Report for the project

Offshore wind farm effects on Common guillemots (*Uria aalge*) in the Netherlands – Part A: Assessment of the applicability of a Before-After-Control-Impact analysis based on available data

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1. Summary

This report's goal is to summarize seabirds at sea data available for the Netherlands and evaluate if the data is sufficient for a Before and After Control Impact (BACI) analysis for the effects of offshore wind farms (OWF) on Common guillemots (Peschko et al. 2024).

In general, there seems to be a good spatio-temporal survey coverage of the Dutch North Sea. However, each survey method has its limitations.

Ship-based surveys in the Netherlands have been conducted since the early 1980s. However, following the publication of two atlases (Baptist and Wolf 1993, Camphuysen and Leopold 1994), survey efforts on the Dutch Continental Shelf (DCS) became increasingly ad-hoc and project-based (van Bemmelen et al. 2011). Ship-based surveys therefore no longer covered the entire Dutch EEZ, and only dedicated surveys primarily those dedicated to OWF were being conducted (ICES 2020). For example, ship-based surveys were conducted in and around OWF prior to construction, as pre-construction (T-0) monitoring was required (Leopold et al. 2010, Leopold 2012, van Bemmelen et al. 2015). Some ship-based surveys have also been carried out post-construction (T-1) to monitor impacts after the OWFs became operational, or to evaluate whether birds will recognise a corridor as a safe passage route through the wind farm (Leopold 2012, Leemans et al. 2024). In recent literature, ship-based survey data have been considered unbalanced and inconsistent, particularly for the last 10 to 15 years. Nevertheless, some studies still incorporated incidental and systematic ship-based survey data in their analyses (Leopold et al. 2015, van Kooten et al. 2019), while other opted not to use it (van Donk et al. 2024). It should be mentioned that modern regression methods (such as applied for the planned BACI analysis) can cope with a certain degree of unbalance.

Observer-based aerial surveys provide good spatial and temporal coverage and are generally considered to have more consistent coverage than ship-based surveys (van Bemmelen et al. 2011, van Donk et al. 2024). Post-construction plane surveys, as part of the MWTL surveys, are also conducted crossing the OWF throughout the shipping lane (Collier et al. 2022), the regular monitoring passes Gemini wind farm in a certain distance, at the standard altitude of 75 m. Note, however, that the methodology changed after 2014. Prior 2014, planes flew at higher altitudes (150 m) (Baptist and Wolf 1993, Arts 2010, Poot et al. 2016), and thus species such as Common guillemots and Razorbills

could not be reliably distinguished (van Donk et al. 2024) but rather assessed on the level of auks only. Furthermore, the MWTL monitoring program started using bubble windows as a standard after 2014, which could suggest, that in surveys previous 2014, the transect line below the plane could not be properly observed, and consequently many birds on the transect line were probably missed (Poot et al. 2016). To address the issue of individuals not determined to species level, some studies using observer-based aerial surveys after 2014, have estimated the proportion of each species, and applied these proportions to assign species to undetermined Common guillemots / Razorbills (van Bemmelen et al. 2022). This might be appropriate if total species-specific numbers are estimated. However, if species-specific OWF-effects are evaluated, this approach is not appropriate, as it does not solve the problem that species-specific reactions cannot be extracted from individuals that are not determined at species level. Other studies, after exploratory analyses, have decided that aerial surveys conducted before 2014 yielded no usable species-level data (van Donk et al. 2024). Because assessing the effects of offshore wind farms (OWFs) via a BACI analysis following Peschko et al. 2024 typically requires a dataset spanning six years, this lack of usable pre-construction species specific data might pose a limitation for the analysis of some OWF, or analysis methods need to be adapted accordingly. It is however probable, that data collected in the same time span via ship-based surveys and observer-based aerial surveys can be combined. Although the analysis is highly likely, a final decision on how to deal with the data before 2014 can only be made once the data including survey effort, weather conditions, and the sightings of Common guillemots, Razorbills and undetermined Auks is available and can be evaluated in detail.

Digital aerial surveys are only project based, and no regular monitoring in the DCS is conducted. For digital surveys only two studies were found, and both cover the post-construction period of OWFs. One study included eight surveys in Gemini: the first as pilot in March 2022, and seven following between October 2022 and March 2023 (Grundlehner et al. 2025). The other study was conducted in Borssele (Collier et al. 2022) which included surveys carried out between 2021 to 2022. There are more digital surveys coming in the next years (Leopold et al. 2021, Bos et al. 2023, Fijn *pers. comm.*, Zomer *pers. comm.*), but at the present time, it was not clear when and where.

Based on the current overview, it appears highly likely that sufficient data have been collected to support a BACI analysis. Compared to the studies on OWF effects conducted in the German EEZ, effort and guillemot sightings collected via ship-based surveys (currently available through the ESAS data base) are available in a similar order of magnitude, which makes a successful analysis highly likely.

To date it is however impossible to assess the outline and precision of a potential BACI analysis, since several aspects concerning the amount of data available per OWF cluster and per data collection method (ship-based, aerial observer-based or digital surveys) are still partly unclear since the data is not yet entirely available to us. Relevant information per OWF cluster such as the surveys methods used, the area covered (in km^2), the weather conditions during the survey, and detailed sightings data for Common guillemots, Razorbills and individuals recorded as undetermined Auks would be required. Some of this information is openly available in the ESAS database (mainly for ship surveys in the focused area). However, key parts of this information could be located in some, but not all, of the available reports in such detail that conclusions on the data availability and quality would be possible on the spatial level of OWF clusters. This probably was due to the reports targeting different questions as the one targeted here. Consequently, our understanding on data availability, particularly for observer-based aerial surveys, remains incomplete. Once this data is accessible, the proportion of birds identified to species level in observer-based aerial surveys could be determined. As mentioned before, it would be necessary to evaluate the proportion of animals detected at species level on the specific area of interest. Without a better understanding on the proportion of species-level identification prior to 2014, it currently remains unclear whether these data can be included in the analysis. Thus, although we have identified necessary actions for a future analysis, such as compiling all data available across survey methods, and assessing the proportion of records identified to species level, some uncertainty remains regarding general aspects. These include the amount of survey effort available for each OWF and survey method, as well as the number of individuals determined to species level, during both the pre- and post- construction phases. Consequently, whether all operational OWF are to be included in the analyses, as well as the level of analytical precision that can be expected, is due to future analyses based on the entire dataset available.

Based on the current understanding of data availability, we assume that a BACI analysis will be feasible, either for single or clustered OWF. Given the temporal and spatial occurrence of Common guillemots in the Dutch North Sea, the analyses will likely focus on the winter and autumn seasons. Where possible, we aim to incorporate all available data collected through different survey methods into a combined analysis (Mercker et al. 2021, Garthe et al. 2023), while explicitly accounting for methodological limitations, such as those associated with aerial survey data collected before 2014.

Once all data sources have been compiled (a task that would be undertaken in a potential part B of the project), it will be possible to evaluate which OWF areas are adequately represented. Based on the available data, decisions will then be made regarding which OWF, and which survey methods can be included in the analysis. It will therefore be essential to obtain full access to all relevant datasets, in order to assess their quantity and quality and to further develop the analytical approaches. It could be valuable to include data collected by neighbouring countries that surveyed the areas of interest (see Figure S25 to S27). For example, data collected in Belgium, especially in and around the Belgian OWF located along the border to the Dutch EEZ, could be potentially included (see Figure S27 and S28). In the OWF as well as in control areas close by, data was collected monthly since the year 2009 via ship-based surveys (https://odnature.naturalsciences.be/mumm/en/windfarms/), thus a comparably good coverage would be available. This data could provide valuable additional information for the analysis because they covered the OWF regularly with ship surveys since 2009. Likewise, also data that was collected in the German EEZ could be included in an analysis.

Access to all available data is therefore important. The datasets should be provided as raw data collected with the different survey methods. Datasets should include the surveyed transects (latitude and longitude), the effort covered (in km^2), together with the weather conditions during the survey such as seastate, glare and turbidity. Moreover, it should include the sightings of Common guillemots, Razorbills and individuals recorded as undetermined Common guillemots / Razorbills/Auks collected, accompanied to latitude and longitude of the sightings and a position key to link to the basic information on the survey effort.

2. Survey methods: Data availability and challenges

2.1. Ship-based surveys

According to van Bemmelen et al. 2011, data on the distribution of seabirds and marine mammals on the Dutch Continental Shelf (DCS) were published in two atlases. One atlas was based on ship-based surveys (Camphuysen and Leopold 1994), while the other resulted from aerial surveys conducted as part of the monitoring program stablished in 1989 (Baptist and Wolf 1993). After publication of these atlases the aerial monitoring programme continued to the present day, but the ship-based surveys in the DCS became more ad-hoc, and project based. As a result, ship-based data on the distribution of seabirds in the DCS is unevenly distributed in time and space.

Ship-based observations, if merged, appear to have good coverage of the general DCS area prior to the start of OWF construction (Van Der Wal et al. 2010, Leopold et al. 2015) (Table S8 for overview of reports). In addition, many ship-based surveys were conducted in and around OWF prior to construction, given that pre-construction (T-0) monitoring is required (Leopold et al. 2010, Leopold 2012, van Bemmelen et al. 2015). Some ship-based surveys have also been carried out post-construction (T-1). The post-construction surveys were conducted to monitor impacts after the OWFs became operational, or to evaluate whether birds will recognise a corridor as a safe passage route through the wind farm (Leopold 2012, Leemans et al. 2024).

By 2020, ship-based surveys were no longer covering the entire Dutch EEZ, and only dedicated surveys were being conducted (ICES 2020). Moreover, for 2020-2026, the Marine Strategy Plan considers that counts of marine birds from ships are no longer required as part of the Marine Strategy Framework Directive (MSFD). This is due to improvements in counts from planes (Ministry of Infrastructure and Water Management 2020).

In 2024, van Donk, following an exploratory analysis, decided to not use ship-based survey data. This decision was based on the unbalanced nature of the ESAS dataset, which contains very limited data from the past 10-15 years. In addition, differences in observation methods within the ESAS database introduced analytical challenges, as the dataset includes both incidental and systematic observations. The problem with incidental and systematic observation is also highlighted in van Kooten et al. 2019, although here, the data was used (see Table S2 for details on the methodology used in this study).

Much of the ship-based survey data is publicly available for download in the ESAS database (see Table S4). This includes data from NIOZ (NLD-NIOZ) covering the period 1985-2008. For NIOZ, Kees Camphuysen is the point of contact, and additional data may exist and could be requested. Publicly available data also includes data from WMR (Wageningen Marine Research) covering the period 1993-2018. For WMR, Steve Geelhoed is the point of contact, and additional data may exist and could be requested. Mardik Leopold was listed in the ESAS publication for WMR (Reyserhove et al. 2021) but is now retired (Fijn *per. comm.*). Data from BuWa (Bureau Waardenburg) is also available in the ESAS database, but the data is "Restricted" and access needs to be granted. Ruben Fijn is responsible for this data (2004–2021: NLD-BuWa-SHIP) and a few additional surveys will likely be included over the coming winter (Fijn *per. comm.*).

2.2. Observer-based aerial surveys

In 1984, Rijkswaterstaat (the Dutch Ministry of Infrastructure and Water Management) began a routine inventory of seabirds and marine mammals at the DCS. At the time, a conscious decision was made to carry out this form of monitoring from airplanes. In 1989, this program was incorporated into the biological monitoring program of the then RIKZ (Rijksinstituut voor Kust en Zee), which is carried out within the framework of the Monitoring of the Hydrological State of the Country (MWTL: Monitoring Waterstaatkundige Toestand des Lands). The objective of this program is to describe changes in space and time in the numbers of seabirds and marine mammals in the North Sea (Arts 2015, van Bemmelen et al. 2022).

There is a distinction between the "old" MWTL and the "new" MWTL data collection (van Donk et al. 2024, Figure 1 & 2). Before 2014, during the old MWTL, the plane reached an altitude of 150 m (Baptist and Wolf 1993, Arts 2010) and at this height, species recognition was not always possible (van Donk et al. 2024). In addition, although there was a bubble window trial in 2011 (Fijn *pers. comm*), the bubble window was not used as a standard before 2014. Therefore, surveys prior 2014 were mainly carried out from aircrafts without protruding, convex windows, and the observers could not look straight down which created a blind spot underneath the plane (Poot et al. 2016) (Figure S9). It has however to be clarified if some surveys between 2011-2014 were conducted using bubble windows. Additionally, during observer-based aerial surveys previous 2014, birds were counted within defined narrow strips, which assumes that no detection loss occurs within the strip (Poot et al. 2016, Bos et al. 2023), but years of experience have shown that fewer birds were seen in the “old MWTL” compared to the “new MWTL” (Figure S9). After 2014, the method was revised, and during the revision, also the transect design was adjusted (Figure 1 & 2).

Starting from 2014, the new MWTL has been in effect (Arts 2015, ICES 2020). The survey design was restructured both temporally and spatially, shifting from a strip-transect analysis to line-transect (distance) analysis (Arts 2015, van Bemmelen et al. 2024). Moreover, after the redesign, a much denser network of transects across the density gradients of seabirds, was included, as well as extra counting efforts in the coastal zone and protected areas far out at sea (see Figure 2 left panel). The more extensive survey transect design resulted in a more even spread survey effort across the DCS compared to the survey design before 2014. In addition, these surveys were carried out in aircrafts with spherical windows, so that the area below the aircraft can also be observed. Moreover, flights were conducted at a lower altitude (75 m) and after this change, the lower flight height allowed identification to species level of almost all groups, including Common guillemot and Razorbill.

By 2020, the survey plan was revised again to increase the sampling effort in the coastal zone (ICES 2020) (see Figure 2 central panel). The new program comprises of two modules: (1) the DCS, which surveys the whole Dutch North Sea in August, November, January, February, April and June; and (2) Dutch Wadden Sea and Coastal Zone, which covers November and January, and occasionally March (ICES 2020). The construction of the first OWF in the Netherlands started in 2006. Observer based-aerial surveys in or close to OWF are mainly conducted at an altitude of 75 m (250 ft) and keep a certain distance to the OWF (Fijn *pers. comm*), in some OWF the survey transects were adjusted after OWF were constructed (see Figure 2). For example, the MWTL regular monitoring passes Gemini OWF in a certain distance (Fijn *pers. comm*), and through a corridor of Borssele, from 2023-onwards the area of Luchterduinen doesn’t seem to be covered (Figure 2 right panel).

Only very limited observer-based aerial survey data collected in the DCS are publicly available in the ESAS database (see Table S5). Ruben Fijn is responsible for MWTL plane surveys (1991–2021: NLD-MWTL), and as shown by the reports (Table S5 & S10), most observer-based aerial data are centralized in the MWTL database. Until 2022, the MWTL data is up to date in the ESAS database, but data access is restricted and needs to be granted. Data until June 2025 is expected to be included this winter (Fijn *pers. comm.*).

