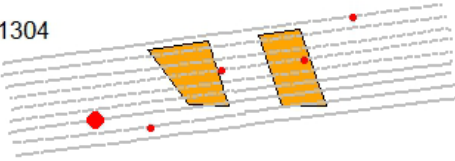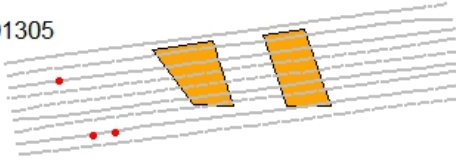
Figure 26. Great Black-backed Gull. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Black-legged Kittiwake

The Black-legged Kittiwake is present year-round in the eastern North Sea and breeds there only on Helgoland with about 5,000 to 7,000 pairs and with about several dozens of pairs on offshore production platforms in the Dutch part of the North Sea (Camphuysen & Leopold 2007; Geelhoed et al. 2011). The North Sea breeding population has been decreasing in recent years. In the German Bight there is a focus on the vicinity of Helgoland in the breeding season, and in Dutch waters Kittiwakes are always concentrated north of the Frisian Front. Dierschke et al. (2004) showed that foraging flights from breeding birds on Helgoland reached distances up to 35 km, whereas Camphuysen (2005) found distances up to 80 km for the much larger breeding colonies at the coast of Scotland. From any source, the Gemini site is out of reach for breeding birds. Unlike many other gull species of the region Black-legged Kittiwakes avoid near shore waters in all seasons. In autumn and winter the species is dispersed evenly over the entire North Sea (Carter et al. 1993).

During the Gemini surveys, Kittiwakes were mostly seen from November through February, i.e., in the non-breeding season, with densities of more than 1 bird per km^2 (Figure 26). However, also during the breeding season, some Kittiwakes visited the area. In summer they were most abundant in June and it was noted that: '*most birds were seen centrally and in the east of the study area, possibly indicating a link to the distant colony on Helgoland. 90 out of 91 birds [seen during that survey] were adult or near-adult, only one young of last year was seen*' (Leopold et al. 2013b). A similar pattern was found in July, with most birds seen in the eastern part of the study area, i.e., closest to Helgoland (Figure 27). Breeding birds from the Helgoland colony may thus reach the Gemini area, but without GPS-logged birds it is hard to determine if this is truly the case.
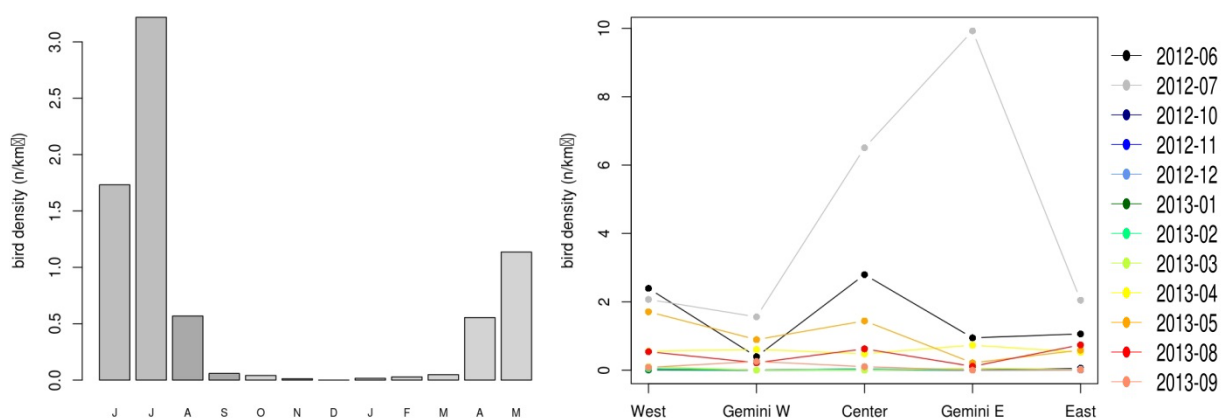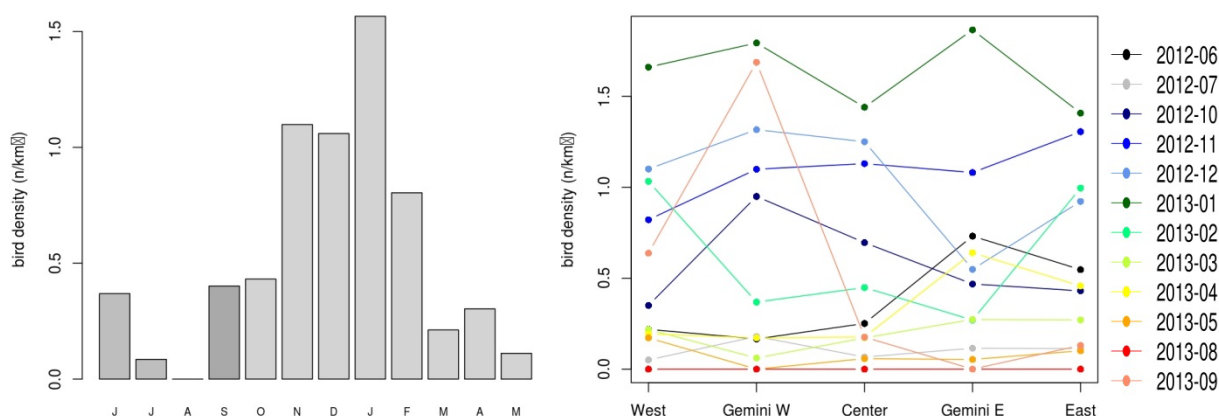

Figure 27. Black-legged Kittiwake. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
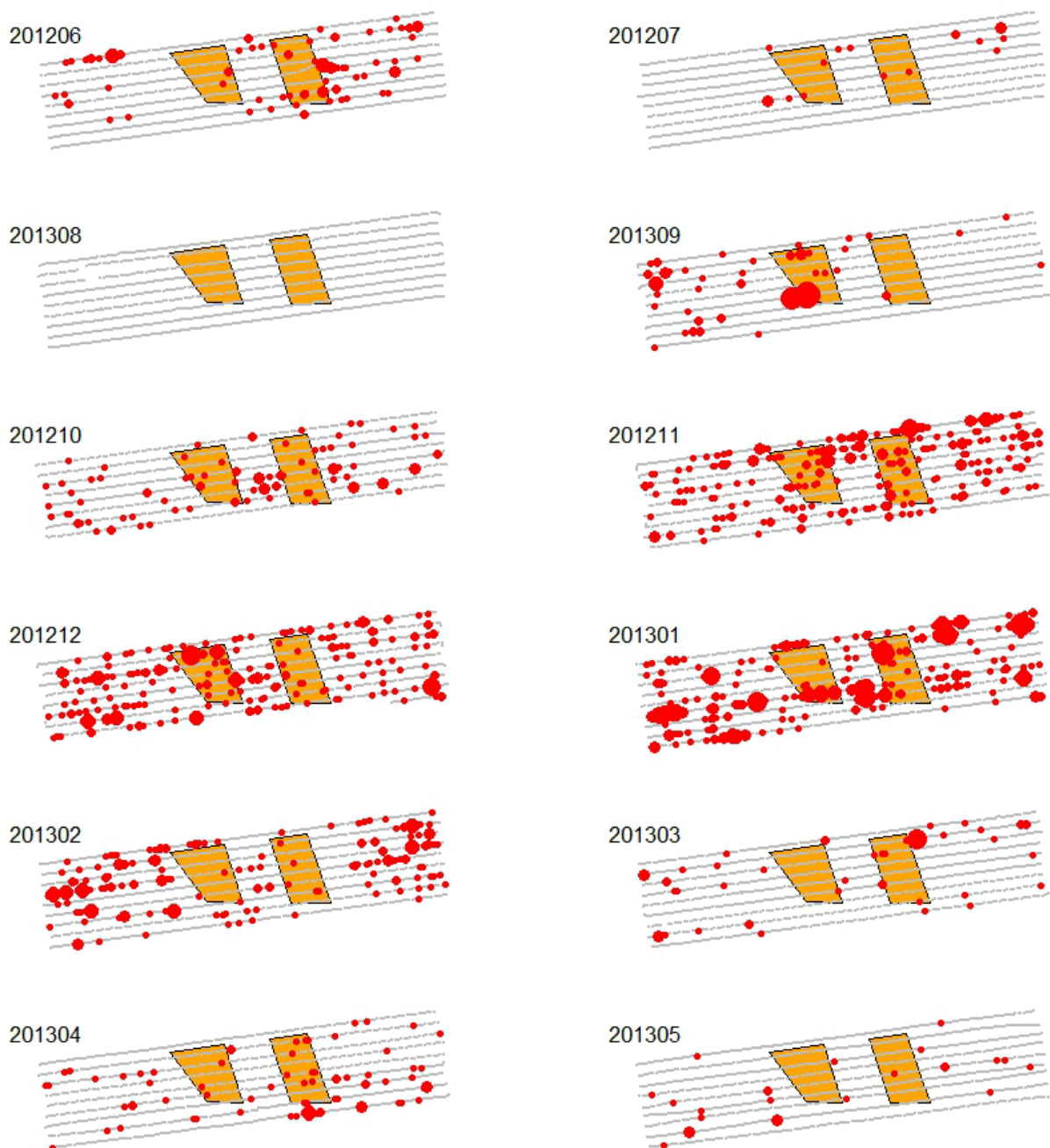
Figure 28. Black-legged Kittiwake. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Arctic Tern

The Arctic Tern has a circumpolar breeding distribution in the Holarctic region with the North Sea as its southern limit of breeding. In the southeastern North Sea, Arctic Terns typically arrive on the breeding grounds in May and depart again in August, which is the shortest duration of all tern species breeding along the North Sea coast (Mendel et al. 2008). During the breeding period, the spatial distribution of Arctic Terns is mainly restricted to coastal areas and the Wadden Sea, although some non-breeders and/or failed breeders may occur more offshore (Camphuysen & Winter 1996). This species is well known for its extensive long-distance migration (Egevang et al. 2010; Fijn et al. 2013), and during both autumn and especially spring migration numbers of migrants can be substantial in offshore waters. During winter, Arctic Terns live away from the North Sea and winter in the southern hemisphere.