Figure 1. Observer-based aerial surveys: flying routes from 1991-2009. Taken from Arts 2010.

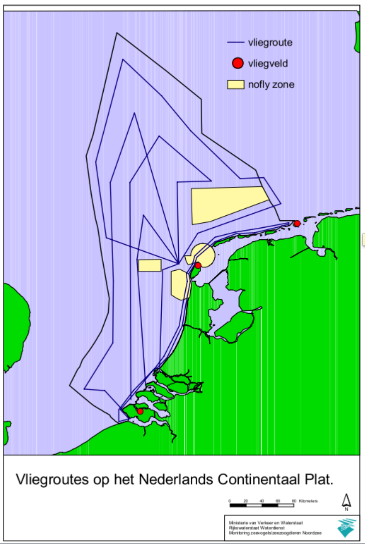
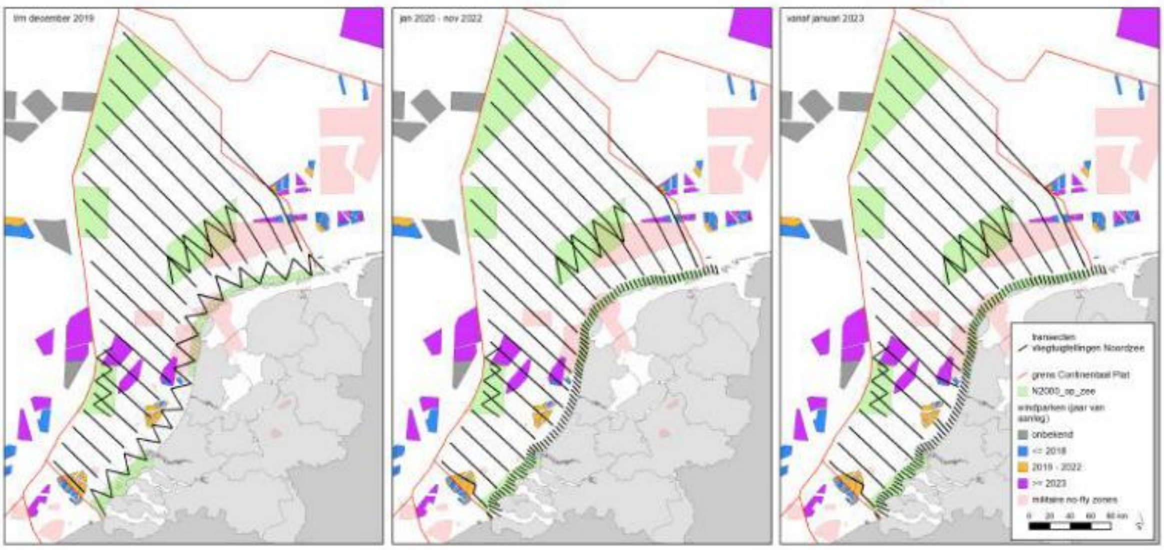


Figure 2. Observer-based aerial surveys: monitoring transects during 2014-2019 (left), from 2020-2022 (centre) and from 2023 (right). Note the change of design in the coastal transects and transects near offshore wind farms. Taken from van Bemmelen et al. 2024.

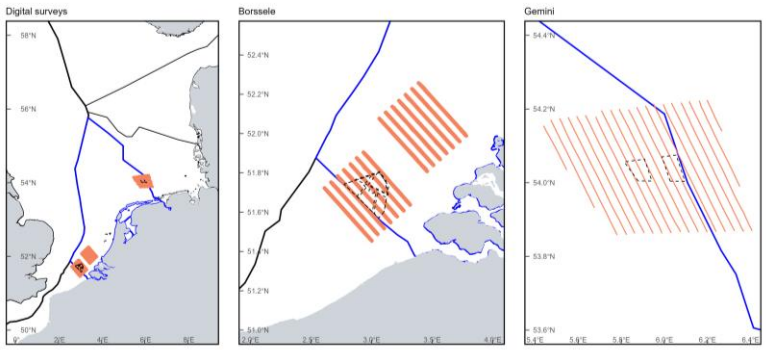


2.3. Digital aerial surveys

No digital surveys are conducted as part of a regular monitoring of the DCS. Two post OWF construction studies were identified (Figure 3, Table S11). One study conducted eight surveys in Gemini OWF. The first survey ran as a pilot study in March 2022, and seven surveys followed between October 2022 and March 2023 (Grundlehner et al. 2025). Another study includes those surveys conducted in Borssele OWF (Collier et al. 2022). Surveys from 2021 to 2022 are aggregated in six groups: 1 (13 and 20 February 2021), 2 (21 and 30 March, 8 and 22 April 2021), 3 (12 and 20 May 2021; 6 and 23 June), 4 (18 and 29 July; 13 and 29 August; 12 and 20 September 2021), 5 (9 and 23 October, 6 November, 1, 11 and 21 December 2021), and 6 (6 and 17 January; 5 February 2022) (Area surveyed is summarised in Table S7).

According to the Waardenburg webpage, digital survey datasets are managed by the MWTL programme (lead by Ruben Fijn). The data are stored by both the data owners (Rijkswaterstaat, Ecowende) and executors of the programs (Waardenburg Ecology) (Fijn *pers. comm;* Zomer *pers. comm.*). These datasets can be provided either by Waardenburg or by Rijkswaterstaat. Data from Collier et al. 2022 is also available for download from WOZEP, and access already was granted (Figure 3). Data from the OWF Gemini (Grundlehner et al. 2025) is freely available for download in a github repository but only contains data from one survey (Figure 3). There is additional data from a currently running project in OWF Hollandse Kust West. Those data are collected by Waardenburg (via HiDef/BioConsult) and paid for by an operator (Ecowende) (Fijn *pers. comm.*). Data acquisition and image analyses are still ongoing.

Figure 3. Digital surveys. Left: transects in Borssele OWF. Data from Collier et al. 2022. Available via WOZEP. Right: transects in Gemini OWF. Data from Grundlehner et al. 2025. Limited availability via github repository. Only data from one survey (2022-03-10) was available.



3. Offshore Wind Farms

By 2025, there are 10 operational Offshore Wind Farms in the Netherlands (Figure 4 and Table S12).

OWEZ and PAWP are the first OWF constructed, operating since 2007/2008, and are located in close proximity to each other (Figure 4, Table S13); therefore, they could be considered as a cluster for a potential analysis. Ship-based survey data was collected for both, the pre-construction (TO) (Leopold et al. 2010) and post-construction (T1) phases (Leopold 2008, Hartman et al. 2012) (Table 1). For the pre-construction phase (T0), a total of eight ship surveys were carried out, and six of these were repeated during the post-construction (T1) phase (Leopold et al. 2010). Data from these ship surveys for both T0 and T1 are publicly available in the ESAS database (see Figure S14 for coverage). With regards of observer-based aerial surveys, data collected by the MWTL program could be potentially used (considering only data previous 2014, when the survey methodology had not yet been revised). However, only by examining the data itself will we be able to assess how much information is available for the OWF areas and whether it is sufficient for an effect analysis.

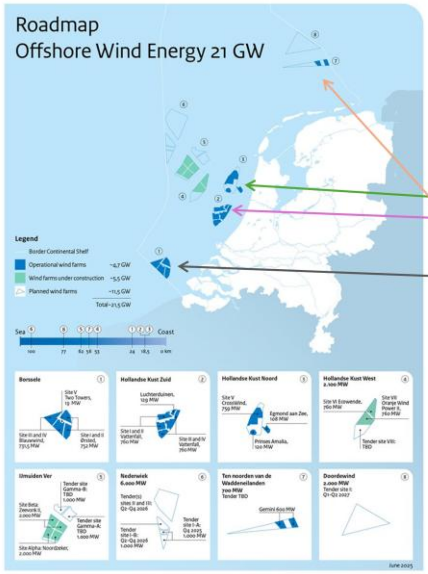
Luchterduinen, operational since 2015, could be considered another cluster. Ship-based surveys were conducted during pre-construction (Skov et al. 2015a), during construction (Skov et al. 2015b), and post-construction (Skov et al. 2016, 2017, Skov and Heinänen 2018) phases. However, this data is not publicly available at the ESAS database (Figure S15), thus data needs to be requested through Rijkswaterstaat. For observer-based aerial surveys, the MWTL methodology, might pose a challenge for this particular OWF, given that it includes the methodology change implemented in 2014. No digital survey covering this area were publicly found.

Gemini, operational since 2017, could be considered as its own cluster, as this twin OWF is well separated from the other OWFs in the DCS (Table S13). For Gemini, ship survey data was collected during the T0 phase (van Bemmelen et al. 2015). However, no post-construction ship-survey reporting seabirds was found. Ship surveys pre-construction are stored in the ESAS database and publicly available (Figure S16). Observer-based aerial surveys, such as those from the MWTL program, appear to cover the area, both pre- (Arts 2015) and post-construction (van Bemmelen et al. 2024). However, the change in methodology during pre-construction and post-construction represents a challenge. Additional data includes post-construction digital surveys which had been conducted within and around this OWF (Grundlehner et al. 2025). Data from digital surveys is partially available in a github repository (Figure 3), but the complete dataset needs to be requested either to Waardenburg or to Rijkswaterstaat.

Borssele I, II, III, IV and V, operational since 2020/2021, could also be considered as single cluster, as their construction periods overlap (Table S12) and they are spatially close (Table S13). For these OWFs, specific ship-based survey reports for T0 were not found; but there are ship-based surveys conducted, as part of other projects before construction started, which are available in the ESAS database (Van Der Wal et al. 2010, van Bemmelen et al. 2011, Leopold et al. 2015) (see Figure S17). Post-construction ship-based surveys were conducted inside the OWF, mainly along the shipping lane passing through the OWF, as the goal from this study was to evaluate if birds would use it as a corridor (Leemans et al. 2024). Although ship-based data until 2018 (before construction started) is available in the ESAS database, it doesn't include data collected along the shipping lane in 2021. Observer-based aerial surveys from MWTL likely provide good coverage of the area pre-construction (van Bemmelen et al. 2024). However, post-construction observer-based aerial surveys cover this area with only a single transect along the shipping lane (Figure 2). Given that the construction of this cluster began in 2020 and considering that six years of pre-construction data are ideal, data collected after 2014 could be used for the pre- and post-construction period (see Table 1 for timeline), ensuring methodological comparability. For this OWF, in addition, digital surveys have been performed post-construction (Collier et al. 2022) (effort in Table S7), although only one year of images had been analysed, the data is available in the WOZEP repository (Figure 4). Additionally, it might be very valuable to include data collected in and around the Belgian OWF located along the border to the Dutch EEZ (see Figure S27 and S28). This data could provide valuable additional information for the analysis because the OWF and surrounding areas were covered regularly with ship surveys since 2009.

The Hollandse Kust (Zuid): I, II, III and IV and Hollandse Kust (Nord): V possibly would be excluded from the BACI analyses because they were completed in 2023, and therefore post-construction data is most likely not sufficient. However, data that was collected in this areas pre-construction could be valuable to increase the data basis for the analysis.

Figure 4. Offshore wind farms in the Netherlands. Left: map taken from Noordzeeloket, also available at Rijkswaterstaat 2025. Numbers 1,2,3 and 7 (in blue) show operational OWFs by June 2025, whereas numbers 4, 5 and 8 (in green) show those commissioned that will become operational in the future. Right: Table with potential clusters of OWF for a BACI analysis. The table shows the start of the 6-year pre-construction data period, as well as the start of construction and operation.



Groups	OWF	6 years before (data needed)	Start of construction	Operational (post-construction)
1	Egmond aan Zee (OWEZ)	2000	2006	2007
1	Prinses Amalia Windparken (PAWP)	2000	2006	2008
2	Luchterduinen	2007	2013	2015
3	Gemini	2009	2015	2017
4	Borssele I & II: Ørsted	2014	2020	2020
4	Borssele III & IV: Blauwwind	2014	2020	2021
4	Borssele V	2014	2020	2021
	Hollandse Kust (Zuid): I and II	2015	2021	2023
	Hollandse Kust (Zuid): III and IV	2015	2021	2023
	Hollandse Kust (Noord): V	2015	2021	2023

Table 1. Timeline showing survey coverage (in years) separated by method (ship, plane and digital) and offshore wind farms (OWF).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Ship																										
Plane																										
Digital																										
OWF																										
OWEZ & PAWP			**T0**	**T0**	**T0**			**T1**	**T1**	**T1**	**T1**	**T1**	**T1**													
Luchterduinen														**T0**	**T0**	**T1**	**T1**	**T2**	**T3**							
Gemini													**T0**	**T0**									**D**			
Borssele																						**T1,D**	**T1**	**T1**		
Hollandse Kust Zuid																										
Hollandse Kust Noord																										

Ship: Yellow colours represent years in which surveys were conducted. Darker yellow tones are used to show years that coincide with project-based surveys (T0 and T1). **Plane:** Green colours represent years in which surveys were conducted. Darker tones are used to show the change in methodology (after 2014). **Digital:** Orange colours represent years in which surveys were conducted. Softer orange tones are used to represent years for which data might be available. **In the OWF section:** Yellow represent the pre-construction period (six years prior to the start of construction); Red represents the construction period; Dark purple represents the beginning of operation (if not coinciding with the year of end of construction); Soft purple represents the six-year period following the start of operation. **Letters:** the label T0 indicates years when pre-construction ship-based surveys were conducted, while T1, T2, and T3 indicate years when post-construction ship-based surveys were conducted. The label D indicates years when digital surveys were conducted.

4. Common guillemots

Based on the survey methods considered in this report (ship-based, observer-based and digital aerial surveys), all methods documented the occurrence of auk species (see Table S18 for an overview of the reports showing Common guillemot information).

Ship-based surveys have the advantage that species identification is generally straightforward. For example, in van Bemmelen et al. 2011, a very small proportion of the large alcids was left unidentified (0.8%), and of the remaining alcids, 88.7% was identified as Common guillemot and 10.6% as Razorbill. The main limitation of ship-based surveys probably is the restricted temporal and spatial coverage (see Table S4 for the survey coverage). For example, in cases when only single surveys with limited spatial and temporal coverage were used for evaluation, van Bemmelen et al. 2015 reported that in ship-based surveys in the area of Gemini OWF, some months had to be excluded because too few individuals were sighted in May, June, and August. However, July was retained because an unexpectedly high number of Common guillemots was recorded. This indicates that, depending on the spatial and temporal coverage, and the seasonal window surveyed, some areas and seasons may be more suitable for inclusion in the analyses than others. Combining multiple surveys can help address the issue, as low number of sightings may be confined to single surveys or seasons with low densities. It should therefore be assessed whether data adequacy improves when multiple sources, and several data collection methods, are integrated.

For observer-based aerial surveys, temporal and spatial coverage doesn't seem to be a limitation, but methodological changes before and after 2014 need to be taken into account. Before 2014, the potential absence of bubble windows, and thus the transect line not visible under the plane, may have resulted in fewer animals reported during these surveys (see Figure S9). Another aspect to consider is that, due to survey altitudes, before 2014 surveys did not reliably distinguish between Common guillemot and Razorbills (van Donk et al. 2024). Since data from the Dutch monitoring program for observer-based aerial survey were not publicly available in the ESAS database, the proportion of auks identified to species level before 2014 currently remains unknown. The only available observer-based aerial data from surveys crossing the Dutch EZZ stems from the German monitoring program (see Table S3 for number of Common guillemots, Razorbills, undetermined Common guillemots / Razorbills and unidentified auks), but this proportions does not represent the MWTL dataset. After 2014, the proportion of unidentified auks in the MWTL dataset also remains unclear for most areas and time periods (but see Table S1, which presents the proportion of identified auks per surveys conducted in 2023 and 2024, van Bemmelen et al. 2024). Nevertheless, due to the change in survey methodology after 2014 leading to improved species-level detection, this aspect might not pose a challenge for the analysis. To address the issue of individuals not determined to species level, some studies using observer-based aerial surveys after 2014, have estimated the proportion of each species, and applied these proportions to assign species to undetermined Common guillemots / Razorbills (information on the approach and the respective correction factors can be found in Table S1 and S2; estimated proportion of undetermined species from observer-based aerial surveys in Table S3).

For digital surveys, temporal and spatial coverage in the Netherlands is currently limited to two areas (see Figure 3). In addition, comparable identification challenges as those known from observer-based surveys occur. Digital surveys often cannot reliably differentiate between Common guillemots / Razorbills in the footage (Collier et al. 2022, van Bemmelen et al. 2024, Lerma et al. in prep.). As a result, digital surveys frequently report a considerable proportion of unidentified Common guillemots / Razorbills observations (Collier et al. 2022, Lerma et al. in prep.). To address the issue of indistinguishable species, as also mentioned for observer-based aerial surveys after 2014 (van Bemmelen et al. 2024), an option is to estimate the proportion of each species and apply this ratio to individuals not identified to species level. However, a decision on how to deal with these issues can only be made when working on the data itself.

Beyond methodological considerations, it is necessary to evaluate whether sufficient Common guillemot data exist across the different OWFs and to identify which season yields to the best coverage. Spatial and temporal variation in the number of auks present in the different areas of the Dutch EEZ stills needs to be explored when working on the entire dataset. The information provided in the available reports suggests that Common guillemots occur in highest densities in winter and autumn (Arts 2013, van Bemmelen et al. 2015, Collier et al. 2022, Leemans et al. 2024, Grundlehner et al. 2025). The largest numbers are recorded in August and September, with estimates reaching up to 491,300 individuals (van Bemmelen et al. 2024). During the rest of the year, the highest densities are reported for April with 118,200, February with 104,400 and January with 60,800 individuals (van Bemmelen et al. 2024). Regarding the spatial distribution, van Bemmelen et al. (2024) and van Donk et al. (2024) show that the highest densities during August and September occur in the northern and north-eastern Dutch Continental Shelf (see Table S18 for corresponding maps). The Frisian Front also appear of particular importance during this period as in August 84,700 individuals remained in this area (van Bemmelen et al. 2024). Moreover, the Frisian Front is important outside this period as well, as moulting birds and parent-chick pairs gather there during summer (Leopold et al. 2015). During other months, Common guillemots appear to be more evenly distributed**,** with relatively higher densities in the north and north-west of the DCS. Based on the current knowledge, an analysis focusing on one or two seasons, most likely species-specific autumn (from 16.07 to 30.09) and winter (from 01.10 to 29.02) appears justified. However, a key next step is to formally assess the temporal and seasonal coverage to determine which OWF clusters and which seasons are most appropriate to focus on.

If data on Common guillemots is scarce for some seasons or areas, some studies have opted to group Common guillemots with Razorbills. However, this would be not considered for the planned analyses as the aim is to investigate the effect of the OWF at the species level and grouping both species together could lead to confounding results. Common guillemots have been found to avoid OWF more strongly and up to further distances, while Razorbills may avoid them less (Peschko et al. 2025), be indifferent to them (Collier et al. 2022) or occur in larger groups inside the OWF (Leemans et al. 2024). A well-informed decision on how to address the mentioned issues can only be made once all relevant data is available, enabling analysis of the complete dataset.

Table 2. Total number of observations per auk species, area surveyed (km^2), and densities per season. Seasons are defined as follows: Winter from 01.10 to 29.02, Spring from 01.03 to 15.0, Summer from 16.04 to 15.07, and Autumn from 16.07 to 30.09. Seasons slightly modified from Garthe et al. 2007. Data sources: Ship surveys: data from the ESAS database from 2000 to 2023 (increasingly incomplete data after 2017, see Table S4 for coverage). Densities are not distance corrected. Digital surveys: data from WOZEP database (limited to the OWF Borssele) from 2021-2022. Distance correction is not applicable for digital surveys. Digital survey data from Grundlehner et al. 2024 were not included as it was incomplete. With regards to observer-based

aerial surveys only data collected during German surveys was available in the ESAS database, thus numbers are not representative and are therefore not included. Caution should be taken when interpreting these values as densities vary according to the area and season surveyed.

Ship surveys			
Common Guillemot	n	Area (km²)	Density
Winter	52835	11841	4.46
Spring	4953	3634	1.36
Summer	5052	5460	0.93
Autumn	27764	6213	4.47
Razorbill			
Winter	17693	11841	1.49
Spring	4157	3634	1.14
Summer	206	5460	0.04
Autumn	401	6213	0.06
Razormot			
Winter	6742	11841	0.57
Spring	473	3634	0.13
Summer	27	5460	<0.01
Autumn	167	6213	0.03
Unidentified auk			
Winter	5	11841	<0.01
Spring		3634	<0.01
Summer		5460	<0.01
Autumn	7	6213	<0.01
Digital			
Common Guillemot	n	Area (km²)	Density
Winter	11991	2933	4.09
Spring	3083	860	3.58
Summer	96	1393	0.07
Autumn	163	1704	0.10
Razorbill			
Winter	6385	2933	2.18
Spring	990	860	1.15
Summer	1	1393	< 0.01
Autumn	9	1704	0.01
Razormot			
Winter	3671	2933	1.25
Spring	1027	860	1.19
Summer	13	1393	0.01
Autumn	28	1704	0.02
Unidentified auk			
Winter	76	2933	0.03
Spring	37	860	0.04
Summer	5	1393	< 0.01

5. Assessment of the applicability of a BACI analysis for OWF effects on Common guillemots in the Netherlands based on available data

Based on the current understanding of data availability, we assume that a BACI analysis will be feasible, either for single or clustered OWF. Compared to the studies on OWF effects conducted in the German EEZ, effort and guillemot sightings collected via ship-based surveys (as currently available through the ESAS data base) are collected in a similar order of magnitude, which makes a successful analysis highly likely.

To date it is however impossible to assess the outline and precision of a potential BACI analysis, since several aspects concerning the amount of data available per OWF cluster and per data collection method (ship-based, aerial observer-based or digital surveys) are still partly unclear because the data is not yet entirely available to us. We found that little information is currently available on the survey effort collected through observer-based aerial surveys. These data were not publicly available in the ESAS database, and key details, such as total area covered and the number of individuals recorded per season, could be located in some, but not all, of the available reports. Consequently, our understanding on data availability of observer-based aerial surveys remains incomplete. Furthermore, because these data were not accessible, the proportion of birds identified to species level in observer-based aerial surveys could not be determined. Without a clearer understanding on the proportion of species-level identification prior to 2014, it remains unclear whether these data can be included in the analysis.

Thus, although we have identified necessary actions for a future analysis, such as compiling all data available across survey methods, and assessing the proportion of records identified to species level, some uncertainty remains regarding general aspects. These include the amount of survey effort available for each OWF and survey method, as well as the number of individuals determined to species level, during both the pre- and post- construction phases. Consequently, whether all operational OWF are to be included in the analyses, as well as the level of analytical precision that can be expected, is due to future analyses based on the entire dataset available.

Based on the current understanding of data availability, we assume that a BACI analysis will be feasible, either for single or clustered OWF. Given the temporal and spatial occurrence of Common guillemots in the Dutch North Sea, the analyses will likely focus on the winter and autumn seasons. Where possible, we aim to incorporate all available data collected through different survey methods into a combined analysis (Mercker et al. 2021, Garthe et al. 2023), while explicitly accounting for methodological limitations, such as those associated with aerial survey data collected before 2014.

Optional next steps for a potential part B of the project

In part B it will be essential to obtain access to all relevant datasets available in order to assess their quantity and quality (see Table 3) and to further develop the analysis approaches. Data collected in Belgium would be valuable to consider, as the OWF and the surrounding areas have been regularly covered by ship-based surveys since 2009, thereby providing important additional information. If data from Belgium would be included, authorities and data owners will be contacted.

With access to all data available, the next step would be the harmonisation of the datasets, to allow inclusion of all data in the analysis. Based on the current data overview, a reliable estimate of the time required for data harmonisation is difficult, as not all datasets are currently available.

After all data sources have been gathered, a final data driven evaluation can be conducted to determine which OWF areas are sufficiently represented, it will then be decided which OWF can be included in the analysis. It will be furthermore important to investigate the proportion of records identified to species level per survey method, with a special focus on the data collected via observer-based aerial surveys conducted before 2014. Based on this evaluation decisions will be made regarding which datasets and survey methods can be included in the analysis.

Once data harmonisation is complete, final decisions regarding the inclusion of survey methods have been taken, the OWF have been selected, and all remaining issues have been resolved, a BACI analysis could be conducted. We would focus the BACI analysis on the most important season(s) for Common guillemots in the DCS and on the OWFs with sufficient data availability. The dataset would be divided into pre- and post-construction periods, and if appropriate the OWFs would be grouped into clusters that are analysed collectively.

Table 3. Databases and overview of data availability separated by survey method.

Ship-based surveys	Observer-based aerial surveys	Digital aerial surveys
•ESAS (ICES) Public https://esas.ices.dk/inventory ✓ Contains: T0 and T1 data from OWEZ and PAWP, Gemini and Belgium × Missing: Luchterduinen data collected by ENECO (Skov et al. 2015b, 2016, 2017), & Borssele data collected by Waardenburg (Leemans et al. 2024). ✓WOZEP contains Ship data from an area close to Borssele (Figure S25) • Additionally: Contact Steve Geelhoed (steve.geelhoed@wur.nl) and Kees Camphuysen (kees.camphuysen@nioz.nl) to confirm that no additional datasets remain to be included.	• ESAS (ICES) Public ✓ Contains data from surveys from 2011-2016, but only data collected as part of German monitoring programme. All observer-based aerial survey data thus needs to be requested. • ESAS (MWTL) Restricted A new update is planned to include data up to June 2025 (Fijn *pers.comm.*). (r.fijn@waardenburg.eco)	✓WOZEP (Wind op zee ecologisch programma) contains Digital data from Collier et al. 2022. ×Github contains Digital data from Grundlehner et al. 2025 but incomplete. •Missing datasets can be provided either by Waardenburg or by Rijkswaterstaat.

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7. Supplementary materials

Table S1. From van Bemmelen et al. 2024 using observer-based aerial surveys: The ratio between species is less skewed among auks, guillemots and gulls. In order to include undetermined birds in the population estimates for these species groups, the following methodology was used. First, a distance analysis was performed for each species. The population estimates per survey and area are then corrected on the basis of the ratio between the species within the individuals that have been identified with certainty and the percentage of unidentified individuals. For example, if nalk is the number of auks observed, nzeekoet is the number of guillemots observed, and nalk/zeekoet is the number of undetermined auks, then the percentage of auks among the identified birds is palk= nalk /(nalk + nzeekoet) and the correction factor can be calculated as (nalk + nalk/zeekoet* palk)/ nalk. Because the undetermined individuals are distributed among the species according to the ratio among the determined individuals, the correction factor within a survey is the same for all species within the species group. Below: from van Bemmelen et al. 2024 Table 78. Per species and survey, the percentage of unidentified individuals within the same species group and the correction factor to include unidentified individuals in the population estimates.

soortgroep	**telling**		**correctiefactor**
species group	*survey*	$p_{unidentified}$	*correction factor*
alken	2023-08	0.0006	1.0006
	2023-11	0.0037	1.0037
	2024-01	0.0183	1.0186
	2024-02	0.0019	1.0019
	2024-04	0.0116	1.0117
	2024-06	0.0000	1.0000

Table S2. Methods used by van Kooten et al. 2019 for modelling species distribution from different data sources.

For modelling at-sea seabird distribution, data are needed on seabird counts at sea (density estimates) that are geo-referenced. We used two sources of data: (1) the ESAS (European Seabirds At Sea) database (mostly ship-based counts of seabirds), kept at JNCC, Aberdeen, covering the entire North Sea. And (2) the MWTL database (Monitoring Waterstaatkundige Toestand des Lands, plane-based counts, available via Noordzeeloket, Rijkswaterstaat), for the Dutch section of the North Sea only, also including the ship-based Shortlist Masterplan Wind data collected in 2010-2011 (Van Bemmelen et al. 2011). ESAS contains both ship-based (ESAS-ship) and aerial surveys (ESAS-fly), which were treated separately. From each database, only observations were used from 1991 to the most recent data available (2017). For an overview of the locations of observations in these two data sets, see Figure 2.1.

ESAS ship. ESAS sampling effort is strongly directed by specific projects often connected to wind farm locations or special protection zones. The ship-based observations in ESAS are made using a strip-count with series of strips on one or both sides of the ship. Based on density sampling theory and on the assumption that the birds were evenly distributed before the observing ship entered the area, and that equal densities should be present at all distances from the ship's track line, species-specific correction factors were derived to compensate for birds missed at greater perpendicular distances (Table 4.2 in Leopold et al. 2014, for details see Fijn et al. 2015).

MWTL. The survey design of this programme has been restructured both temporally and spatially in 2014 and was shifted from a strip-transect analysis to line-transect (Distance) analysis. In the analysis we did not correct for this transition in methods. Sampling surface was calculated as effective-strip-width × speed × time. For methods used to arrive at densities see Van der Wal et al. (2018).

Table 2.1. The selected months for every species used in the habitat and IBM models.

species	selected months	period for which a habitat model was constructed	data source used
red-throated diver	Oct-March	non-breeding season	MWTL
northern gannet	Sept-March	non-breeding season	ESAS + MWTL
northern gannet	April-Aug	breeding season	ESAS + MWTL
sandwich tern	April-August	breeding season	MWTL
razorbill	Oct-March	non-breeding season	ESAS + MWTL
common guillemot	July-April	non-breeding season	ESAS + MWTL

Table S3. Observer-based aerial surveys available in the ESAS database, collected via German aerial surveys: number of individual auks, separated between Common guillemot, Razorbills, Razormot (Common guillemot/Razorbill) and unidentified auks. Number of individuals is presented per year, and the proportion was calculated based in the total auk observations (sum of all species). Data was obtained from the publicly available information in the ESAS database, limited to data collected via German aerial surveys, and limited to the area that crossed the Netherlands.