The presence of Arctic Terns in the Gemini area reflects the migration of the species, with birds flying through the area in spring and autumn and the species being absent both in the breeding and wintering seasons (Figure 28). The absence of the species in the breeding season shows that the Gemini site is out of reach of breeding birds. As the birds only migrate through, they can turn up anywhere in the area (Figure 29). Most migrating smaller terns (Arctic and Common Terns combined) were noted flying at low altitudes: 82% below 10 m above sea level; 18% at 10-25 m asl.
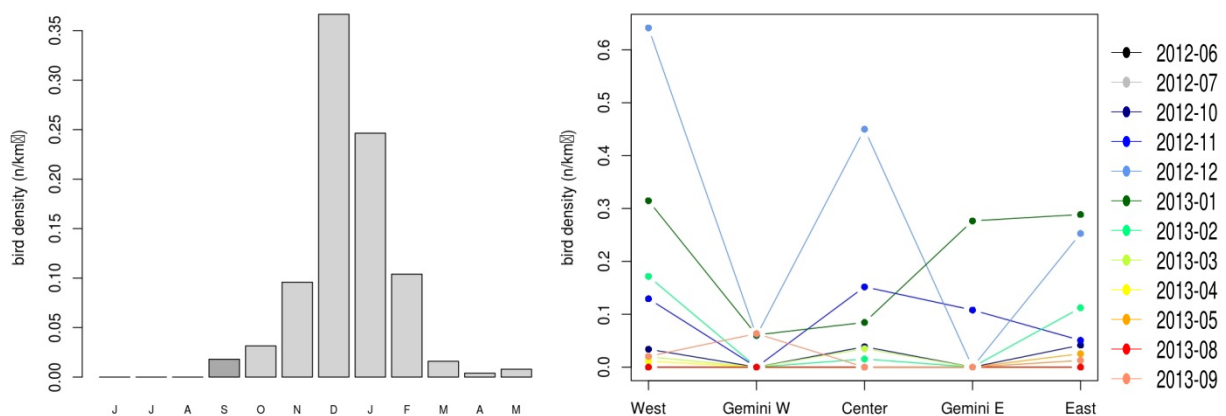

Figure 29. Arctic Tern. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.
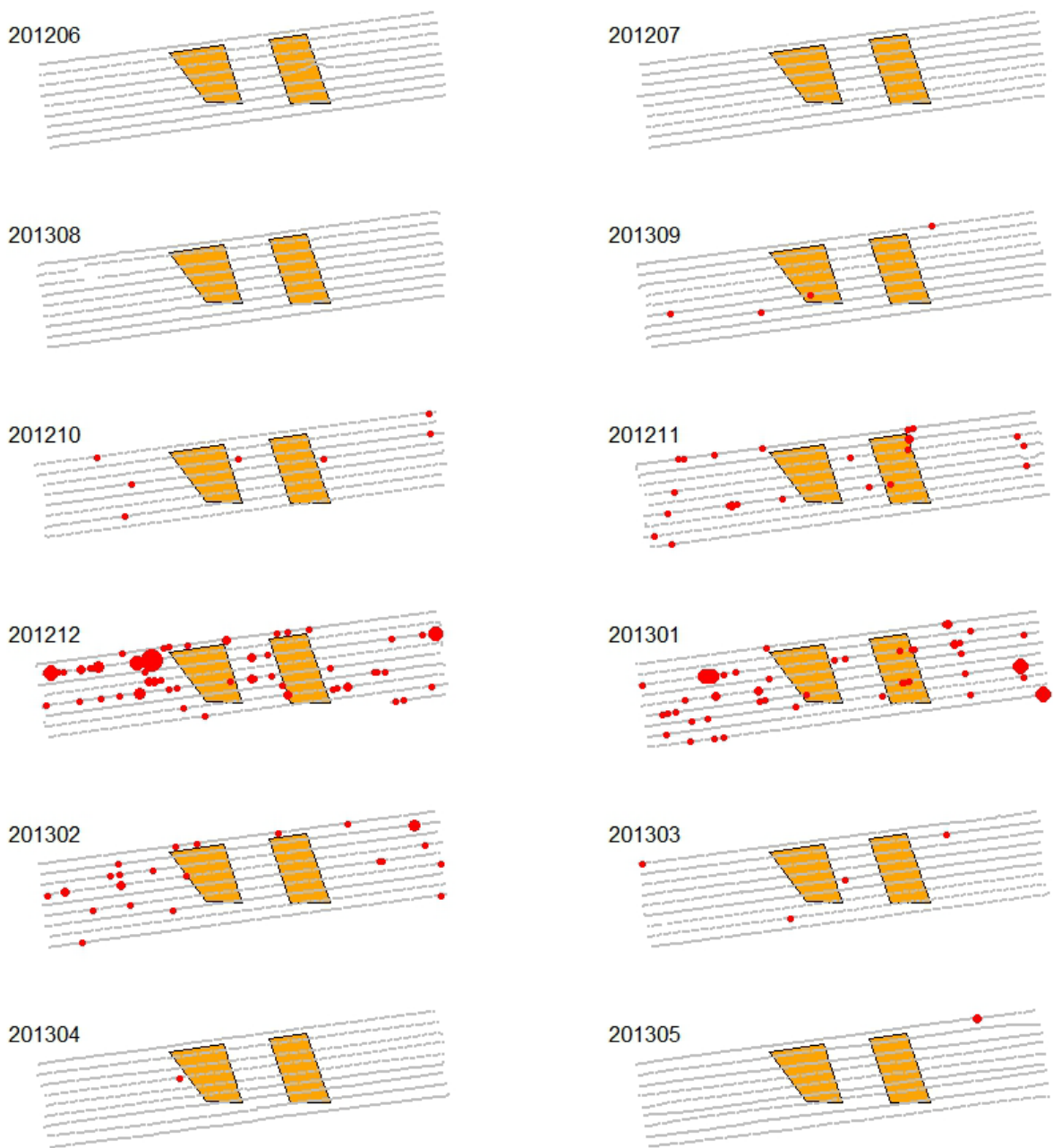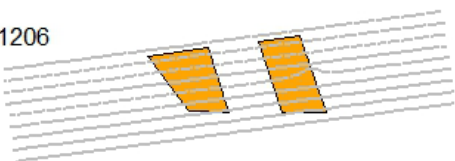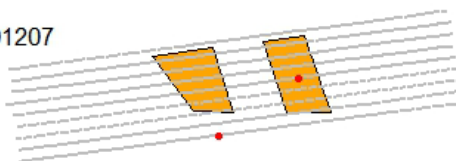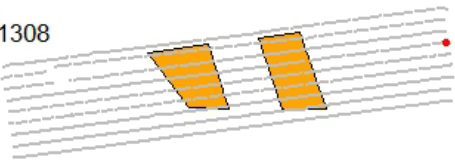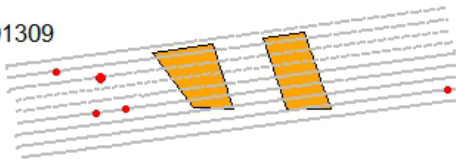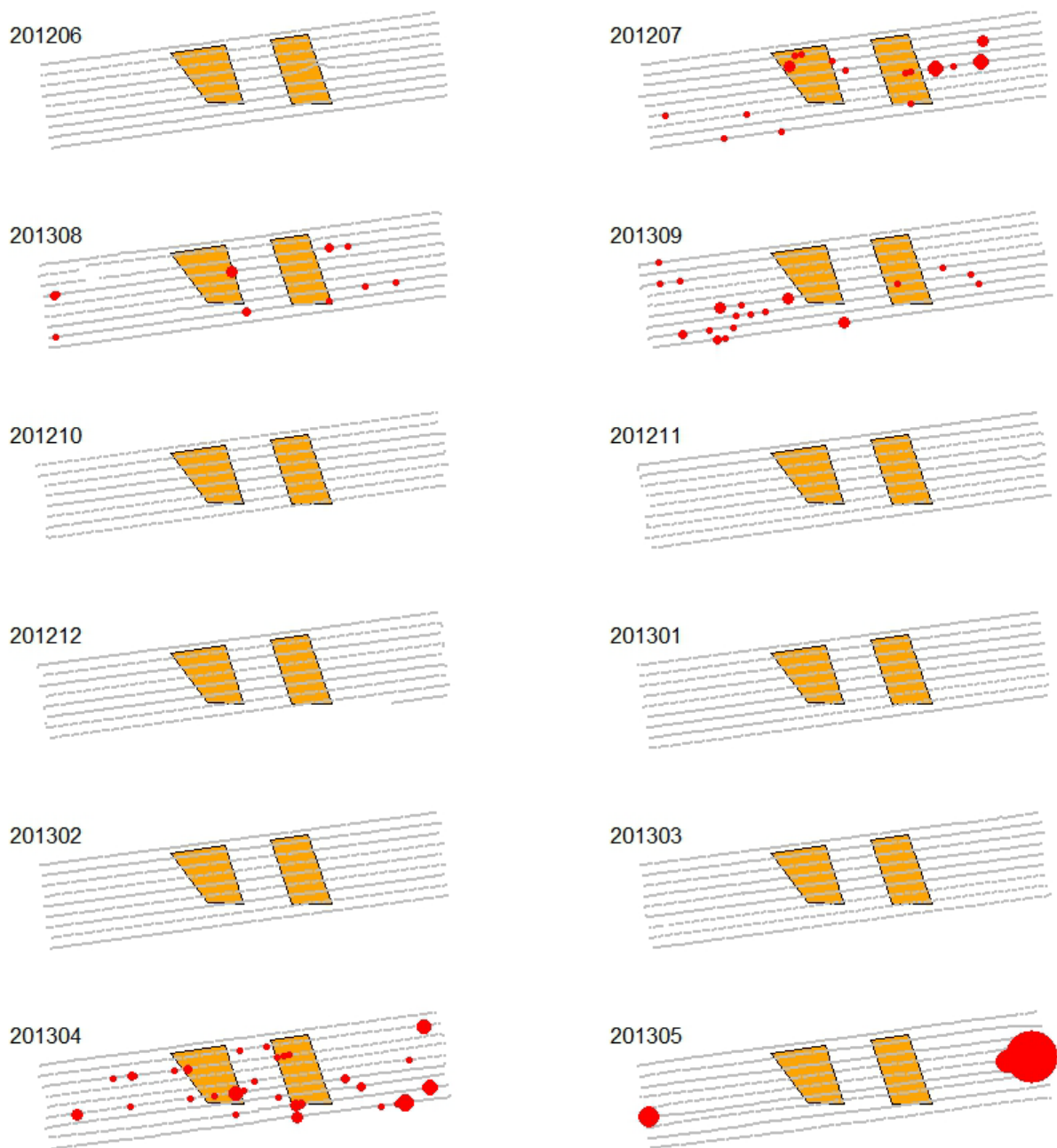
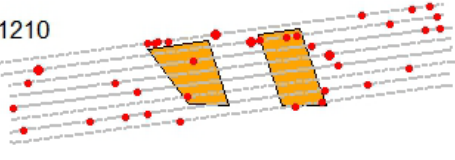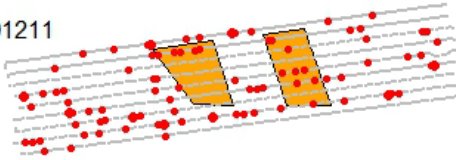Figure 30. Arctic Tern. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Common Guillemot

The Common Guillemot is the most abundant species of the Alcidae family in the North Sea and can be observed year-round in Dutch and German offshore waters. In summer, these birds are confined to the waters north of the Frisian Front and around the only breeding colony in the area, at the island of Helgoland where 2,000 to 2,600 breeding pairs nest (Dierschke et al. 2011). During the breeding period, abundance estimates for areas > 30 km away from Helgoland are rather low (Mendel et al. 2008), which puts the Gemini area largely out of reach of the Helgoland birds. Chicks leave the colony before being fully grown and able to swim, accompanied by one parent, usually the male, away from the colony to the open sea. Most likely, Helgoland birds swim away with the prevailing currents, to the north, i.e., away from the Gemini site. During this stage of post-fledging dispersal, Guillemots move rapidly away from the colony and may cover distances of several hundreds of kilometres (Camphuysen 2002). Given the prevailing winds and currents, it is likely that the majority of Guillemots observed in the central and south-eastern part of the North Sea originates from the UK east coast. Although the spatial distribution of Guillemots seems to depend on several key factors such as prey availability, predator presence and (tidal) currents (Camphuysen 2002), Guillemots seem to prefer areas with water depths between 40-50 m (Mendel *et al.* 2008) in autumn. In winter, total abundance of Guillemots is generally high in German and Dutch waters and the species is widespread over the North Sea including the Southern and German Bights and the coastal areas along the Frisian islands (Camphuysen & Leopold 1994; Mendel et al. 2008).

Common Guillemots were found year-round in medium to high densities during the Gemini surveys, except during summer months (May, June, August), when breeding birds remain in the surroundings of the colonies. Observations of remarkably high densities in July (Figure 30, left panel) may be related to a wave of post-breeding dispersal passing through the area from the UK. This peak occurrence is known from waters further west, i.e. the Frisian Front (van Bemmelen et al. 2013; van Bemmelen & Leopold 2014), but the Gemini area has received relatively little survey effort in the past. This peak of Guillemots in July was marked by a rather westerly distribution (possibly signifying their origin) and a high number of father-chick pairs (72) noted, among a grand total of 562 birds seen during that survey (Leopold et al. 2013b). After a remarkable dip in August, densities sharply increased again from September onwards reaching highest values (>5 Ind/km²) in December, indicating that the area supports a wintering population. From January through March densities remained rather stable before Guillemots left the area in April, to return to the breeding colonies.

The spatial distribution (Figure 31) shows no significant pattern (no remarkable 'hot spots') except for a notable West-East gradient in December 2012 (but note that opposite patterns were noticeable in some other months). It appears from these patterns, that several waves of Guillemots move through the area successively. Consequently, both future wind farm sites, Gemini W and Gemini E, are part of the habitat commonly used by Common Guillemots during the annual cycle (see also detailed analysis). This should be monitored in future surveys in the Gemini wind farms, with regard to potential habitat loss, because recent studies (Leopold et al. 2013a; Mendel et al. 2013) suggest that the Common Guillemots may be more vulnerable to offshore wind farms than previously postulated (Garthe & Hüppop 2004; Furness et al. 2013). The Gemini site has thus good potential to learn more about the impact on vulnerable seabirds such as the Common Guillemot, in terms of habitat loss.
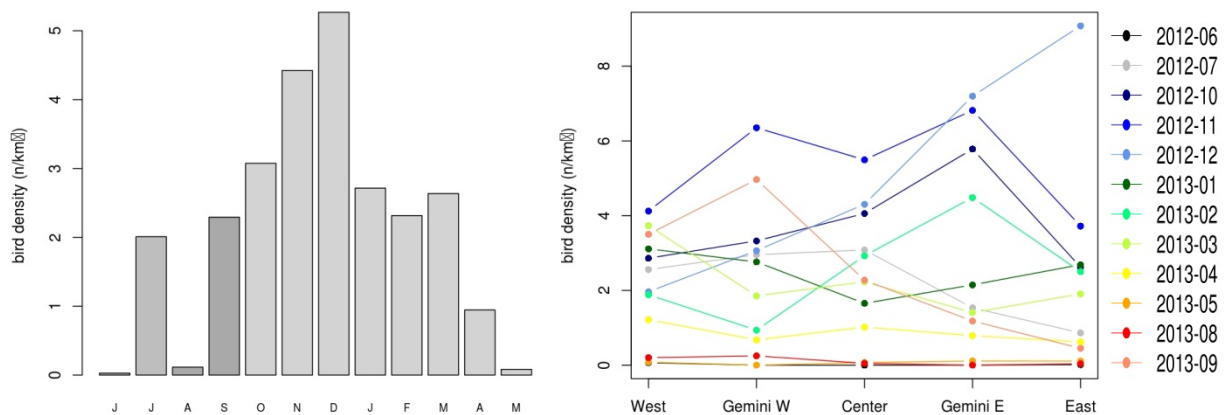
Figure 31. Common Guillemot. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'. Different shades of grey represent different survey years.

Comparably surveys have been conducted by IBL in the future BARD offshore wind farm area, north of the shipping lane that flanks the Gemini study area (Figure 2b). Here, the summer peak, of father/chicks pairs was also noted, both in July and August. The August-low found in the Gemini surveys may thus have been an anomaly. Winter densities in the BARD area were much lower than during these Gemini surveys, reaching 1.5 Guillemots/km².

Also winter densities over Borkum Riffgrund in 2001 and 2004 (data: IBL) were lower than found in the Gemini area during the present surveys, indicating either that this Gemini site is a "good" area for Guillemots, or that the Gemini T-0 surveys were conducted in a year with unusual, high Guillemot densities.
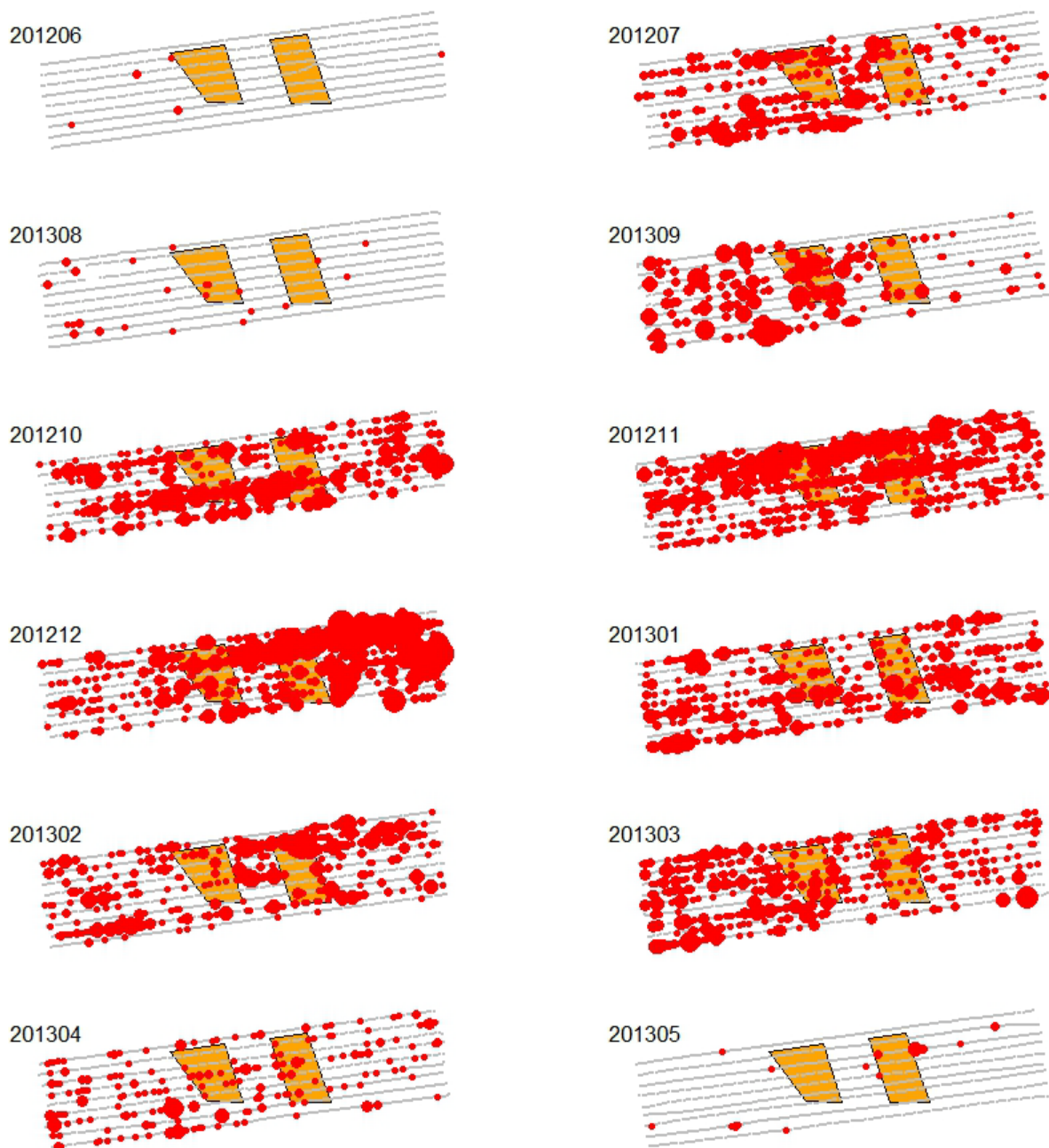
Figure 32. . Common Guillemot. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Razorbill

Since Razorbills mainly breed on cliffs around the British Isles and along more northern Atlantic coast (the breeding population on Helgoland is negligible; Dierschke et al. 2011), this species is rarely registered in the southern North Sea in summer. Here, they typically arrive months later than Common Guillemots, in October and reach highest densities in winter (Van Bemmelen et al. 2012, 2013; Leopold et al. 2013a). At this time, Razorbills can be regularly observed along the coastline in areas with 20 m depth of water (Camphuysen 1998). In the German Bight, highest concentrations are found north of the East Frisian Islands Borkum and Norderney (Mendel et al. 2008); in Dutch waters, concentrations are known from the Frisian Front (October/November: Van Bemmelen et al. 2013), the central Southern Bight (late winter: Camphuysen 1998; Van Bemmelen et al. 2012). Razorbills are often associated with Common Guillemots and may form mixed flocks.

In agreement with other surveys in the southern North Sea, Razorbirds were only seen from autumn (October) through April, with some very late birds still present in May (Figure 32). In concert with temporal patterns observed in Dutch waters, Razorbills showed two peaks in abundance, in November and in February. During winter, the birds showed little pattern in their distribution, only in February they were concentrated east of the future wind farms (Figure 33).
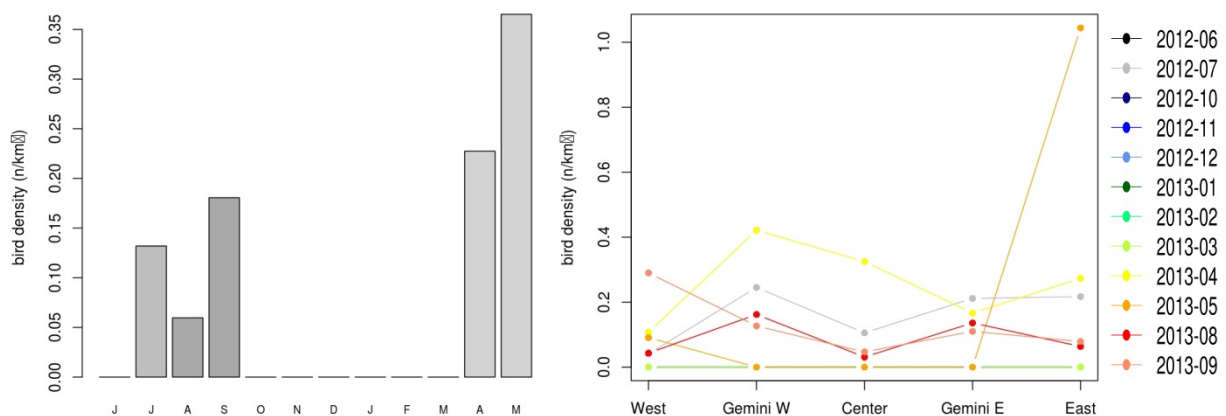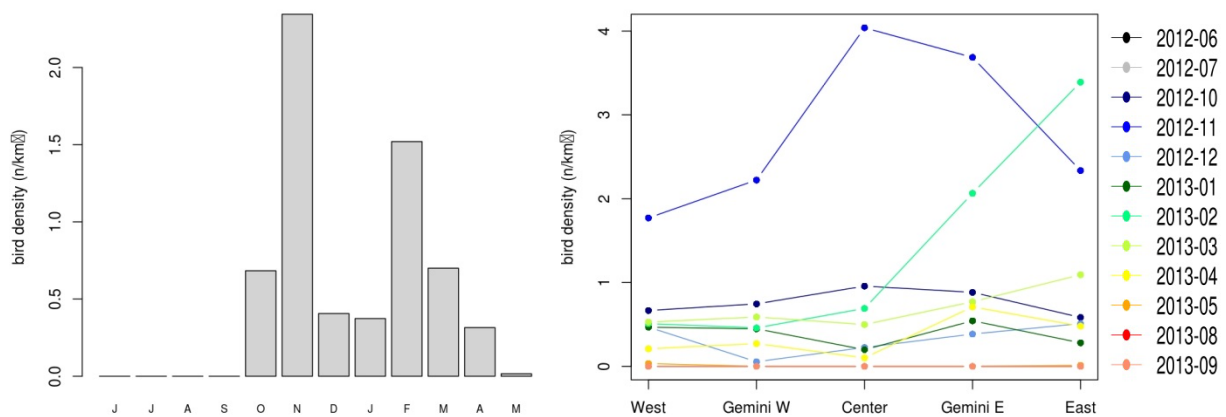