Plane	Common Guillemot	Razorbill	Common Guillemot/ Razorbill	Unidentified Auk	Total	Proportion Guillemots
2011	213		140		353	60.34
2012	58	2	2		62	93.55
2013	146	52	56		254	57.48
2014	646	21	218		885	72.99
2015			36		36	
2016	317	39	242	33	631	50.24

Table S4. Ship-based surveys: area in km² per bimonthly period. The total was calculated summing the values in column „Area". Data was obtained from the ESAS database and cropped to the area within the Dutch EEZ (see also attached figure). Surveys include data from other countries that entered the Dutch EEZ, such as Germany, Belgium and the UK. Originally data included the period from 1981 to 2023, but here presenting from 2000 onwards.

	Period 1 August September	Period 2 October November	Period 3 December January	Period 4 February March	Period 5 April May	Period 6 June July
2000	28.0	7.2	*NA*	86.0	29.2	*NA*
2001	9.2	5.6	45.7	32.5	7.7	137.5
2002	528.5	336.2	121.5	40.9	5.7	449.2
2003	531.5	699.7	*NA*	91.4	1021.0	711.1
2004	17.7	1.1	97.8	415.7	1.3	97.1
2005	87.2	399.5	276.2	176.8	7.1	303.6
2006	78.5	1.9	217.1	230.1	277.7	432.8
2007	608.6	450.6	3.3	4.3	494.1	385.0
2008	872.7	410.4	341.4	32.5	484.3	505.3
2009	433.5	941.9	239.3	15.5	399.4	502.1
2010	635.1	322.6	562.8	572.2	411.1	500.9
2011	181.2	835.0	239.3	329.6	9.3	63.5
2012	4.4	567.1	908.4	654.5	345.1	797.5
2013	373.1	3.7	576.0	398.0	397.8	5.8
2014	13.8	9.2	2.5	167.9	10.9	4.0
2015	2.1	*NA*	2.8	5.4	9.2	6.0
2016	6.7	492.3	1.7	325.8	5.4	24.4
2017	2.0	107.6	229.9	137.3	11.3	225.4
2018	2.0	133.8	0.9	*NA*	*NA*	368.4
2019	*NA*	*NA*	*NA*	*NA*	5.4	*NA*

2020	*NA*	*NA*	0.3	*NA*	*NA*	10.9
2021	*NA*	*NA*	*NA*	13.4	*NA*	*NA*
2022	14.8	9.2	11.0	*NA*	9.6	9.9
2023	*NA*	12.1	11.1	8.2	12.9	*NA*

Table S5. Observer-based aerial surveys: area in km² per bimonthly period. The total was calculated summing the values in column „Area". Data was obtained from the ESAS database and cropped to the area within the Dutch EEZ. Surveys include data from other countries that entered the Dutch EEZ, such as Germany. Only data collected via German surveys were included in the ESAS database, thus the reported effort and sightings is very low (see also attached figure).

	Period 1 August September	Period 2 October November	Period 3 December January	Period 4 February March	Period 5 April May	Period 6 June July
2011	24.8					
2012	1.5				2.3	
2013				8.4		
2014	17.8			5.3		
2015						17.2
2016			15.08	16.5	6.0	24.4

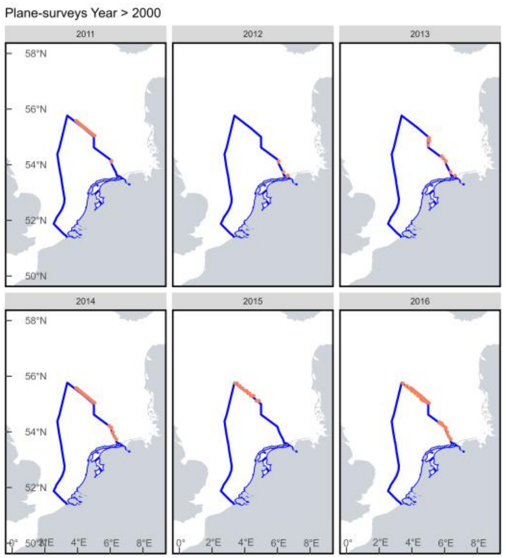


Table S6. Observer-based aerial surveys: area in km^2 from observer-based aerial (plane) surveys (copied from Arts 2015) per bimonthly period. The total area surveyed was copied from the report. Only data from 2000-2013 is presented.

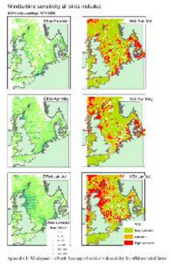
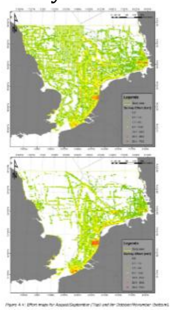
	Period 1 August September	Period 2 October November	Period 3 December January	Period 4 February March	Period 5 April May	Period 6 June July
2000	186	291	275	302	285	359
2001	345	448	332	412	384	368
2002	404	416	432	396	401	309
2003	302	376	404	394	396	272
2004	349	423	424	353	349	383
2005	378	368	480	409	378	406
2006	422	262	346	135	370	353
2007	535	451	627	*NA*	365	361
2008	456	*NA*	356	545	352	384
2009	383	457	451	397	376	374
2010	449	436	484	612	329	347
2011	441	453	525	375	447	386
2012	384	469	460	368	*NA*	*NA*
2013	NA	838	839	742	194	211

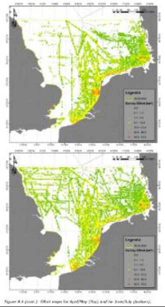
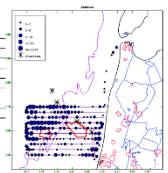
Table S7. Digital aerial surveys: area in km² from surveys per bimonthly period. Data collected from Wozep and github. The total area was calculated summing the values in column „PIC_AREA_ANALYSED".

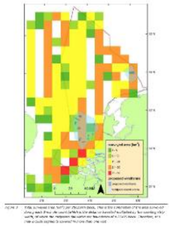
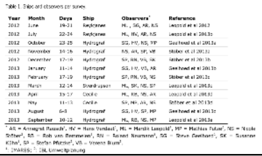
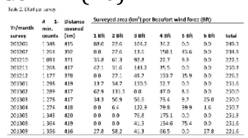
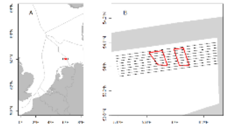
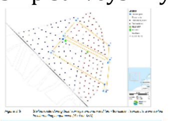
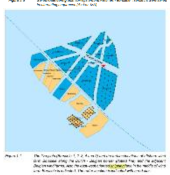
	Period 1 August September	Period 2 October November	Period 3 December January	Period 4 February March	Period 5 April May	Period 6 June July
2020						
2021	1133.8	796.9	647.9	1163.6	1179.8	1075.3
2022			588.3	304.0, 411.3*		
2023						

*Gemini OWF (Grundlehner et al. 2024). Only data from one survey is publicly available.

Table S8: The table gives an overview on the reports presenting data collected via ship-based surveys. The time frame of the data, frequence of coverage, transect lines/effort, data set, data manager, data collection program and contact person/reference are shown. Organized in chronological order according to the first year represented in the data.

Time Frame	Frequence of Coverage	Study area/transect lines/effort	Dataset	Data manager	Data collection programme	Contact person/Reference
1979-2009	Bimonthly periods (cumulative data for 1979-2009).	 Note that: Effort in most seasons is concentrated in waters that are relatively close to shore, while the Central North Sea is underrepresented.	Using the European Seabirds At Sea database (ESAS) that holds densities of all seabirds, across the entire North Sea, for all seasons.	ESAS (ICES)	Data was not collected. ESAS DB was used.	ESAS database ✓ Public Author: (Van Der Wal et al. 2010)
1990-2014	Combines ship and plane surveys: Coverage has been unequal, both between seasons and between various regions within the southern North Sea. In August/September, the whole area has been covered (but note that effort of all survey years has been combined). In the other seasons, the eastern parts of the southern North Sea: the Belgian and Dutch	Combines ship and plane surveys: 	The original data on seabird distributions and densities that were available for this study came from two sources, the ESAS-database and the MWTL North Sea Monitoring program. Three separate databases were created: 1) ESAS ship 2) ESAS fly 3) MWTL fly From each database only observations were used	ESAS database (ICES) for ship surveys (see Table S9 for plane surveys).	The latest available ESAS-database (http://jncc.defra.gov.uk/ page-4469) used was v5 ESAS, to which several Dutch ship-based surveying trips were added that were not yet included. After additional checks on the quality and integrity of the data in this updated version (v6) the data was released for use in producing the density maps of seabird distribution.	ESAS database ✓ Public Author: (Leopold et al. 2015)

	Continental shelves and the inner German Bight tend to have been covered (much) better than UK waters, particularly the waters off Norfolk.		from year>1990, i.e. data from 1991 to the most recent data available (March 2014).		ESAS contains both ship-based and aerial surveys, that were treated separately.	
1991-2022	After exploratory analyses, only MWTL data was included in the analyses due to unbalanced data in the ESAS data base; there is almost no data of the last 10-15 years outside the Dutch part of the North Sea. The imbalance of the national and international data was known before starting.	Not shown. Ship-based (ESAS) data were excluded because the dataset was unbalanced and inconsistent across time and space.	Not collected during the study. ESAS database was used. **Table 2-1** Data and covariates that are used or explored in the analyses Type of data / Source / Time period / Frequency ESAS raw data / available at ESAS (ICES datacenter) MWTL data [illegible] / 1991-2022 / Date time stamp for every observation	Data managed by INBO, requested from Waardenburg Ecology.	The ESAS database includes mostly ship-based counts of seabirds in the greater North Sea.	ESAS database ✓ Public Author: (van Donk et al. 2024)
2007-2008	During the first full year of T-1 seabirds studies, six surveys have been completed. **Survey / from / to / Survey vessel** April 2007 / 9/04 / 12/04 / Vos Baltic June 2007 / 27/06 / 29/06 / Vos Baltic August 2007 / 19/08 / 22/08 / SC41 (Osterems) September 2007 / 24/09 / 27/09 / SC41 (Osterems) November 2007 / 5/11 / 6/11 / Vos Baltic November 2007 / 20/11 / 24/11 / Vos Baltic January 2008 / 14/01 / 18/01 / TX33 (Maarten Cornelis)	Ship survey for the OWF Egmond (OWEZ)  Figure 44. Distribution of Guillemots during the main survey (14-17 January 2007), showing an inshore concentration and a much larger concentration in the NW corner (west of the -20 m isobath) of the study area. Note that the ten transect lines were only surveyed once and that a second run might have filled in some to the gaps within this distribution pattern.	Collected during the study. [IMARES Wageningen]()	Study by IMARES Wageningen	IMARES: The institute changed its name in 2016 from IMARES (Institute for Marine Resources & Ecosystem Studies) to Wageningen Marine Research (WMR).	ESAS database ✓ Public Author: (Leopold 2008)
2010-2011	From April 2010 till February 2011 11 (= monthly) surveys, totalling to 48 at-sea days, 4610 5-minute counts were conducted over a distance of 9021 km	Due to changes in the design of the survey grid, the use of several ships, spells of bad weather conditions and seasonal differences in the number of daylight hours, the resulting coverage is not evenly spread in space and	Collected during plankton surveys. Note: After many years of little or no effort in far offshore areas of the DCS, this series of surveys provided the first recent	Study by IMARES Wageningen	During April 2010 – February 2011, monthly surveys of seabirds and marine mammals were conducted aboard ships engaged in plankton surveys	ESAS database ✓ Public Author: (van Bemmelen et al. 2011)

		time. 	ship-based data on seabirds, covering a large area (the entire Dutch Continental Shelf (DCS), including some Belgian and British waters) almost year' round.			
2012-2013	In total, 12 surveys were carried out, using four ships and a team of 11 observers from IMARES and IBL Umweltplanung. 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. 	Ship survey for the OWF Gemini (T0)  	Collected during the study. [IMARES Wageningen](#) and IBL Umweltplanung Note that the study cites: 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 However, it might reflect that point of time, and currently by mixing with other methods data might suffice.	IMARES Wageningen and IBL Umweltplanung	IMARES changed name to WMR, Wageningen Marine Research, mentions ESAS database.	ESAS database ✓ Public Author: (van Bemmelen et al. 2015) Wageningen (https://www.wur.nl/en/show/Counting-seabirds.htm), which refers back to ESAS
2021-2023	Ship surveys planned once a month from December 2021 to December 2023, in total 20 surveys from 24 originally planned were made. The surveys were made in the area inside the OWF.	Ship surveys in yellow.  	Note that this study focuses in evaluating the use of a corridor inside the wind farm by birds. In Borssele, a designated shipping lane, also referred to as a corridor, was established to facilitate vessel traffic, not for birds; but it was thought that birds will habituate and start using it.	The results gathered during this study, in combination with the results of other Wozep projects.	Data were collected during ship-based surveys from the Rijkswaterstaat (RWS) vessel 'Scheldestroom', following the European Seabirds At Sea (ESAS) protocol (Camphuysen et al. 2004). × Not found Wozep: Data was not found in https://wozep.nl/en/data-overzicht/ and not included in the ESAS DB.	Author: (Leemans et al. 2024) × Not in the Public ESAS DB