Figure 33. Razorbill. Seasonal pattern (left) and pattern of density between surveys (lines) and areas (x-axis) (right: each line represents a specific survey). The wind farms are 'Gemini W' and 'Gemini E'.
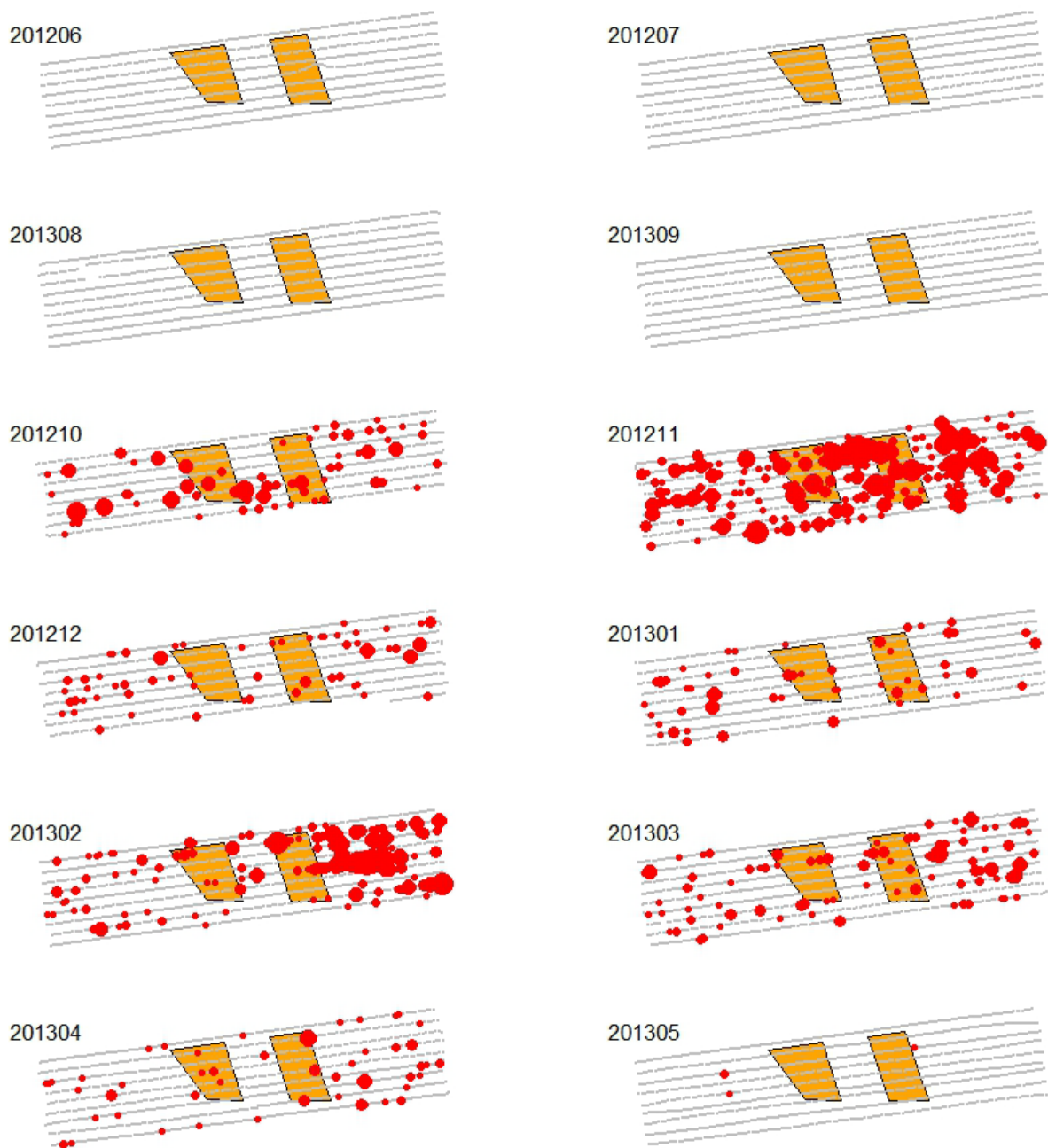
Figure 34. Razorbill. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Migrant cormorants, geese, ducks and waders

As was to be expected, some groups of migrating geese, ducks and waders were seen flying through the Gemini area, mostly in spring and autumn (Appendix A). Numbers were generally low and this study was not set up to collect meaningful data on these non-seabirds, such as flying heights. radar studies are more suitable for this and these observations are not further discussed here. A few Great Cormorants were passing through as well, showing that the future wind farm might be colonized by these birds (see: Leopold et al. 2011, 2013b).

Migrant passerines

In Appendix A, a complete list of recorded species and numbers can be found. Among the recorded species there is a wide variety of species (Appendix 1). Of these, Common Starling was particularly abundant during some surveys, but especially during the October 2012 survey, when many migrating thrushes were recorded as well. Autumn migration was also noted during the September survey, and spring migration during the April and May surveys. Migration of Skylarks was notable in the February survey.

These results indicate that even this far offshore, songbird migration occurs and may be substantial. Seabird surveys are however not suitable to quantify songbird migration; this should be measured using radar observations (Krijgsveld et al. 2011; Lindeboom et al. 2011).

Discussion of the results, with special emphasis on Common Guillemot distribution

Of all bird species seen, the Common Guillemot was by far the most numerous (Appendix A; Figure 34): it was seen in 4 times larger numbers than the next two most abundant wintering birds, the Black-legged Kittiwake and the Razorbill. Guillemots were also more than 3 times as numerous (over all months) than the most abundant summer-bird, the Lesser Black-backed Gull. Other species or species groups of seabirds with more than 100 individuals recorded were: divers, Northern Fulmar, Northern Gannet, Common Scoter, Little, Common, Herring and Great Black-backed Gulls, terns and Razorbill (Figure 34).

The auks (Guillemot, Razorbill and unidentified 'razormots') together comprised over 50% of all (important) seabirds, over all surveys. This is partly due to a prolonged presence in the area, of Guillemots in significant numbers (Figure 30). Guillemots were present in large numbers from July to April (with August as a noticeable exception). Excepting August, Guillemots were only present in low numbers in May and June. Razorbills on the other hand, had a much more restricted presence in time and although Razorbills were present in good numbers from October through April, they peaked only in November and February (Figure 32).

Gulls were found in the study area in all months. One species clearly peaked in summer (Lesser Black-backed Gull), but most in winter and during migration. Divers peaked during spring migration (April); Gannets during spring (March-May), but particularly during autumn migration (August to November) and Common Scoters during autumn migration (October). In other words, no month of the year passed without good numbers of seabirds in the area. Even so, auks (Guillemots and Razorbills) were both the most important birds numerically, and had the longest stay in the study area. The most important auk, in numbers and length of stay, clearly was the Guillemot, a seabird species known to be vulnerable to disturbance from wind turbines. The Guillemot was also the only bird that peaked in the area in the breeding season and the winter, but also during migration when vulnerable father-chick combinations passed (swimming) through the area. For this reason, we consider the Guillemot the most important species within the study area that needs most scrutiny with regard to wind farm development. Therefore, more detailed analyses on this species were carried out.
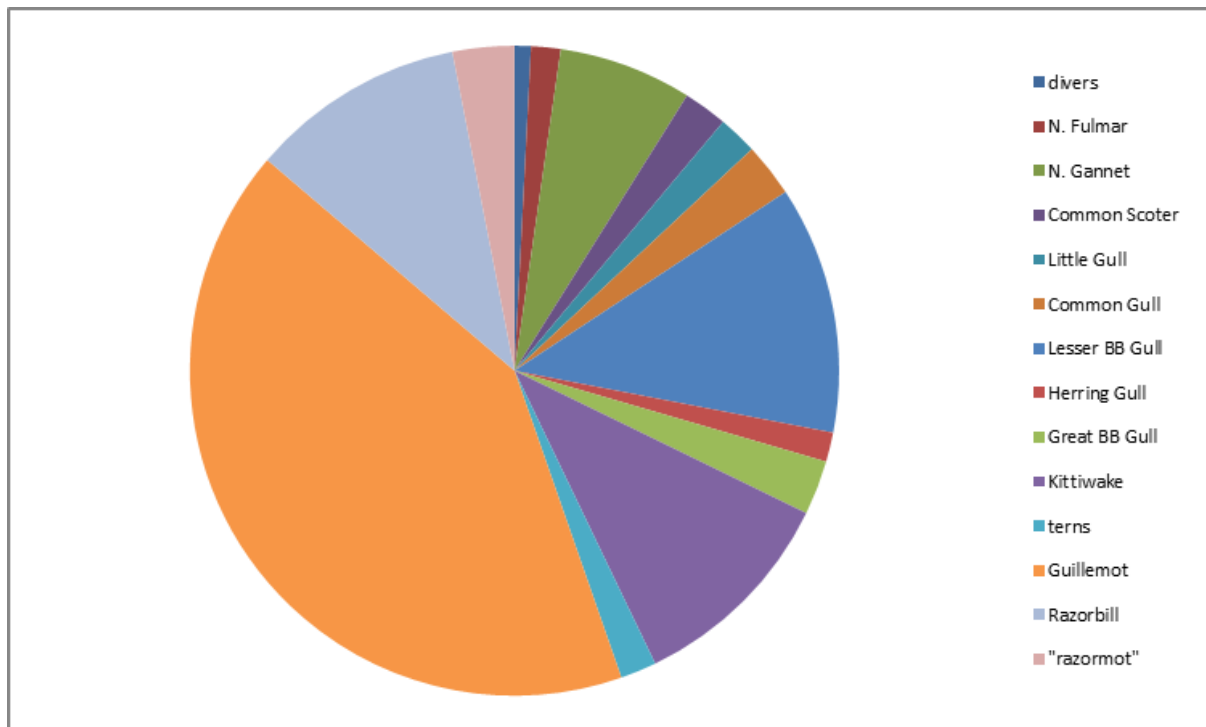
Figure 35. Relative numbers of (important) seabirds recorded during all 12 Gemini surveys.

Guillemot: Distance analysis

The first step in an analysis of numbers present is determining how numbers recorded are related to numbers actually present. Observers miss birds, and the percentage missed increases with distance from bird to observer and with increasing seastate. Moreover, as different ships and observer teams were used over the surveys, the percentage of missed birds is likely to vary between surveys. As several factors (season, ship, observers, sighting conditions) all impact the data at the same time, these factors are confounding variables which makes unravelling the impacts of any singular factor impossible. Measuring the actual percentages of missed birds is not impossible, but would require double-platform observation techniques that have not been used in these surveys. However, as the percentage of missed birds within one survey (same season, ship, observers and, roughly, field conditions) is unlikely to vary systematically between the future 'impact area' (GEMINI E and GEMINI W), the CENTER (the future empty space between the wind farms) and the two reference areas either side (see Figure 2a), such between-survey differences in percentages of missed birds are not further addressed here. All Guillemots recorded as swimming on the water (as opposed to birds seen in flight, which will not be missed easily) were assigned to a particular lateral distance band (see Methods section) and these data were used to model a so-called detection curve, which describes the probability that birds are detected (and missed) at various distances. Several models were tried and compared, including various covariates. The model with both seastate and trip number as covariates was the model that performed best (had the lowest AIC) and was therefore selected. Figure 35 shows the resulting detection functions and Table 4 presents the corresponding effective strip widths for Guillemots per survey and seastate. These were used to calculate the effectively surveyed area; which is used as an offset in the statistical model (see below).
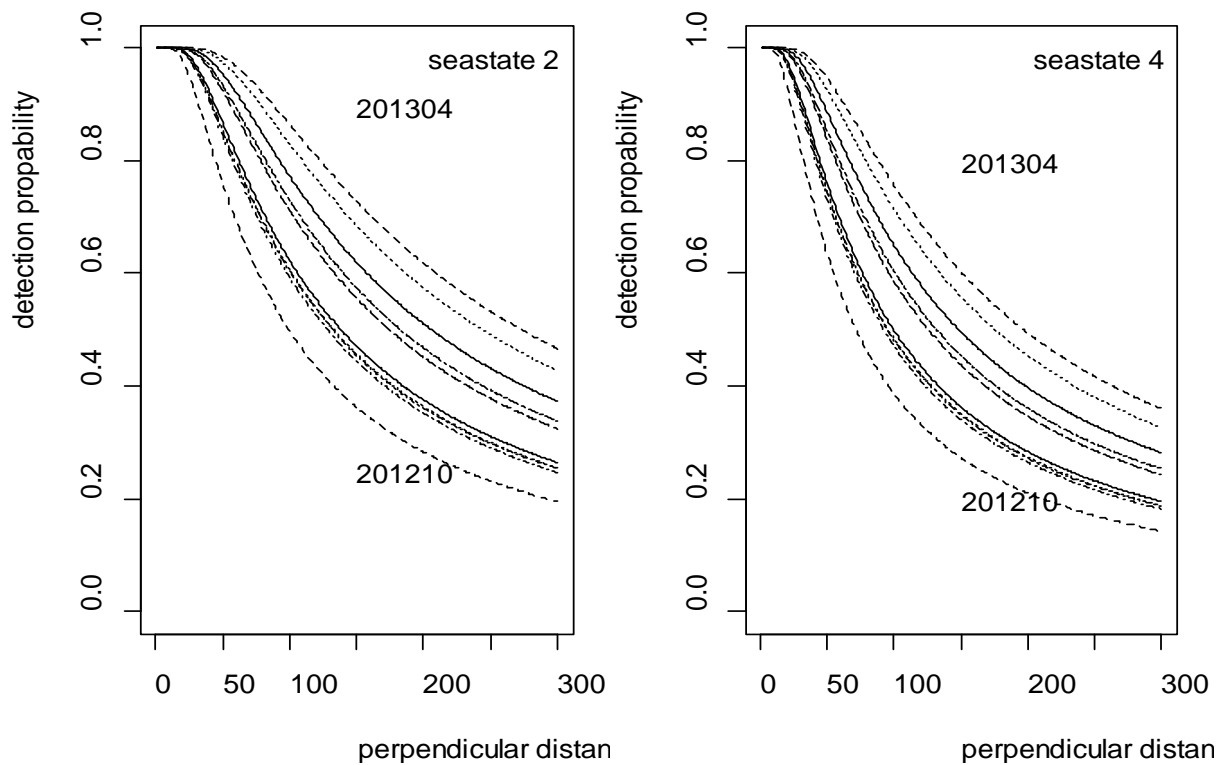
Figure 36. Distance functions for two example seastates: 2 Bft (left) and 4 Bft (right). Each line represents a survey. The highest curve corresponds to the survey in April 2013; the lowest to October 2012.

Table 4. Effective Strip Widths given the survey and seastate. Non-observed combinations (e.g. 6 Bft in October 2012) have been excluded from this table, although the model can give a predicted value for these combinations.

Trip (year/month)	Effective Strip Width (m) at given seastate (Bft)					
	1 Bft	2 Bft	3 Bft	4 Bft	5 Bft	6 Bft
201207		199	170	143	118	
201210	164	137	113	91	73	
201211	240	214	185	157		
201212		158	131	108	87	
201301	213	184	156	130		
201302	217	189	160	134	110	
201303	193	164	137	113	92	73
201304		223	195	167	139	115
201309	189	160	134	110	89	71

Statistical analysis

Generalised Additive Mixed Models (GAMM) are often used to describe distribution patterns but seabirds at sea data invariably have the problem that the data are far from normally distributed. There are always many counts with no birds, and some with birds seen, and some with many birds seen. Such data lead to overdispersion which pose a problem for statistical analysis. A solution to this data structure problem are Zero-Inflated Poisson GAMMs (ZIP GAMMs) that account for a large proportion of zeros in the response variable, by splitting the model in two parts: a binary part modelling the occurrence of zeros and a 'count' (Poisson) part for modelling the positive values. This procedure was developed for analyzing seabirds data around two earlier Dutch offshore wind farms (OWEZ and PAWP) and this is explained in full in Leopold et al. (2013a) and in Zuur et al. (2014); see also Methods.

The overdispersion parameter for the ZIP GAMM developed for the Gemini-guillemot data was 1.25. Mixing of the three chains for the regression parameters β_1 and β_2, and for the parameters $a\beta_1$ to $a\beta_{12}$ (survey intercepts in the binary part of the model) was good.

The aim of the modelling process was to determine whetherGuillemots were structurally attracted to, or avoiding particular parts of the full study area (see Figure 2). Should this be the case, this would have severe implications for T-1 (post-construction) study. The ZIP GAMM results did not show significantly higher or lower Common Guillemot densities at the two future wind farm locations (Table 5, Figure 36.). Note that the direction of the parameters is different (negative for the eastern location; positive for the western location). This means that densities in the study area were patchy and that densities in West tended to be higher than average and densities in East tended to be lower, but that none of these 'differences' were statistically significant.

Table 5. ZIP GAMM parameter estimates for the two future wind farm locations.

Future wind farm location	Mean	Standard Error	95% credible interval limits
Gemini West	0.120	0.076	-0.031 – 0.269
Gemini East	-0.139	0.079	-0.295 – 0.016
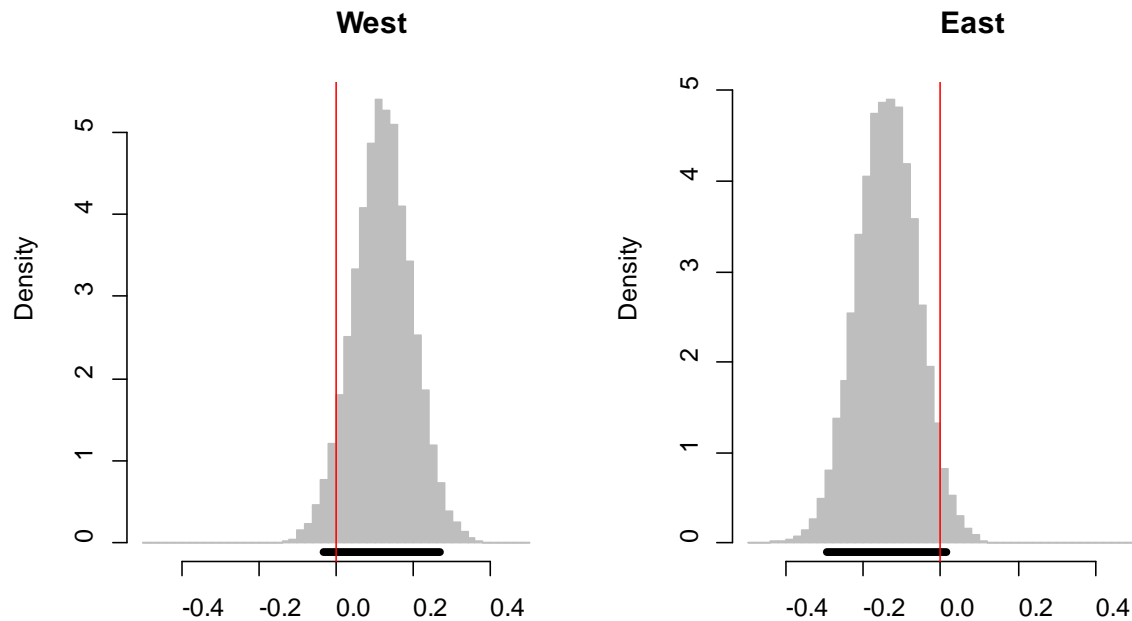
Figure 37. Posterior distribution of the two wind farm location parameters. The black bars at the bottom of the histograms show the 95% credible intervals. If the parameter estimate is zero (indicated by the red line), there would be no significant 'effect' of the wind farm location. Hence, if zero is within the 95%, the parameter estimate does not significantly differ from zero.

5.   Conclusions

5.1 Breeding birds

The Gemini study area, comprising the future wind farms sites, an area in between and two areas on either side (west and east), had good numbers of seabirds throughout the yearly cycle. The avifaunal composition varied greatly through the year. During the breeding season, protected breeding birds from Wadden Sea Natura 2000 sites or from Helgoland might be implicated but the results indicate that only very small numbers are likely involved. Note, again, however, that only one year of T-0 data is available. Species concerned may be Northern Gannet, Black-legged Kittiwake and Common Guillemot (Helgoland), and Lesser Black-backed Gull (Wadden Sea). Given the rather long distance between the Gemini sites and these breeding locations, the impact on breeding birds will be low, given the amount of habitat available at and up to these distances from the colonies, compared to the size of the Gemini future wind farms. We found no indications that the Gemini sites were of particular importance to breeders as a foraging area, as we could not detect significant transiting between the study area and breeding colonies. On the other hand, the Gemini wind farms will be part of a future wind farm conglomerate, with many more wind farms being built in its vicinity. This may lead to cumulative effects and a much greater habitat loss than by Gemini itself.