<table>
<tr>
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<td>
Table 2.2 Date, direction in which the transects were sailed (from point A to J, or the other way around, see Figure 2.5) and weather conditions during the boat surveys.
<table>
<tr><th>Date</th><th>Direction</th><th>Sea state</th><th>Wind</th><th>Temperature</th><th>Visibility</th></tr>
<tr><td>14-12-2021</td><td>A > J</td><td>2-3</td><td>SW4</td><td>10</td><td>>10 km</td></tr>
<tr><td>25-01-2022</td><td>J > A</td><td>1</td><td>N3</td><td>4</td><td>2-5 km</td></tr>
<tr><td>08-03-2022</td><td>A > J</td><td>2-3</td><td>S4</td><td>11</td><td>>10 km</td></tr>
<tr><td>22-04-2022</td><td>J > A</td><td>4-5</td><td>NE6</td><td>11</td><td>>10 km</td></tr>
<tr><td>31-05-2022*</td><td>A > J</td><td>2</td><td>W3</td><td>13</td><td>>10 km</td></tr>
<tr><td>21-06-2022*</td><td>J > A</td><td>2</td><td>NE3</td><td>15</td><td>6-9 km</td></tr>
<tr><td>29-07-2022</td><td>A > J</td><td>2</td><td>N3</td><td>18</td><td>>10 km</td></tr>
<tr><td>26-08-2022</td><td>J > A</td><td>3</td><td>N4</td><td>18</td><td>>10 km</td></tr>
<tr><td>30-09-2022</td><td>A > J</td><td>2-3</td><td>SW5</td><td>15</td><td>>10 km</td></tr>
<tr><td>14-10-2022*</td><td>J > A</td><td>2</td><td>SW4</td><td>15</td><td>>10 km</td></tr>
<tr><td>06-12-2022</td><td>A > J</td><td>3</td><td>N4</td><td>8</td><td>>10 km</td></tr>
<tr><td>08-02-2023</td><td>A > J</td><td>2</td><td>S3</td><td>5</td><td>>10 km</td></tr>
<tr><td>14-02-2023</td><td>J > A</td><td>2</td><td>S2</td><td>8</td><td>6-9 km</td></tr>
<tr><td>17-03-2023</td><td>A > J</td><td>1-2</td><td>S3</td><td>12</td><td>>10 km</td></tr>
<tr><td>27-05-2023</td><td>J > A</td><td>3</td><td>NE4</td><td>12</td><td>>10 km</td></tr>
<tr><td>13-06-2023</td><td>A > J</td><td>2-3</td><td>NE5</td><td>21</td><td>>10 km</td></tr>
<tr><td>11-07-2023</td><td>J > A</td><td>3</td><td>SW5</td><td>19</td><td>>10 km</td></tr>
<tr><td>15-08-2023</td><td>A > J</td><td>2</td><td>SW3</td><td>18</td><td>>10 km</td></tr>
<tr><td>06-09-2023</td><td>J > A</td><td>1</td><td>E2</td><td>25</td><td>>10 km</td></tr>
<tr><td>01-12-2023</td><td>A > J</td><td>2-3</td><td>E4</td><td>3</td><td>>10 km</td></tr>
</table>
*Both sides of ship counted
</td>
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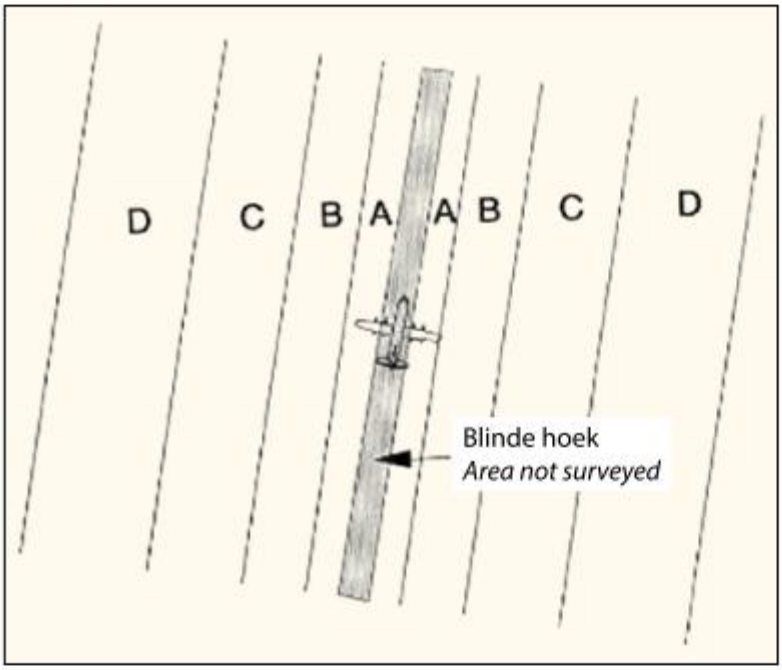
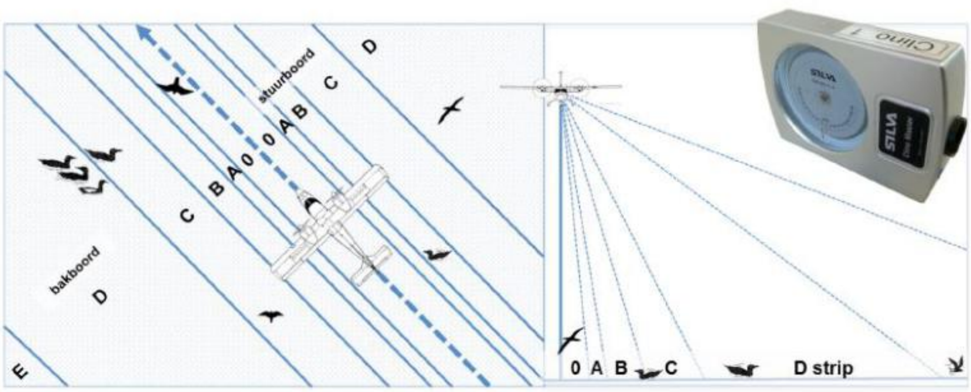
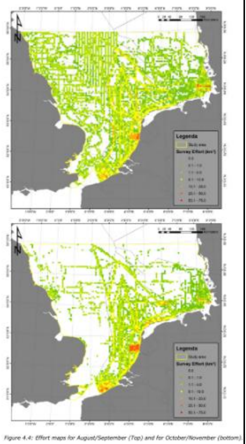
Figure S9. Observer-based aerial surveys method description. Upper: Below the plane there is an area where birds cannot be seen (taken from Poot et al. 2016). Lower: Schematic representation of the strip transects from the survey plane in top view (left) and front view (right). Angles of strip boundaries are measured with a clinometer (inset) (taken from van Bemmelen et al. 2024).

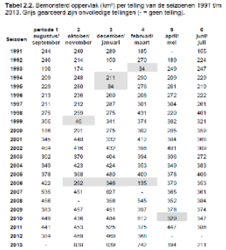
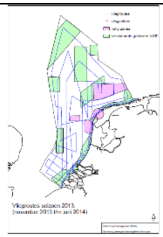
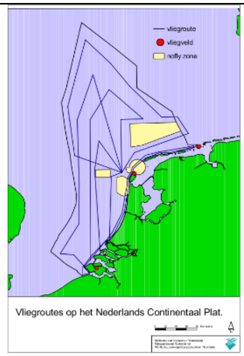
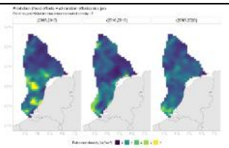




Figuur 5 *Schematische weergave van afstandsbanden vanuit een vliegtuig in bovenaanzicht (links) en vooraanzicht (rechts). De hoeken behorende bij afstandsbandgrenzen zijn hellingshoeken (zie tabel 2.1) en worden gemeten met een clinometer (inzet).* Schematic representation of strip transects from the survey plane in top view (left) and front view (right). Angles of strip boundaries (see table 2.1) are measured with a clinometer (inset).

Table S10. The table gives an overview on the reports presenting data collected via observer-based aerial surveys. The timeframe of the data, frequence of coverage, study area/transect lines/effort, dataset, data manager, data collection program and contact person/ reference are shown. Organized in chronological order according to the first year represented in the data.

Time Frame	Frequence of Coverage	Study area/transect lines/effort	Dataset	Data manager	Data collection program	Contact person/Reference
1990-2014	Combined plane +ship. Coverage has been unequal, both between seasons and between various regions within the southern North Sea. In August/September, the whole area has been covered best (but note that effort of all survey years has been combined). In the other seasons, the eastern parts of the southern North Sea: the Belgian and Dutch Continental shelves and the inner German Bight tend to have been covered (much) better than UK waters, particularly the waters off Norfolk.	Combined plane +ship. 	The original data on seabird distributions and densities that were available for this study came from two sources, the ESAS-database and the MWTL North Sea Monitoring program. Three separate databases were created: 1) ESAS ship 2) ESAS fly 3) MWTL fly From each data base only observations were used from year>1990, i.e. data from 1991 to the most recent data available (March 2014).	ESAS database (ICES) and MWTL (Waardenburg)	The latest available ESAS-database (http://jncc.defra.gov.uk/page-4469) used was v5 ESAS, to which several Dutch ship-based surveying trips were added that were not yet included. After additional checks on the quality and integrity of the data in this updated version (v6) the data was released for use in producing the density maps of seabird distribution. ESAS contains both ship-based and aerial surveys, that were treated separately.	ESAS (ICES) & MWTL (Ruben Fijn) × Observer-based aerial survey data not Public in the ESAS DB Author: (Leopold et al. 2015)
1991-2014	All seasons, bimonthly (the year is divided in groups of two months).	Note that transects changed after 2014, and this figure shows the coverage before.	MWTL, same data as used in Leopold et al. 2015	Waardenburg	MWTL	MWTL (Ruben Fijn) × Observer-based aerial survey data not Public in the ESAS DB Author:

						(Arts 2015)
2009-2010	A season runs from August/September to June/July of the following year. The 2009 season therefore begins in August/September 2009 and continues until June/July 2010. A full count consists of three days and is carried out six times a year.	 Figuur 2.1. Vliegroutes op het Nederlands Continentaal Plat.	Collected own data. Carried out within the framework of the Monitoring of the Water Management Situation of the Country (MWTL).	According to the Waardenburg webpage, the Head of Department Bird Ecology is Ruben Fijn.	Monitoring of the Hydrological State of the Country (MWTL - Monitoring Waterstaatkundige Toestand des Lands)	MWTL (Ruben Fijn) × Observer-based aerial survey data not Public in the ESAS DB Author: (Arts 2010)
2014-2022	Consistent, as surveys have been conducted in six months over the course of the year in a standardized way.		The 'Monitoring Waterstaatskundige Toestand des Lands' (MWTL) dataset holds aerial surveys covering the Dutch section of the North Sea.	MWTL (Waardenburg)	MWTL This dataset was requested from Waardenburg ecology.	MWTL: Ruben Fijn × Observer-based aerial survey data not Public in the ESAS DB Author: (van Donk et al. 2024)
2023-2024	Plane: August, November 2023, January, February, April, June 2024, Many transects that cover different areas on different days.	In 2020 the survey plan for MWTL was revised again to increase sampling effort in the coastal zone (ICES 2020).	This work is conducted within the Biological Monitoring (BIOMON) framework of the MWTL (Monitoring van de Waterstaatkundige Toestand des Lands)	According to the Waardenburg webpage, the Head of Department Bird Ecology is Ruben Fijn.	Monitoring of the Hydrological State of the Country (MWTL - Monitoring Waterstaatkundige Toestand des Lands)	MWTL: Ruben Fijn × Observer-based aerial survey data not Public in the ESAS DB Author: (van Bemmelen et al. 2024)

Tabel 2.2. Bemonsterd oppervlak (km²) per telling van de seizoenen 1991 t/m 2013. Grijs gearceerd zijn onvolledige tellingen (- = geen telling).

Seizoen	periode 1 augustus/ september	2 oktober/ november	3 december/ januari	4 februari/ maart	5 april/ mei	6 juni/ juli
1991	244	240	289	185	-	165
1992	246	214	160	270	189	224
1993	160	174	-	34	249	247
1994	200	248	211	290	209	229
1995	229	280	84	276	281	219
1996	213	238	260	208	272	222
1997	211	212	287	301	304	281
1998	275	259	275	431	220	401
1999	356	46	341	374	382	321
2000	188	291	275	302	285	359
2001	345	440	332	412	384	388
2002	404	416	432	388	401	389
2003	302	370	404	394	306	272
2004	340	423	424	353	349	383
2005	378	368	480	409	378	408
2006	422	262	348	135	370	353
2007	535	451	627	-	385	361
2008	456	-	358	545	352	384
2009	383	457	451	397	378	374
2010	449	438	484	612	329	347
2011	441	453	525	375	447	308
2012	384	468	460	388	-	-
2013	-	838	839	742	184	211

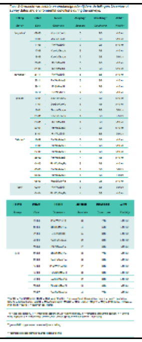
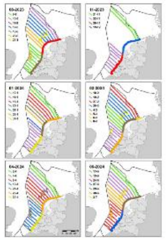
		 Figuur 51: Dataverspreiding en gebiedsdekking van de monitoringsvluchten in op het NCP. Survey timing and spatial coverage of aerial surveys during the monitoring on the DCS.				

Table S11. The table gives an overview on the reports presenting data collected via digital aerial surveys. The timeframe of the data, frequence of coverage, study area/transect lines/effort, dataset, data manager, data collection program and contact person/reference are shown.

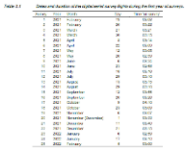
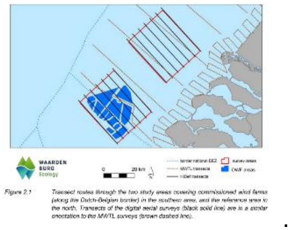
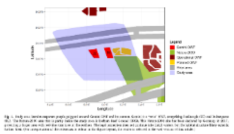
Time Frame	Frequence of Coverage	Study area/transect lines/effort	Dataset	Data manager	Data collection program	Contact person/Reference
2021-2022	From February 2021 to February 2022, two surveys were conducted per month. 		Digital surveys were conducted by BioConsult. .	Data owners (Rijkswaterstaat, Ecowende) and executors of the programs (Waardenburg Ecology).	Waardenburg Ecology and HiDef / BioConsult SH have collected digital video image.	✓ WOZEP Granted access WOZEP: Martijn ter Steege (martijn.ter.steege@witteveenbos.com) Author: (Collier et al. 2022)
2022-2023	The first as pilot in March 2022, and seven following between October 2022 and March 2023	Blue polygon shows study area. Red polygon shows Gemini OWF. 	Digital surveys were conducted by BioConsult. .	The repository belongs to Grundlehner.	Collected by Wageningen Marine Research + BioConsult.	× Data and R scripts are publicly available via the following link Repository doesn't include all data. Optional sources: Rijkswaterstaat: Henri Zomer (henri.zomer@rws.nl); Waardenburg Ecology: Ruben Fijn (r.fijn@waardenburg.eco) Author: (Grundlehner et al. 2025)

Table S12. Overview of offshore wind farms in the Netherlands. Links to each OWF main page with more detailed description are included.

Optional Clusters	OWF	6 years before (data needed)	Start of construction	Operational (post-construction)
1	Egmond aan Zee (OWEZ)	2000	2006	2007
1	Prinses Amalia Windparken (PAWP)	2000	2006	2008
2	Luchterduinen	2007	2013	2015
3	Gemini	2009	2015	2017
4	Borssele I & II: Ørsted	2014	2020	2020
4	Borssele III & IV: Blauwwind	2014	2020	2021
4	Borssele V	2014	2020	2021
	Hollandse Kust (Zuid): I and II	2015	2021	2023
	Hollandse Kust (Zuid): III and IV	2015	2021	2023
	Hollandse Kust (Noord): V	2015	2021	2023

Table S13. Distance in straight line (in km) between OWFs.