5.2 Migrants

Several seabirds were seen mostly during the migration season: divers, Northern Gannets, Common Scoters, Little Gulls, and terns. Even though such birds might feed *en route* and may thus suffer habitat loss if they will not venture into the future wind farms, such effects are probably limited given the size of wind farms in relation to the length of the flyways. Again, cumulative effects may kick in, once many wind farms have been built in close proximity, e.g., in the German Bight, but even in this scenario, there will be corridors for the birds to fly through and it will still be possible to fly around the conglomerate and reach SW Europe or NW Africa (or the Southern Hemisphere in the extreme case of Arctic Terns) without a significant increase of flyway length.

5.3 Wintering birds

Birds most likely to be impacted by the future Gemini wind farms are wintering birds. Birds that choose to winter in the German Bight do so for a reason (even if this is unknown) and might be pushed out of parts of their winter habitat by wind farm development. Displacement from wind farm sites equals habitat loss in such cases and even though it is not yet known how detrimental this actually is, habitat loss may lead to reduced fitness of the birds concerned. If displaced, they must move to other areas that might be equal in quality (if surplus habitat is available), but at the very least, bird density would increase here, leading to increased competition for resources. If birds are to move to less suitable alternative areas, fitness implications may be even greater (for a review see Furness et al. 2013).

Several species were found mostly as wintering birds in the Gemini area: Little Gull (next to being autumn migrants), Common Gull, Herring Gull, Great Black-backed Gull, Black-legged Kittiwake (next to being breeders), Guillemot (next to being migrants and breeding birds) and Razorbill. Of this list, the gulls are least likely to be displaced as they seem rather indifferent to offshore wind farms and may thus show little displacement. Hence, habitat loss seems a minor problem for these birds, but this also means that they will be more vulnerable to collisions with rotor blades than birds that avoid wind farms. Collision vulnerability depends on flying height and the species-specific ability to avoid a wind farm and the rotor-swept areas within a wind farm; gulls are probably rather good with the latter.

It might be argued that collision mortality may be offset by the species ability to reproduce and replace lost lives. Habitat degradation on the other hand, is likely to have more permanent repercussions on population sizes of birds, if suitable habitat is in short supply. Loss of habitat through offshore wind farm development will impact particularly those species that avoid wind farms to a large extent, such as Guillemots and Razorbills (Leopold et al. 2013a). These two auks were also the two most numerous birds in the study area (summed over the twelve survey months), and are therefore probably the key species for assessing future effects of the Gemini wind farms.

The Razorbill has a rather short (peak) presence in the area and seems most at risk in November and February. Guillemots on the other hand, have a very long significant presence in the area. Birds from Helgoland may use the area late in the breeding season (May/June). In July, a first wave of birds thought to come in (swimming) from the UK was noted in the Gemini area, but these arrived in force in a second wave, from September onward and numbers remained high until April. It is not impossible that also birds from Helgoland use the area in winter, and future (T-1) studies should clearly focus on the months of high Guillemot presence. This leaves out (only) the months May and June and August. August however, at present (one year of data only) poses a gap in Guillemot presence which is not yet understood and which may thus be a fallacy: August numbers may be as high as in July and September in other years.

It will thus be tempting to exclude May and June from future (T-1) surveys, as we found little evidence that local breeders (cliff breeders from Helgoland) reach the area. However, this can only be done if we accept that the area is also of little importance to the breeding gulls and gannets from the Wadden Sea and from Helgoland. At present, this will be difficult to determine. Gannets, Lesser Black-backed Gulls and Kittiwakes from protected colonies may use the Gemini area, but this cannot yet be proven, or disproven. With only one year of T-0 surveys, while at-sea surveys will find it hard to prove a connection with distant breeding colonies, telemetry studies provide probably better value for money in this respect, The most suitable species for such studies would be the Lesser Black-backed Gull. First, Kittiwakes and Northern Gannets in this area breed only on Helgoland and are partly cliff-nesting species and thus not easily accessible. Second, previous studies on the Lesser Black-backed Gull have proven that it is possible to obtain data on individual movements during the breeding season given the currently available GPS-tracking technique (e.g. Klaassen et al. 2011, Shamoun-Baranes et al. 2011).

A point of concern is, that only one year of T-0 data have been obtained. Between-years variation can thus not be examined and a one-year T-0 study can only serve to 'get a feel' for the general area. Anomalies in seabird distribution patterns or densities, occurring by chance in the year of data collection, cannot be easily detected and great care should be taken if T-0 results are to be compared to future T-1 data. Several rather striking anomalies were found in the current T-0 distribution patterns, that should probably be attributed to chance, given that no wind farms were yet present. However, should similar anomalies be found in the T-1 situation, incorrect conclusions may be reached later, in the T-1 situation, about possible effects of wind farms. Apparent 'displacement' (from non-existing OWFs) for instance, might seem present in the Northern Fulmar (September, January, May); the Common Scoter (October); the Black-legged Kittiwake (February) and the Arctic Tern (May; see the appropriate distribution maps). To avoid finding such 'Type I' errors, it will be important to collect more years of data, or collect data from more than just one survey per month, during the T-1 phase of this OWF study, particularly for the most important species in the Gemini area, the Common Guillemot.

5.4 Preliminary analysis of Common Guillemot distribution

The general rationale of collecting T-0 data is to get 'control' measurements that allow for correcting for local anomalies in seabird densities during the effect study. In this study, we have statistically tested for such anomalies at the two wind farm localities, in the pre-construction phase, for the most abundant seabird in the area, the Common Guillemot. No statistically significant departure of Common Guillemot densities at the two future wind farm locations relative to the surrounding study area was detected. Note that this does not mean that there is no such deviation; if present, it simply could not be detected with this data. There is, however, no evidence that Common Guillemots a priory avoid the sites where the future wind farms will become operational. From this it follows, that if a statistically significant effect on Common Guillemot densities of wind farms is found repeatedly in the T-1 study, that this will likely be an effect of wind farm presence. The current T-0 study thus set the scene for future T-1 studies to be carried out for this species.

Recommendations for T-1 study design

- If breeding birds can be excluded from impact studies, T-1 surveys could run from July-April, excluding the months May and June when no auks are present.
- If breeding birds such as Lesser Black-backed Gulls should be considered, suitable tracking methods should be implemented in the T-1 surveys. Other options would be to measure bird

- reactions to turbines locally, e.g. by using radar, hd-video or the sound that a collision must make (by using WT-Bird like technologies, if operational).
- The auks (Guillemot and Razorbill) should be the focal species of future at-sea studies. The auks are numerically the most important species in this OWF area, the species most likely to be impacted, and the species most easily modelled to find (or dismiss) effects of the future wind farms.
- North to south clines, or other north-south anomalies in seabird densities are unlikely to be important within the restricted study area. Future studies should therefore concentrate on anomalies in west to east direction. For this reason the different transect lines should be replicates and the northernmost and southernmost transect lines should probably be skipped from future survey designs, as these do not cross the wind farms (in contrast to the other lines).
- Any future study should also take the nearby German wind farms, to be being installed in 2015-2016, into account. The current eastern reference area may become another impact area, so probably a more integrated, international study would be needed to study the future cluster of wind farms in the area.
- There is probably little scope for a BACI-type analysis of future T-1 survey data. A BACI approach relies on T0 and T1 data having the same statistical power. With only one year of T-0 data, this will, in all likelihood, not be the case and a better option therefore will be, to focus on the T-1 data by comparing impact and no-impact areas along the same transects. Given the foreseeable developments in German waters, in and beyond the eastern parts of the current study area, a new no-impact zone may need to be found east of these future wind farms in German waters and studies on Gemini and the future German wind farms directly east of Gemini may be the best option for a valid T-1 study. Only if the development of these wind farms in Germany is slower than anticipated or if these wind farms are sufficiently far removed from the current study area, can the current approach remain valid.

- The extra value of studying other birds as well, for which effects (if present) are less likely to be found, should thus be discussed. This means that future (T-1) surveys are probably best concentrated within the months when these auks are abundantly present, i.e. when Guillemot father-chick combinations pass through the area in July and when wintering concentrations of both auks are present, from November through March. Survey effort could be doubled in these months (surveying every other week instead of once per month) to increase statistical power, at no extra cost (compared to surveying once per month, in each month of the year. Increasing statistical power is important to provide a fair estimate of effects (if present) and scientifically preferable over covering all birds in all months. The best value for money will therefore be gained by focussing on Guillemots and Razorbills.

As a final note: even if major displacement will be found of seabirds from the future Gemini wind farms, this will be too late for this site, as the permit has been granted and the wind farms will be built here. T-1 Gemini surveys will thus mainly serve the decision process for further wind farms. The future Gemini results will be most meaningful in this respect, if they will be evaluated together with data from other wind farms, of different lay-outs and in different settings. Only be comparison can we learn what good and poor sites are, for offshore wind farms in relation to seabird habitat.

6.   Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with

number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

Rapport C056/15
Project Number: 43.02503105

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Dr. T. van Kooten
                           Researcher

Signature:

Date: 20 May 2015

Approved: Drs. J. Asjes
                           Head department Ecosystems

Signature:

Date: 20 May 2015

Appendix A. List of observed species

List of observed species and species groups (greyed out), with totals per survey.

Species	2012-06	2012-07	2013-08	2013-09	2012-10	2012-11	2012-12	2013-01	2013-02	2013-03	2013-04	2013-05	total
Birds													
Red-throated Diver (Gavia stellata)	0	0	0	0	2	5	2	3	18	10	28	11	79
Black-throated Diver (Gavia arctica)	0	0	0	0	0	0	1	0	3	2	1	0	7
unidentified diver (Gavia spec.)	0	0	0	0	1	1	7	0	0	8	15	1	33
Northern Fulmar (Fulmarus glacialis)	19	7	13	51	8	0	17	70	3	4	1	21	214
Sooty Shearwater (Puffinus griseus)	0	0	0	0	0	0	0	1	0	0	0	0	1
Manx Shearwater (Puffinus puffinus)	0	0	1	0	0	0	0	0	0	0	0	0	1
European Storm-petrel (Hydrobates pelagicus)	0	0	0	0	2	0	1	0	0	0	0	0	3
Leach's Storm-petrel (Oceanodroma leucorhoa)	0	0	0	0	0	0	0	1	0	0	0	0	1
Northern Gannet (Sula bassana)	47	96	138	60	158	219	28	21	18	50	77	58	970
Great Cormorant (Phalacrocorax carbo)	0	0	0	0	13	0	0	0	0	2	7	0	22
Greater White-fronted Goose (Anser albifrons)	0	0	0	0	0	0	0	0	0	0	21	0	21
Greylag Goose (Anser anser)	0	0	0	0	0	19	0	0	42	0	7	0	68
unidentified goose (Anser spec.)	0	0	0	0	0	84	0	0	0	0	0	0	84
Barnacle Goose (Branta leucopsis)	0	0	0	0	0	2	0	0	0	0	0	0	2
Brent Goose (Branta bernicla)	0	0	0	0	6	0	0	0	0	0	0	0	6
White-bellied Brent Goose (Branta bernicla)	0	0	0	2	0	0	0	0	0	0	0	0	2
unidentified goose (Anser/Branta spec.)	0	0	0	0	0	60	0	0	0	0	0	0	60
Common Shelduck (Tadorna tadorna)	0	0	0	0	0	0	0	0	1	0	0	1	2
Eurasian Wigeon (Anas penelope)	0	0	2	0	25	4	0	0	0	0	0	0	31
Gadwall (Anas strepera)	0	0	0	0	0	2	0	0	0	0	0	0	2
EurasianTeal (Anas crecca)	0	0	0	0	2	0	0	0	1	0	0	0	3
Mallard (Anas platyrhynchos)	0	0	0	0	0	3	0	0	0	0	0	0	3
Northern Shoveler (Anas clypeata)	0	0	0	0	0	0	0	0	0	0	4	0	4
Common Eider (Somateria mollissima)	0	0	0	0	0	4	0	0	0	0	5	0	9
Common Scoter (Melanitta nigra)	8	7	3	23	211	13	0	2	23	4	26	0	320
Goosander (Mergus merganser)	0	0	0	0	0	1	0	0	0	0	0	0	1
unidentified duck (unidentified duck)	0	0	0	0	6	9	0	0	0	0	0	0	15
European Honey-buzzard (Pernis apivorus)	0	1	0	0	0	0	0	0	0	0	0	0	1
Common Kestrel (Falco tinnunculus)	0	0	0	0	0	0	0	0	0	0	0	0	0
Ringed Plover (Charadrius hiaticula)	0	0	0	0	0	0	0	0	0	4	0	0	4
European Golden Plover (Pluvialis apricaria)	0	0	0	0	2	0	0	0	0	0	0	0	2
Dunlin (Calidris alpina)	0	0	0	0	0	0	0	1	0	0	0	0	1
Whimbrel (Numenius phaeopus)	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomarine Skua (Stercorarius pomarinus)	0	1	0	0	0	0	0	0	0	0	0	0	1

Species	1	2	3	4	5	6	7	8	9	10	11	12	Total
Arctic Skua (Stercorarius parasiticus)	0	0	3	13	0	0	0	0	0	0	3	2	21
Long-tailed Skua (Stercorarius longicaudus)	1	0	0	4	0	0	0	0	0	0	0	0	5
Great Skua (Stercorarius skua)	0	0	1	2	0	5	0	0	0	0	0	0	8
Little Gull (Larus minutus)	0	0	0	55	35	15	10	33	46	68	22	0	284
Black-headed Gull (Larus ridibundus)	8	1	1	4	29	1	0	0	3	1	1	1	50
Common Gull (Larus canus)	0	7	7	6	69	8	70	61	70	71	16	5	390
small gull (Larus / Rissa spec.)	0	0	0	0	0	0	0	0	2	0	0	0	2
Lesser Black-backed Gull (Larus fuscus)	432	756	143	9	9	3	0	4	7	12	139	286	1800
Baltic Gull (Larus fuscus fuscus)	0	1	0	0	0	0	0	0	0	0	0	0	1
Herring Gull (Larus argentatus)	0	0	0	4	7	24	83	62	26	4	1	2	213
Caspian Gull (Larus cachinnans)	0	0	0	1	0	0	0	0	1	0	0	0	2
Yellow-legged Gull (Larus michahellis)	0	0	0	0	0	0	0	0	1	0	0	0	1
Common / Herring Gull (L. canus / L. argentatus)	0	0	0	0	3	0	0	0	0	0	0	0	3
Great Black-backed Gull (Larus marinus)	0	2	1	6	40	96	108	90	33	7	9	3	395
large gull (Larus spec.)	0	0	0	0	1	1	1	2	8	0	0	0	13
black-backed gull (L. fuscus / L. marinus)	0	0	0	0	2	0	1	0	0	0	0	0	3
Black-legged Kittiwake (Rissa tridactyla)	92	20	0	79	96	275	240	394	201	53	76	28	1554
gull (Larus spec.)	0	0	0	0	1	0	0	0	0	0	0	0	1
Sandwich Tern (Sterna sandvicensis)	0	9	0	0	0	0	0	0	0	0	28	0	37
Common Tern (Sterna hirundo)	0	2	4	25	0	0	0	0	0	0	1	0	32
Arctic Tern (Sterna paradisaea)	0	22	3	3	0	0	0	0	0	0	45	92	165
Common / Arctic tern (S. hirundo / S. paradisaea)	0	7	8	0	0	0	0	0	0	0	11	0	26
Black Tern (Chlidonias niger)	0	0	0	0	0	0	0	0	0	0	0	2	2
Common Guillemot (Uria aalge)	7	472	29	400	684	1107	1193	683	579	659	237	21	6071
Common Guillemot / Razorbill (Alca torda / Uria aalge)	0	0	0	0	72	203	92	8	96	15	0	2	488
Razorbill (Alca torda)	0	0	0	0	152	587	92	94	380	175	79	4	1563
Atlantic Puffin (Fratercula arctica)	0	0	0	0	0	0	0	0	3	0	1	0	4
unidentified auk (unidentified auk)	0	0	0	0	0	0	4	0	0	0	0	0	4
domestic pigeon (Columba 'domestica')	0	0	0	0	0	0	0	0	0	0	1	0	1
Common Wood Pigeon (Columba palumbus)	0	0	0	0	0	0	0	0	0	0	1	0	1
Common Swift (Apus apus)	10	1	0	0	0	0	0	0	0	0	0	0	11
Great Spotted Woodpecker (Dendrocopos major)	0	0	0	1	0	0	0	0	0	0	0	0	1
Sky Lark (Alauda arvensis)	0	0	0	0	2	0	0	0	66	2	0	0	70
Barn Swallow (Hirundo rustica)	0	0	0	0	0	0	0	0	0	0	2	3	5
House Martin (Delichon urbica)	0	0	0	0	0	0	0	0	0	0	1	0	1
Meadow Pipit (Anthus pratensis)	0	0	0	0	6	3	0	0	0	0	8	0	17
unidentified pipit (unidentified pipit)	0	0	0	0	0	0	0	0	0	0	3	0	3
Winter Wren (Troglodytes troglodytes)	0	0	0	0	1	0	0	0	0	0	0	0	1

Species													Total
European Robin (Erithacus rubecula)	0	0	0	0	5	0	0	0	0	0	0	0	5
Common Redstart (Phoenicurus phoenicurus)	0	0	0	1	0	0	0	0	0	0	0	0	1
Northern Wheatear (Oenanthe oenanthe)	0	0	0	7	0	0	0	0	0	0	0	0	7
Common Blackbird (Turdus merula)	0	0	0	0	17	1	0	0	1	0	0	0	19
Fieldfare (Turdus pilaris)	0	0	0	0	23	8	0	0	0	0	0	0	31
Song Thrush (Turdus philomelos)	0	0	0	0	11	1	0	0	0	0	0	0	12
unidentified thrush (Turdus spec.)	0	0	0	0	3	16	0	0	0	0	0	0	19
Redwing (Turdus iliacus)	0	0	0	0	143	3	0	0	0	0	0	0	146
Mistle Thrush (Turdus viscivorus)	0	0	0	0	7	0	0	0	0	0	0	0	7
Common Whitethroat (Sylvia communis)	0	0	0	0	1	0	0	0	0	0	0	0	1
Blackcap (Sylvia atricapilla)	0	0	0	0	2	0	0	0	0	0	1	0	3
Common Chiffchaff (Phylloscopus collybita)	0	0	0	0	1	0	0	0	0	0	3	0	4
Goldcrest (Regulus regulus)	0	0	0	0	11	0	0	0	0	0	0	0	11
Carrion Crow (Corvus corone corone)	0	0	0	0	1	0	0	0	0	0	0	0	1
Common Starling (Sturnus vulgaris)	0	0	0	1	381	206	0	3	3	0	25	0	619
Chaffinch (Fringilla coelebs)	0	0	0	0	33	1	0	0	0	0	1	0	35
Brambling (Fringilla montifringilla)	0	0	0	0	1	0	0	0	0	0	0	0	1
Eurasian Siskin (Carduelis spinus)	0	0	0	0	1	0	0	0	0	0	0	0	1
unidentified passerine (unidentified passerine)	0	0	0	0	48	2	0	0	0	0	8	0	58

Marine mammals

Species													Total
Harbour Porpoise (Phocoena phocoena)	135	4	22	15	62	44	38	24	91	28	3	4	470
unidentified seal (unidentified pinniped)	0	0	0	0	0	0	0	0	3	1	0	0	4
Grey Seal (Halichoerus grypus)	0	0	0	0	0	2	0	3	2	0	1	0	8
Common Seal (Phoca vitulina)	1	0	0	1	2	2	2	10	12	3	2	0	35

Varia

													Total
set net (flag)	3	0	0	1	0	0	0	0	0	1	2	1	8
balloon	64	6	7	22	11	4	1	5	6	1	9	25	161
balloon (foil)	7	1	2	0	0	0	0	1	1	0	0	1	13

Appendix B. Ships used for the Gemini seabirds surveys

From top to bottom: Reykjanes, Hydrograf, Sverdrupson and Cecilie. Note 'bird boxes' on the top of the bridge (first three vessels) or further forward (Cecilie) for unrestricted views forward and sideways.

Name of Vessel	Flag	Type	Length over all	Width	Height of Bridge deck	Height of monkey island/ Observation box	Max. speed to operate continuously
Reykjanes	Danish	Survey Vessel	40.1 m	8.2 m	5.5 m	7.5 m	11 knots
Hydrograf	Norwegian	Survey Vessel	38,9 m	7.2 m	4.5 m	6.5 m	11 knots
Sverdrupson	German	Survey vessel	39.0 m	7.8 m	7.0 m	9.0 m	unknown
Cecilie	Honduras	Survey Vessel	40.0 m	8.0 m	4.0 m	7.6 m	12 knots

Appendix B. Recorded flying heights per species. Altitudes (meters above sea level) were noted in seven Altitude Classes (AC): 1 (0-2 m asl); 2 (2-10); 3 (10-25); 4 (25-50); 5 (50-100), 6 (100-200) or 7 (>200 m asl).