	OWEZ	PAWP	Lucht	Gemini	Gemini	Borssele	Borssele	Borssele	Borssele
OWEZ	0	8	22	180	186	127	134	136	131
PAWP		0	15	189	195	115	124	125	119
Luchterduinen			0	207	213	98	105	107	102
Gemini 1				0	5	309	318	319	313
Gemini 2					0	315	324	325	319
Borssele 1						0	2	2	2
Borssele 2							0	1	8
Borssele 3								0	1
Borssele 4									0

Figure S14. Coverage of OWEZ and PAWP OWF with ship-based surveys (all available years shown). Data includes those surveys that cross the OWF polygon and that were publicly available in the ESAS database. Includes surveys conducted by different countries within the Dutch EEZ. Pre-construction: 2000 -2006. Post-construction: 2007-2012. Data collected via observer-based surveys was not publicly available in the ESAS database. Thus, better coverage is to be expected.

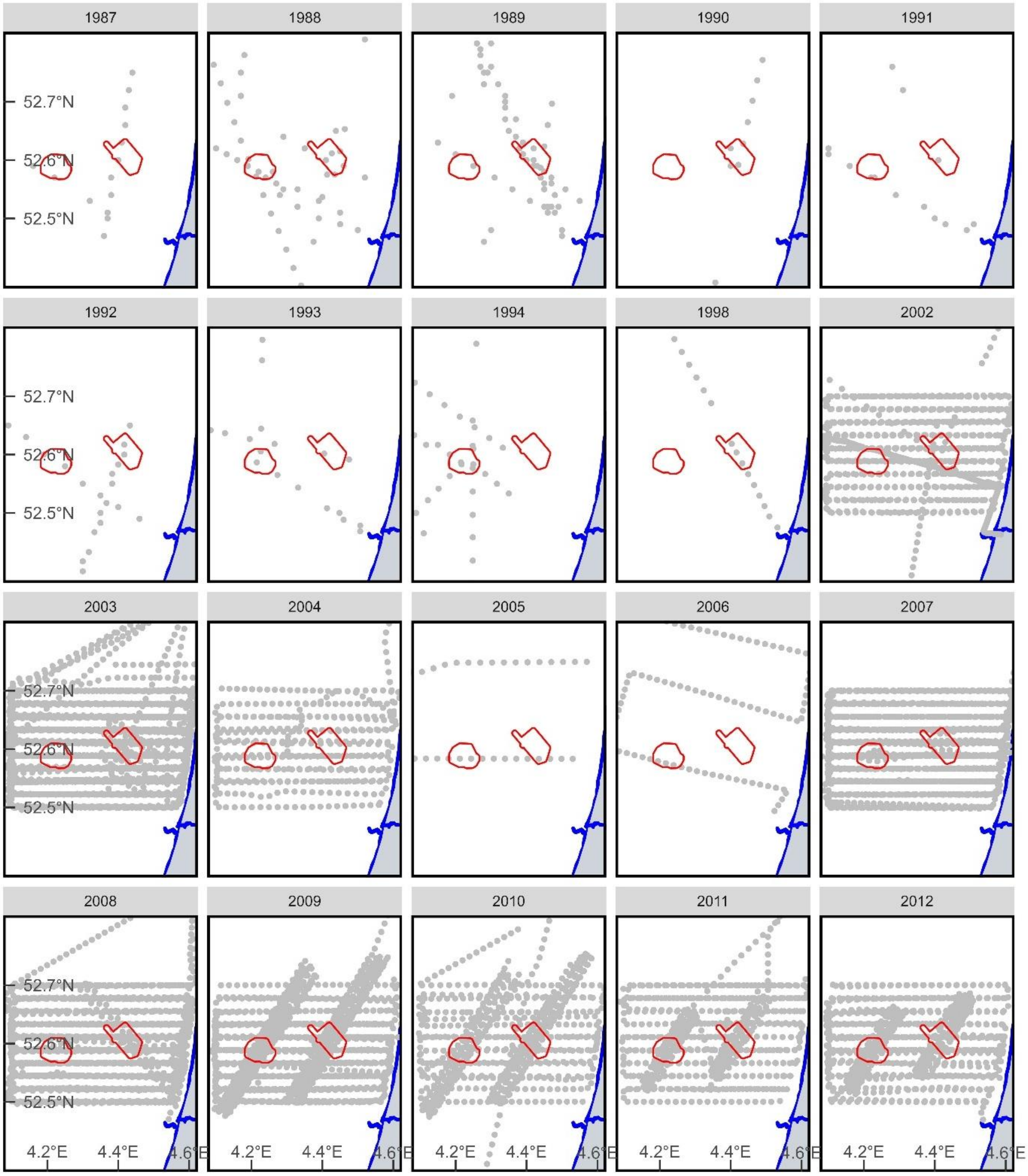


Figure S15. Coverage of Luchterduinen OWF with ship-based surveys (all available years shown). Data includes those surveys that cross the OWF polygon and that were publicly available in the ESAS database. Includes surveys conducted by different countries within the Dutch EEZ. Pre-construction: 2008-2013. Post-construction: 2015-2021. Data collected post-construction by ENECO in the Luchterduinen OWF is missing in the ESAS database and data collected via observer-based surveys was not publicly available. Thus, better coverage is to be expected.

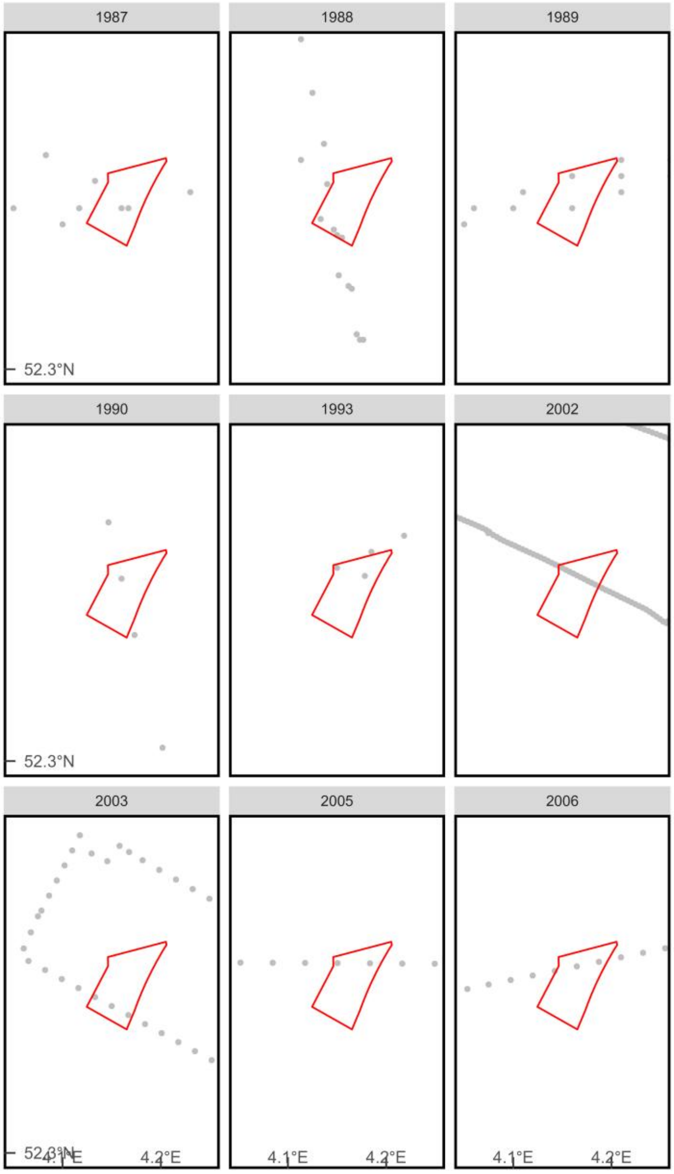


Figure S16. Coverage of Gemini OWF with ship-based surveys (all available years shown). Data includes those surveys that cross the OWF polygon and that were publicly available in the ESAS database. Includes surveys conducted by different countries within the Dutch EEZ. Pre-construction: 2010-2015. Post-construction: 2017-2023. No post-construction data was publicly available. Data collected via observer-based surveys was not publicly available in the ESAS database. Thus, better coverage is to be expected.

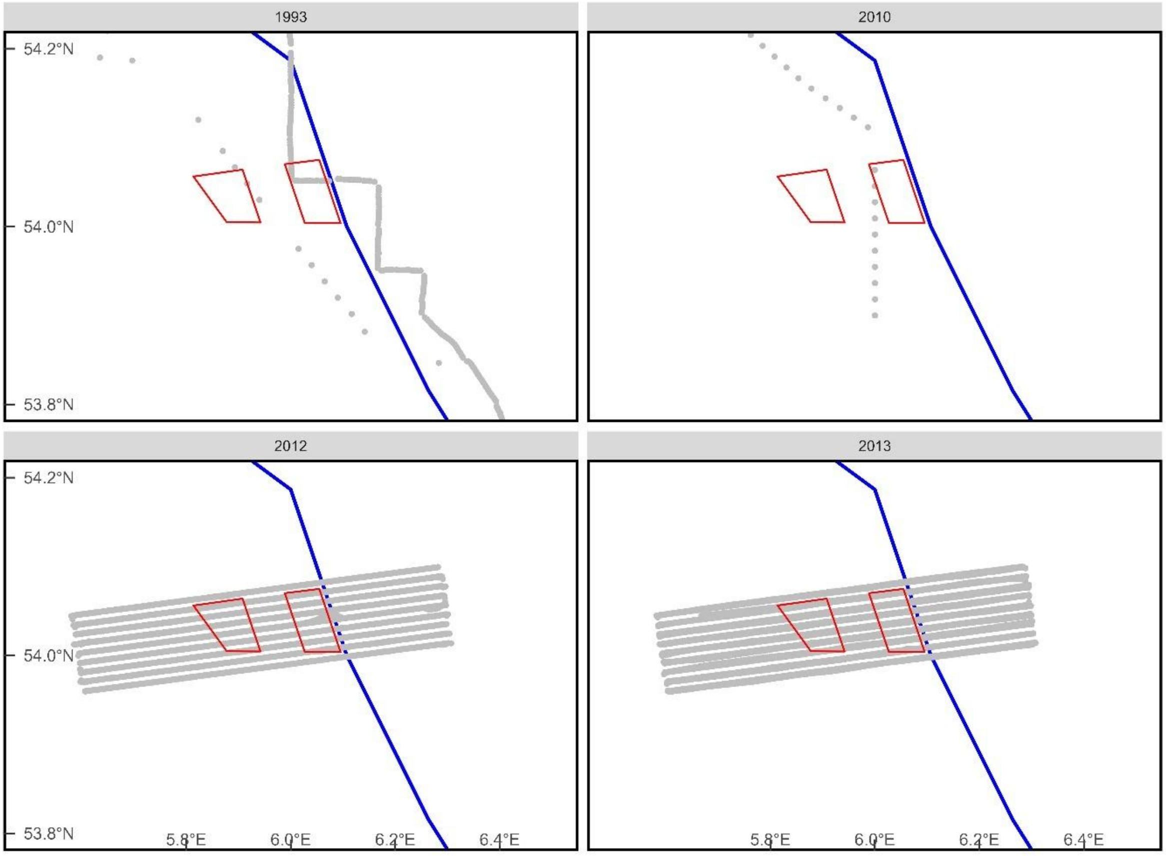


Figure S17. Coverage of Borssele OWF with ship-based surveys (all available years shown). Data includes those surveys that cross the OWF polygon and that were publicly available in the ESAS database. Includes surveys conducted by different countries within the Dutch EEZ. Pre-construction: 2015 - 2020. Post-construction: 2021- 2026. No post-construction data was publicly available. Data collected by Leemans et al. 2024 is missing in the ESAS database and data collected via observer-based surveys was not publicly available. Thus, better coverage is to be expected.