Euring	Species	Scientific species name	AC	n-obs	n-birds
20	Red-throated Diver	*Gavia stellata*	1	8	10
20	Red-throated Diver	*Gavia stellata*	2	15	18
20	Red-throated Diver	*Gavia stellata*	3	16	21
20	Red-throated Diver	*Gavia stellata*	4	3	4
20	Red-throated Diver	*Gavia stellata*	6	1	1
30	Black-throated Diver	*Gavia arctica*	3	2	2
59	unidentified diver	*Gavia spec.*	1	8	8
59	unidentified diver	*Gavia spec.*	2	7	12
59	unidentified diver	*Gavia spec.*	3	3	4
59	unidentified diver	*Gavia spec.*	5	1	1
220	Northern Fulmar	*Fulmarus glacialis*	1	100	103
220	Northern Fulmar	*Fulmarus glacialis*	2	23	26
430	Sooty Shearwater	*Puffinus griseus*	1	1	1
520	European Storm-petrel	*Hydrobates pelagicus*	1	1	1
710	Northern Gannet	*Morus bassanus*	1	146	158
710	Northern Gannet	*Morus bassanus*	2	183	204
710	Northern Gannet	*Morus bassanus*	3	161	174
710	Northern Gannet	*Morus bassanus*	4	50	59
710	Northern Gannet	*Morus bassanus*	5	11	11
710	Northern Gannet	*Morus bassanus*	6	3	3
710	Northern Gannet	*Morus bassanus*	7	1	1
720	Great Cormorant	*Phalacrocorax carbo*	1	8	17
720	Great Cormorant	*Phalacrocorax carbo*	2	1	1
720	Great Cormorant	*Phalacrocorax carbo*	4	2	7
1590	Greater White-fronted Goose	*Anser albifrons*	4	1	21
1610	Greylag Goose	*Anser anser*	1	3	28
1610	Greylag Goose	*Anser anser*	2	1	15
1610	Greylag Goose	*Anser anser*	3	1	18
1610	Greylag Goose	*Anser anser*	4	1	7
1670	Barnacle Goose	*Branta leucopsis*	1	1	2
1680	Brent Goose	*Branta bernicla*	1	1	6
1699	unidentified goose	*Anser/Branta spec.*	1	1	25
1699	unidentified goose	*Anser/Branta spec.*	2	1	35
1730	Common Shelduck	*Tadorna tadorna*	1	3	31
1730	Common Shelduck	*Tadorna tadorna*	2	1	1

1730	Common Shelduck	*Tadorna tadorna*	**3**	1	18
1790	Eurasian Wigeon	*Anas penelope*	**1**	2	4
1790	Eurasian Wigeon	*Anas penelope*	**3**	1	2
1790	Eurasian Wigeon	*Anas penelope*	**4**	2	24
1820	Gadwall	*Anas strepera*	**2**	1	2
1840	EurasianTeal	*Anas crecca*	**1**	2	3
1860	Mallard	*Anas platyrhynchos*	**2**	2	3
1940	Northern Shoveler	*Anas clypeata*	**1**	2	4
2060	Common Eider	*Somateria mollissima*	**1**	2	5
2060	Common Eider	*Somateria mollissima*	**3**	5	6
2130	Common Scoter	*Melanitta nigra*	**1**	37	234
2130	Common Scoter	*Melanitta nigra*	**2**	11	49
2130	Common Scoter	*Melanitta nigra*	**3**	8	29
2130	Common Scoter	*Melanitta nigra*	**4**	3	4
2230	Goosander	*Mergus merganser*	**2**	1	1
2269	unidentified duck	*unidentified duck*	**1**	2	9
2269	unidentified duck	*unidentified duck*	**3**	1	6
2310	European Honey-buzzard	*Pernis apivorus*	**2**	1	1
3040	Common Kestrel	*Falco tinnunculus*	**3**	1	1
4700	Ringed Plover	*Charadrius hiaticula*	**1**	2	4
4850	European Golden Plover	*Pluvialis apricaria*	**1**	1	2
5120	Dunlin	*Calidris alpina*	**1**	1	1
5380	Whimbrel	*Numenius phaeopus*	**5**	1	2
5660	Pomarine Skua	*Stercorarius pomarinus*	**1**	1	1
5670	Arctic Skua	*Stercorarius parasiticus*	**1**	7	7
5670	Arctic Skua	*Stercorarius parasiticus*	**2**	2	2
5670	Arctic Skua	*Stercorarius parasiticus*	**3**	1	1
5680	Long-tailed Skua	*Stercorarius longicaudus*	**3**	1	1
5690	Great Skua	*Stercorarius skua*	**1**	5	5
5690	Great Skua	*Stercorarius skua*	**2**	2	2
5780	Little Gull	*Larus minutus*	**1**	43	65
5780	Little Gull	*Larus minutus*	**2**	50	84
5780	Little Gull	*Larus minutus*	**3**	9	12
5820	Black-headed Gull	*Larus ridibundus*	**1**	7	8
5820	Black-headed Gull	*Larus ridibundus*	**2**	13	23
5820	Black-headed Gull	*Larus ridibundus*	**3**	9	11
5820	Black-headed Gull	*Larus ridibundus*	**4**	4	11
5900	Common Gull	*Larus canus*	**1**	19	22
5900	Common Gull	*Larus canus*	**2**	97	111
5900	Common Gull	*Larus canus*	**3**	89	93
5900	Common Gull	*Larus canus*	**4**	41	46
5900	Common Gull	*Larus canus*	**5**	6	8

5900	Common Gull	Larus canus	6	4	4
5910	Lesser Black-backed Gull	Larus fuscus	1	121	176
5910	Lesser Black-backed Gull	Larus fuscus	2	195	261
5910	Lesser Black-backed Gull	Larus fuscus	3	207	287
5910	Lesser Black-backed Gull	Larus fuscus	4	145	183
5910	Lesser Black-backed Gull	Larus fuscus	5	51	59
5910	Lesser Black-backed Gull	Larus fuscus	6	6	7
5910	Lesser Black-backed Gull	Larus fuscus	7	1	3
5920	Herring Gull	Larus argentatus	1	14	28
5920	Herring Gull	Larus argentatus	2	30	36
5920	Herring Gull	Larus argentatus	3	55	62
5920	Herring Gull	Larus argentatus	4	27	29
5920	Herring Gull	Larus argentatus	5	7	10
5920	Herring Gull	Larus argentatus	6	3	3
5927	Caspian Gull	Larus cachinnans	2	1	1
5927	Caspian Gull	Larus cachinnans	3	1	1
5928	Yellow-legged Gull	Larus michahellis	2	1	1
5929	Common / Herring Gull	L. canus / L. argentatus	5	1	1
5929	Common / Herring Gull	L. canus / L. argentatus	6	2	2
6000	Great Black-backed Gull	Larus marinus	1	34	48
6000	Great Black-backed Gull	Larus marinus	2	41	57
6000	Great Black-backed Gull	Larus marinus	3	82	86
6000	Great Black-backed Gull	Larus marinus	4	78	92
6000	Great Black-backed Gull	Larus marinus	5	10	11
6000	Great Black-backed Gull	Larus marinus	6	6	7
6005	large gull	Larus spec.	4	1	1
6005	large gull	Larus spec.	5	1	1
6005	large gull	Larus spec.	6	1	2
6009	black-backed gull	L. fuscus / L. marinus	2	1	1
6009	black-backed gull	L. fuscus / L. marinus	4	2	2
6020	Black-legged Kittiwake	Rissa tridactyla	1	116	162
6020	Black-legged Kittiwake	Rissa tridactyla	2	409	506
6020	Black-legged Kittiwake	Rissa tridactyla	3	258	279
6020	Black-legged Kittiwake	Rissa tridactyla	4	45	53
6020	Black-legged Kittiwake	Rissa tridactyla	5	2	2
6020	Black-legged Kittiwake	Rissa tridactyla	6	2	2
6049	gull	Larus spec.	3	1	1
6110	Sandwich Tern	Sterna sandvicensis	2	9	15
6110	Sandwich Tern	Sterna sandvicensis	3	13	19
6110	Sandwich Tern	Sterna sandvicensis	4	2	3
6150	Common Tern	Sterna hirundo	1	6	8
6150	Common Tern	Sterna hirundo	2	12	16

6150	Common Tern	*Sterna hirundo*	**3**	9	10
6160	Arctic Tern	*Sterna paradisaea*	**2**	15	103
6160	Arctic Tern	*Sterna paradisaea*	**3**	13	17
6169	Common / Arctic tern	*S. hirundo / S. paradisaea*	**1**	4	6
6169	Common / Arctic tern	*S. hirundo / S. paradisaea*	**2**	2	3
6169	Common / Arctic tern	*S. hirundo / S. paradisaea*	**3**	5	7
6270	Black Tern	*Chlidonias niger*	**2**	1	2
6340	Common Guillemot	*Uria aalge*	**1**	567	850
6340	Common Guillemot	*Uria aalge*	**2**	22	26
6345	Common Guillemot / Razorbill	*Alca torda / Uria aalge*	**1**	57	87
6345	Common Guillemot / Razorbill	*Alca torda / Uria aalge*	**2**	4	6
6360	Razorbill	*Alca torda*	**1**	85	137
6360	Razorbill	*Alca torda*	**2**	5	7
6549	unidentified auk	*unidentified auk*	**1**	1	1
6549	unidentified auk	*unidentified auk*	**2**	1	3
6655	domestic pigeon	*Columba livia*	**3**	1	1
6700	Common Wood Pigeon	*Columba palumbus*	**2**	1	1
7950	Common Swift	*Apus apus*	**2**	1	2
7950	Common Swift	*Apus apus*	**3**	9	26
7950	Common Swift	*Apus apus*	**4**	1	1
7950	Common Swift	*Apus apus*	**7**	1	2
9760	Sky Lark	*Alauda arvensis*	**1**	5	62
9760	Sky Lark	*Alauda arvensis*	**2**	6	8
9920	Barn Swallow	*Hirundo rustica*	**1**	2	3
9920	Barn Swallow	*Hirundo rustica*	**2**	3	3
10010	House Martin	*Delichon urbica*	**4**	1	1
10110	Meadow Pipit	*Anthus pratensis*	**2**	5	10
10110	Meadow Pipit	*Anthus pratensis*	**3**	2	3
10119	unidentified pipit	*unidentified pipit*	**1**	1	3
11460	Northern Wheatear	*Oenanthe oenanthe*	**1**	6	7
11870	Common Blackbird	*Turdus merula*	**1**	2	2
11870	Common Blackbird	*Turdus merula*	**2**	2	2
11870	Common Blackbird	*Turdus merula*	**3**	5	7
11870	Common Blackbird	*Turdus merula*	**4**	2	2
11980	Fieldfare	*Turdus pilaris*	**1**	6	14
11980	Fieldfare	*Turdus pilaris*	**2**	2	7
11980	Fieldfare	*Turdus pilaris*	**3**	1	5
12000	Song Thrush	*Turdus philomelos*	**1**	4	5
12000	Song Thrush	*Turdus philomelos*	**3**	3	3
12000	Song Thrush	*Turdus philomelos*	**4**	1	4
12009	unidentified thrush	*Turdus spec.*	**1**	7	18
12009	unidentified thrush	*Turdus spec.*	**2**	1	1

12010	Redwing	*Turdus iliacus*	**1**	9	20
12010	Redwing	*Turdus iliacus*	**2**	9	104
12010	Redwing	*Turdus iliacus*	**3**	5	8
12020	Mistle Thrush	*Turdus viscivorus*	**1**	3	7
13110	Common Chiffchaff	*Phylloscopus collybita*	**3**	1	1
13140	Goldcrest	*Regulus regulus*	**3**	2	5
15671	Carrion Crow	*Corvus corone corone*	**3**	1	1
15820	Common Starling	*Sturnus vulgaris*	**1**	13	223
15820	Common Starling	*Sturnus vulgaris*	**2**	13	60
15820	Common Starling	*Sturnus vulgaris*	**3**	4	83
15820	Common Starling	*Sturnus vulgaris*	**4**	1	190
16360	Chaffinch	*Fringilla coelebs*	**1**	1	1
16360	Chaffinch	*Fringilla coelebs*	**2**	2	2
16360	Chaffinch	*Fringilla coelebs*	**3**	2	28
19999	unidentified passerine		**1**	2	3
19999	unidentified passerine		**2**	6	30
19999	unidentified passerine		**3**	1	23