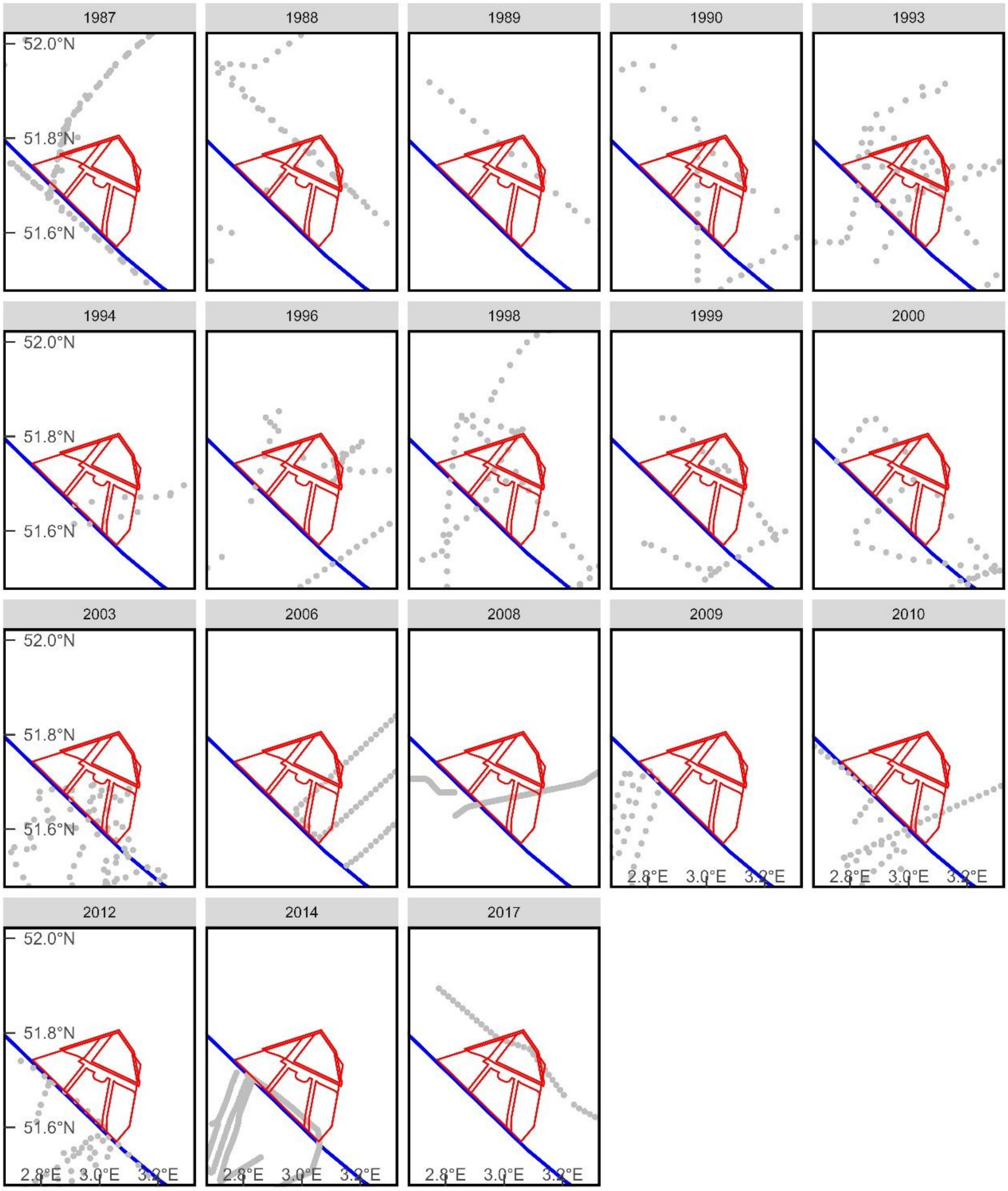
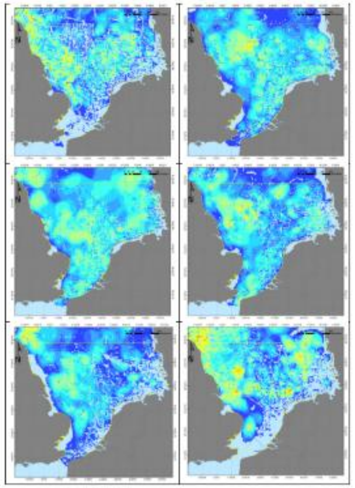
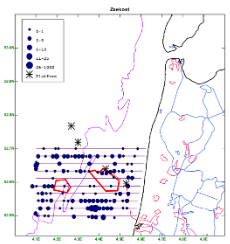
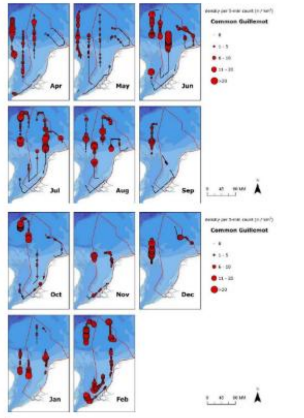
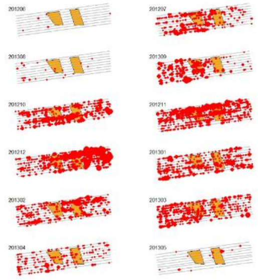
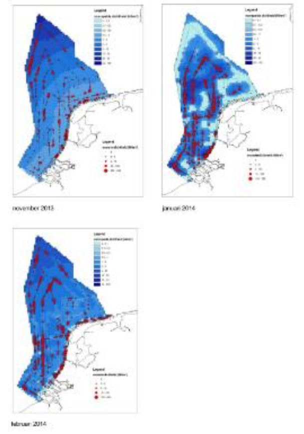
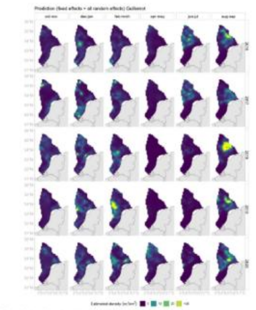
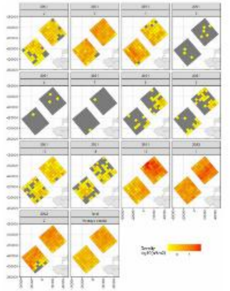


Table S18. The table gives an overview on the information that is included in the reports on Common guillemot abundance and densities, if available. The table shows source (method, year, area covered and author), information about common guillemots, if included in the report, and densities, if any graphical information is included. The table is organized in chronological order according to the first year represented in the data.

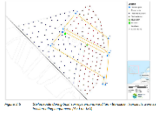
Source	**Information on common guillemots**	**Densities**
Ship and Plane 1990-2014 All EEZ (Leopold et al. 2015)	The highest densities are found, year-round, in UK waters, often with an eastward offshoot, south of the Dogger Bank along a frontal area known in The Netherlands as the Frisian Front. Here, numbers reach international importance in summer, when moulting birds and parent-birds with their chicks flock into the area (Van Bemmelen et al. 2013; Van Bemmelen & Leopold 2014). In the Southern Bight, numbers also reach international importance threshold along the UK/Dutch border, near the Brown Ridge (Van Bemmelen et al. 2012) Common murres are probably the most suitable birds to study effects of wind farms on seabirds, as they occur in relatively large numbers in many water types across the southern North Sea and are not attracted to fishing vessels. These features make them ideal for spatial modelling. Effect studies in and around wind farms have shown that Common murres are susceptible to displacement by offshore wind farms, but that this displacement is not absolute: within wind farm parameters lower bird densities were found than expected on the basis of densities found in the vicinity (Elsam Engineering & Energi 2005; Elsam Engineering 2005; Petersen & Fox 2007; Leopold et al. 2013a; Vanermen et al. 2013; Walls et al. 2013). Results from these studies also indicated that this effect was not limited to the wind farm areas themselves, but that an area of several kilometres around offshore wind farms may also be avoided to some extent (see Annex D3). Murres are not likely to become victims of collisions in large numbers, as these birds rarely fly at rotor heights.	 *Figure 4.39. Common Murre: distributions patterns in August/September, October/November, December/January, February/March, April/May and June/July, from top left to bottom right. For key to colours representing different densities: see Figure Key.*
Ship 2007-2008 OWF: OWEZ (Egmond aan Zee) Leopold 2008	Gulls, Cormorants, Gannets and auks (both Guillemots and Razorbills) were numerically dominant components of the avifauna during the September survey. Guillemot occurred far more widespread, throughout the study area. Guillemots appeared reluctant to enter OWEZ but some birds were seen close to the periphery of the wind farm and one group had actually swam a little way into the park	

Ship 2010-2011 EEZ Van Bemmelen et al. 2011	Common guillemots and Razorbills were ranked amongst the intermediate species in terms of sensitivity to wind farms. Due to its smaller population size, the Razorbill was qualified as the more sensitive species of the two. Unpublished reports suggest partial avoidance of wind farms by these species When seen at greater distances Common guillemots and Razorbills are almost impossible to identify to species level. During the surveys only 0.8% of the large alcids (n = 7,213) was left unidentified. Of the remaining alcids 88.7% was identified as Common guillemot and 10.6% as Razorbill. In other words, the ratio between Razorbills and Guillemots on average was 1:8.6. However, there are marked temporal changes in the ratio between both species. Guillemots dominated throughout the year, but in November and February high proportions of Razorbills were present. In summer the proportion of Razorbills was virtually zero. Guillemots were widely distributed throughout the year, showing a distinct spatial and temporal pattern	 Figure 42 Distribution of Common Guillemots during surveys in April 2010 - February 2011
Ship 2012-2013 OWF: Gemini Van Bemmelen et al. 2015	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. After a remarkable dip in August, densities sharply increased again from September onwards reaching highest values (>5 Ind/km^2) in December, indicating that the area supports a wintering population.	 Figure 32. . Common Guillemot. Spatial pattern of sightings per survey. Dot size is relative to numbers counted per minute.

Plane (MWTL) 2013-2014 All EEZ Arts 2015	Common guillemots are observed throughout the year at the NCP, with the highest densities occurring during the winter months (Arts 2013). In 2013/2014, comparable densities were measured in November, January and February. The average of approximately 3 per km^2 is consistent with previous seasons. The birds were found scattered across the NCP. In November, relatively large numbers of birds were found in the central North Sea. In January, the distribution was concentrated in the southern North Sea. In February, the species was observed in similar densities throughout the NCP. In the past, auks were rarely found in the coastal zone as a pelagic species, but nowadays the species are also frequently seen in the coastal zone. In 2013/2014, many auks were counted in the coastal zone, particularly in the "plume" of the estuaries of the major rivers. In April and June, no auks were seen in the coastal zone.	
Plane (MWTL) 2014-2024 All EEZ van Donk et al. 2024	For Common guillemot and Razorbill, only data from 2014 onwards was used, as before 2014 these species were not distinguishable from each other due to the methods applied. It appears that in all bimonthly periods, Guillemot densities were slightly lower in relatively shallow areas of the Dutch Sea. This can also be seen in the maps of predicted densities; densities were low along the relatively shallow coastline. There were some strikingly large areas with high densities, for instance in 2018 Aug-Sep and Feb-March 2019. Densities were usually low in Jun-Jul.	
Plane (MWTL) and Digital (Waardenburg) 2021-2022 OWF: Borssele Collier et al. 2022	A total of 15,331 Common guillemots were recorded during the year. Common guillemot numbers increased at a regular rate during the initial five surveys before falling sharply. Numbers recorded then remained low before until increasing only slightly to triple figures in October and early December. It was from the second survey in December onwards that numbers recorded rose into the thousands, with a gradual decrease in numbers following the peak count of 4,395 in the second survey in December (figure 3.17). Only one Common guillemot was aged, this was an immature bird. Overall, densities of Common guillemots were slightly higher in the northern area and further from the coast (figure 3.18). This pattern is perhaps most evident in December, January and February 2022. In other months, such as March, this pattern is reversed with highest densities in the southern area. *note the presence of many unidentified to species	
Ship	During winter, the most frequently encountered species during the boat surveys included the guillemot (n = 378).	

<table>
<tr>
<td>2021-2023

OWF: Borssele

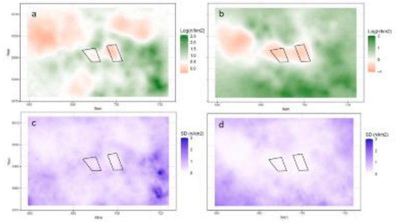
Leemans et al. 2024</td>
<td>Interestingly, the number of observed individuals of razorbill was higher than the number of observed common guillemot, however, Common guillemots were observed more often. This means razorbill generally occurs in larger groups than the common guillemot in the wind farm. This is also shown by comparing average group sizes of razorbill (2.66) and Common guillemot (1.48).</td>
<td>
Table 3.1 Average number of individuals of species of seabirds observed in Borssele wind farm during boat surveys grouped in bimonthly periods. Highlighted fields (in grey) mean a species was seen during that two-month period. Non-highlighted fields mean no observations were done of a species in that two-month period.
<table>
<tr><th>Species</th><th>Dec/ Jan</th><th>Feb/ Mar</th><th>Apr/ May</th><th>Jun/ Jul</th><th>Aug/ Sep</th><th>Oct/ Nov</th></tr>
<tr><td>black-headed gull</td><td>0.5</td><td>0.5</td><td>0</td><td>0.2</td><td>17.8</td><td>3.5</td></tr>
<tr><td>black-legged kittiwake</td><td>90.0</td><td>65.8</td><td>0.5</td><td>0</td><td>0.8</td><td>8.5</td></tr>
<tr><td>common guillemot</td><td>55.0</td><td>35.8</td><td>0</td><td>0</td><td>2.8</td><td>0</td></tr>
</table></td>
</tr>
<tr>
<td>Digital (repository)

2022-2023

OWF: Gemini

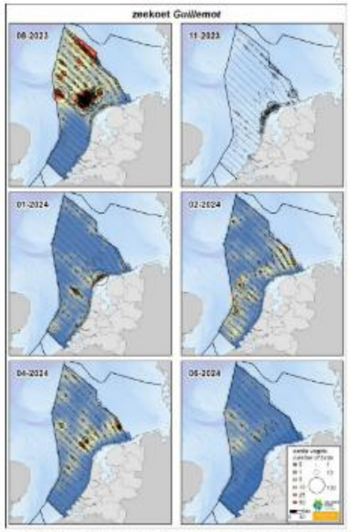
Grundlehner et al. 2025</td>
<td>Winter Auks.

Within the study area they are present in their highest densities in winter (October – March)(Van Bemmelen et al., 2015), hence surveys for the presented study were performed during winter.

Strong displacement was found for both razorbills and guillemots, within the OWF footprint but also in its surroundings. Razorbill and Guillemot densities inside the OWF were reduced by 0.953 and 1.604 individuals per km2, respectively, compared to the remainder of the study area, remaining considerably lower than control densities up to 2 km and 10 km distance.</td>
<td>
Fig. 2. Predicted densities[a] (a-b) and standard deviations (c-d) for razorbills (left, a,c) and guillemots (right, b,d) within the study area. Black polygons represent the twin OWF. Visualised densities and standard deviations represent the mean value per grid cell[b], from the predicted spatial densities per survey that resulted from 1000 datasets simulated using the ZAG-GLMs. Mean spatial densities per survey provided in Supporting Information. Note that as a result of the study area shape, the right top and left bottom corners have high standard deviation as these corners were not covered by transects.
a) Densities are visualised on a natural-logarithmic scale (ᵉLog).
b) Mean values have been calculated on a spatial grid of 200 × 200 cells, distributed over a geographical space of [illegible] km horizontally (Xkm) and 40 km vertically (Ykm). The resolution of the grid cells is [illegible] km × 0.2 km; one grid cell has a surface area of [illegible] m². For making predictions on a spatial grid, INLA requires equal numbers of grid cells in the x- and y-dimension.</td>
</tr>
<tr>
<td>Plane (MWTL)

2023-2024

van Bemmelen et al. 2024</td>
<td>* Trends are calculated for the period 1991/1992 – 2023/2024. In order to gain insight into trends on a shorter timescale, the analysis was also carried out using data from the introduction of "the new MWTL", i.e. in the period 2014/2015 – 2023/2024. In this latter analysis, there is therefore no need to link data from the old and new MWTL, and trends could be analysed at species level for species that can be determined at species level in the "new MWTL" (in particular Razorbill and guillemot). The species most affected by not been able to distinguish between species are Common guillemots and Razorbills. Because the unidentified individuals are distributed among the species according to the ratio among the identified individuals, the correction factor within a survey is the same for all species within the species group.

The guillemot is the most numerous bird on the NCP outside the coastal zone. The largest numbers are estimated in August and September, with approximately 491,300 specimens, followed by April with 118,200 specimens, February with 104,400 specimens and January with 60,800 individuals. The number for November is probably an underestimate, as the most important area was not counted at that time. In that month, large numbers were seen in the coastal zone, with a population estimate of 20,300 individuals. Also in January, considerable numbers remained in the coastal zone: about 10,500 individuals. The Frisian Front is particularly important for the guillemot in late summer. In August, an estimated 84,700 individuals remained here; outside this count, there were 2,400 (January) and 7,500 (April) specimens. It is striking that even in June, several thousand birds of this species were still present here. Guillemots appear later in the autumn in the more southerly areas, such as the Bruine Bank.</td>
<td>

Figuur 41 Verspreiding van zeekoet tijdens zes tellingen in 2023-2024 op het NCP. Weergegeven worden de waarnemingen in stippen en de geïnterpoleerde dichtheden (vogels per km²) in kleur. Distribution of common guillemot on the Dutch continental shelf during six surveys in 2023-2024. Shown are individual sightings (circles) and interpolated density (birds/km²) in colour.</td>
</tr>
</table>

Figure S19. Observations of auks (including Common guillemots, Razorbills and undetermined auks). Data presented is not distance corrected. Data source is the publicly available observations in the ESAS database; data was collected mainly by ship-based surveys. All years are merged; panels are separated by season. Seasons do not correspond to the classification by Garthe et al. 2007. Here, winter is December, January and February; spring is March, April and May; summer is June, July, August; and autumn is September, October and November. Seasonal data separated by year are shown in Figure S20-23.

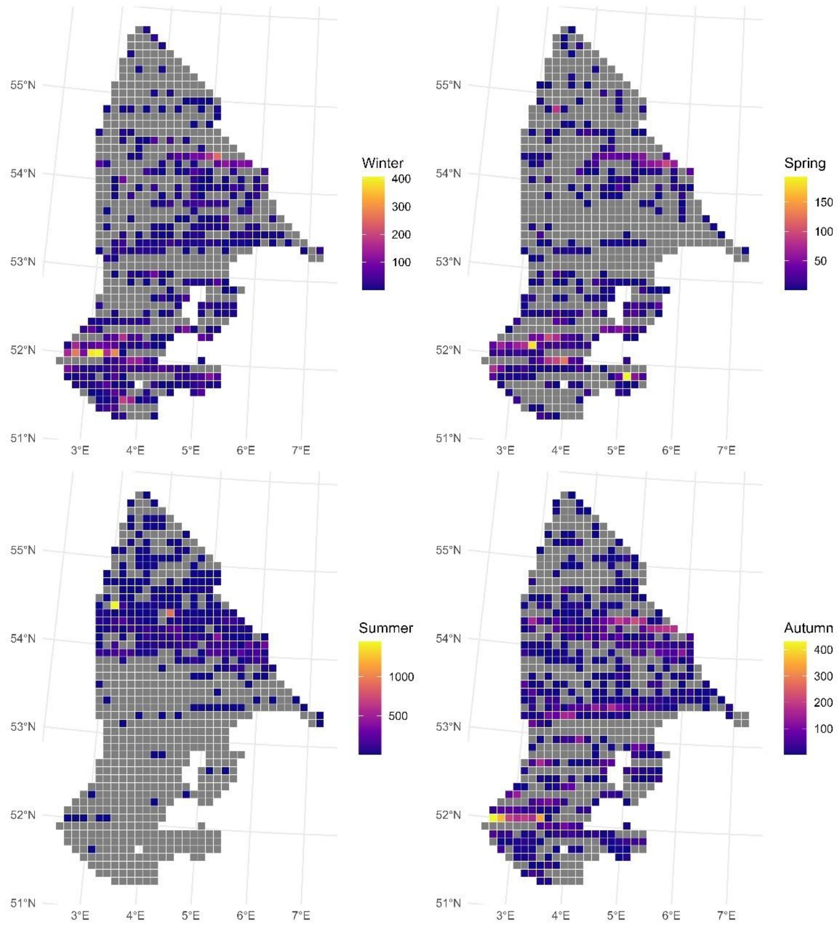


Figure S20. Winter observations of auks separated by year. Data from ESAS database, data was collected mainly by ship-based surveys. Here, winter is December, January and February.

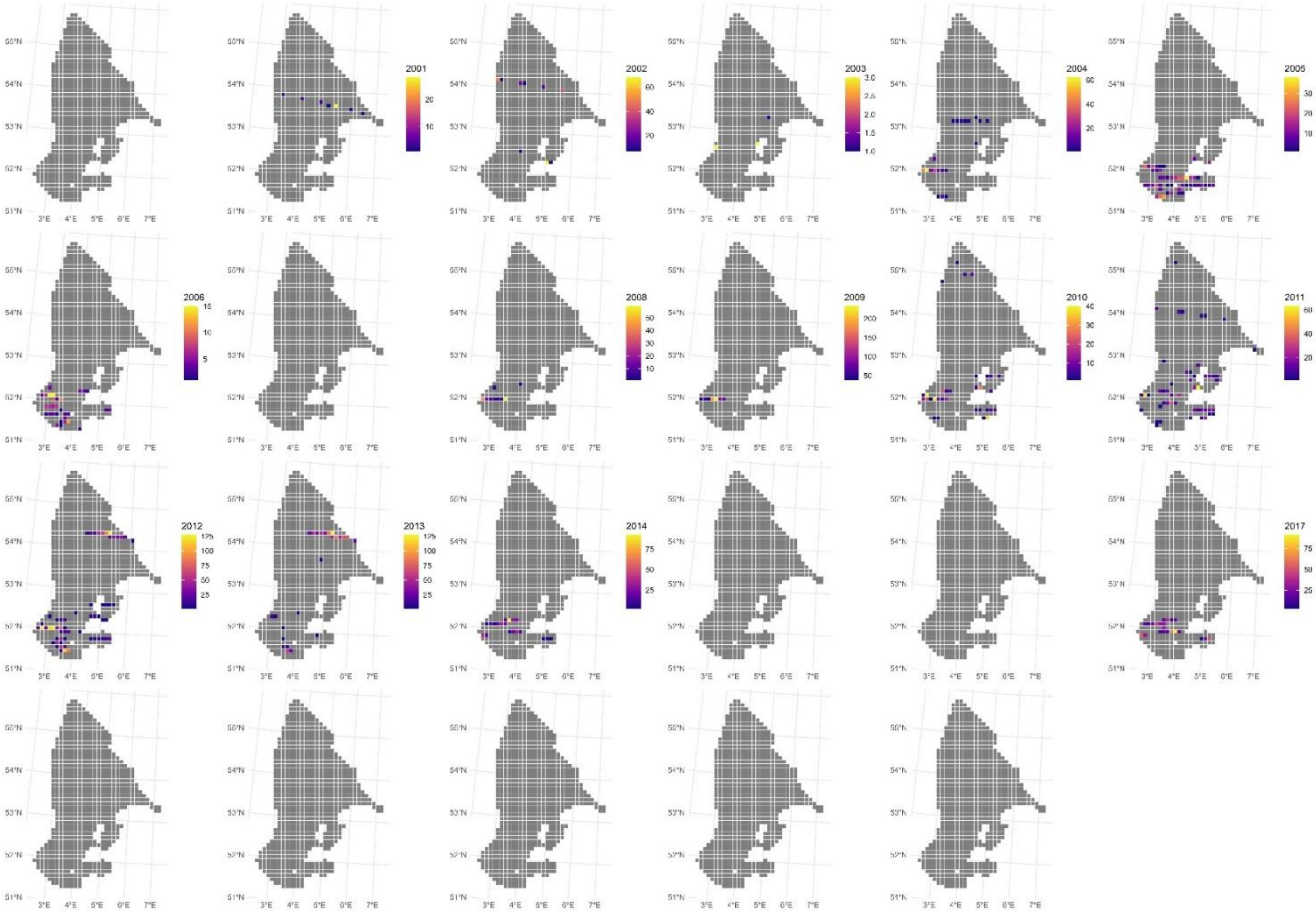


Figure S21. Spring observations of auks separated by the year. Data from ESAS database, data was collected mainly by ship-based surveys. Here, spring is March, April, May.

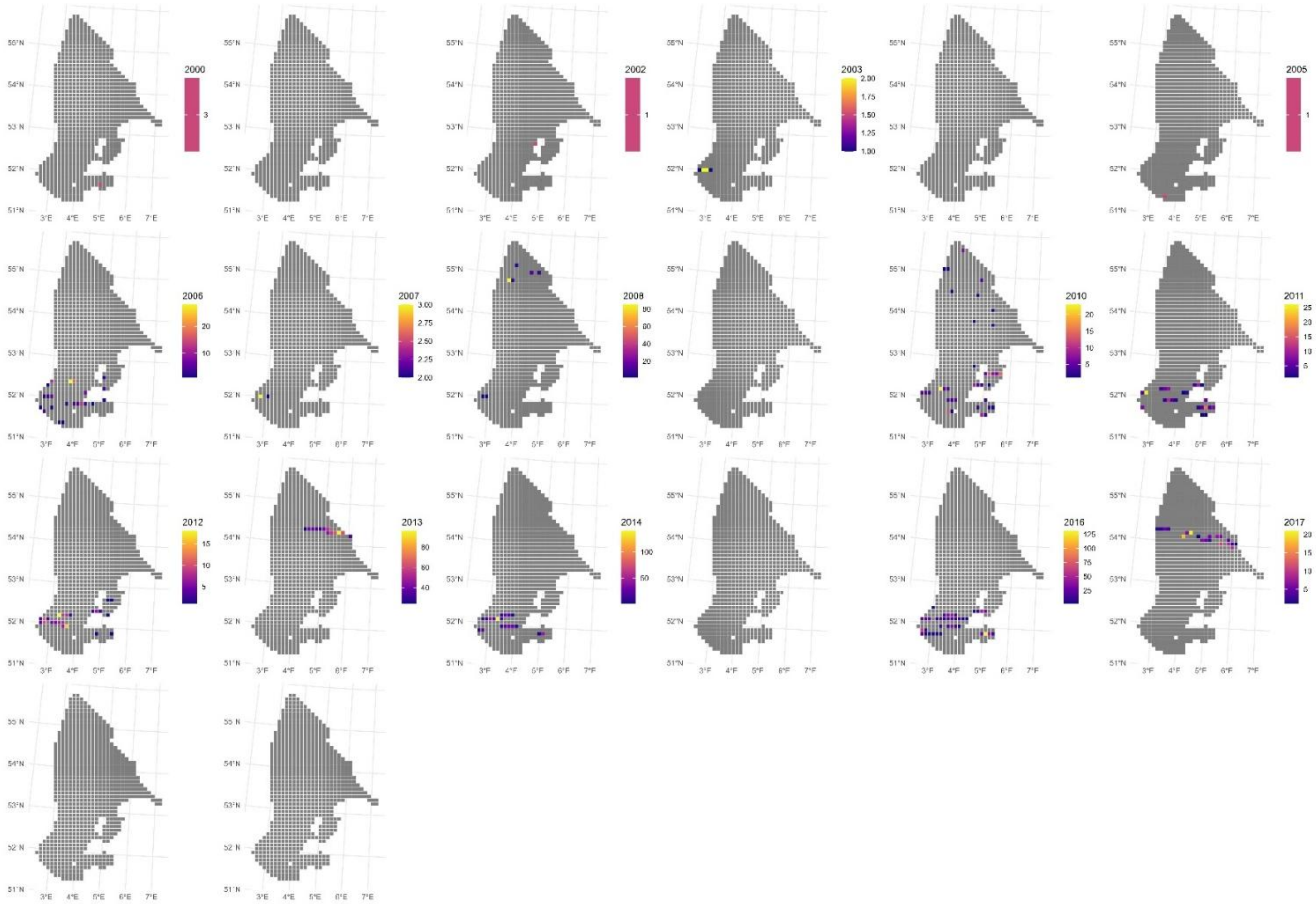


Figure S22. Summer observations of auks separated by year. Data from ESAS database, data was collected mainly by ship-based surveys. Here, summer is June, July, August.

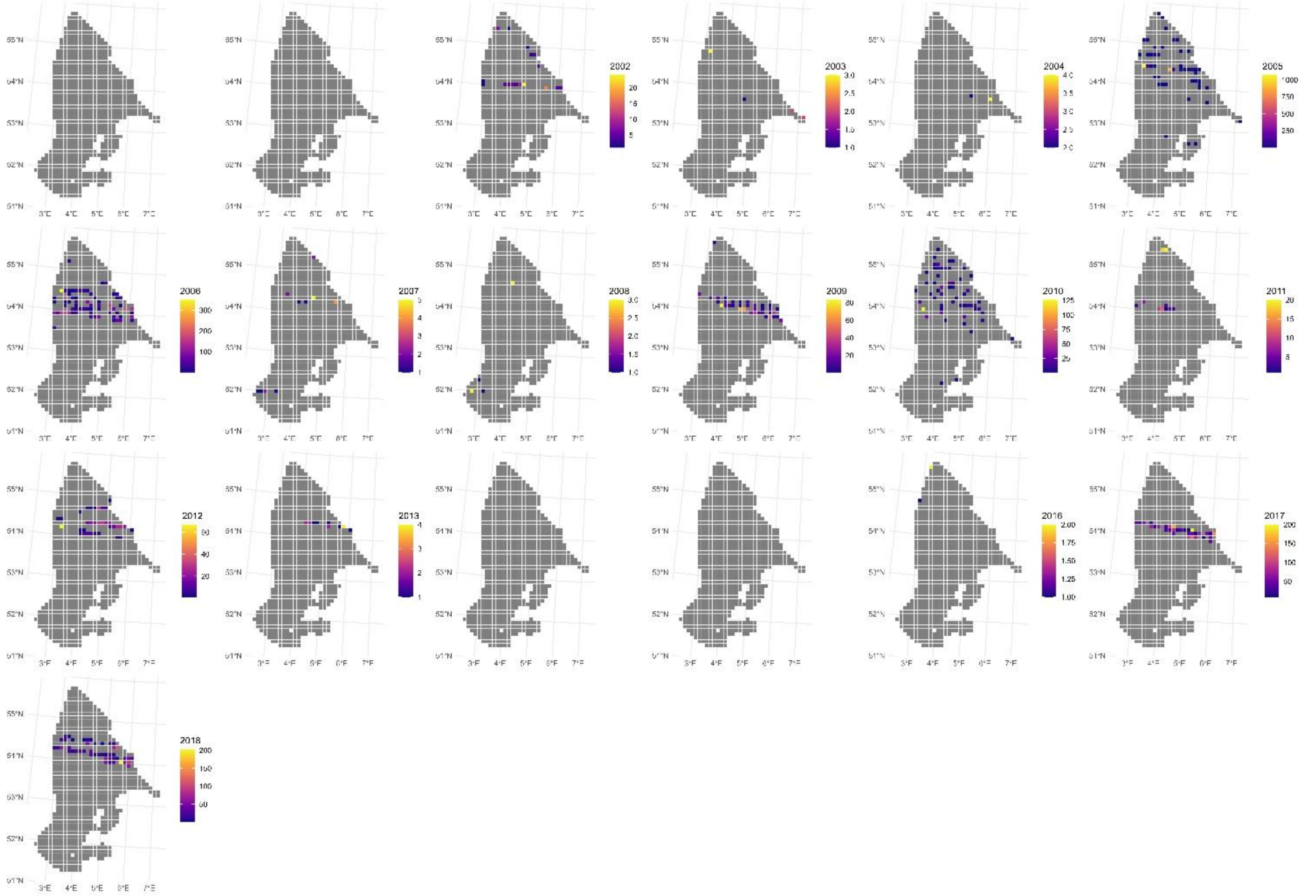


Figure S23. Autumn observations of Auks separated year. Data from ESAS database, data was collected mainly by ship-based surveys. Here, autumn is September, October, November.

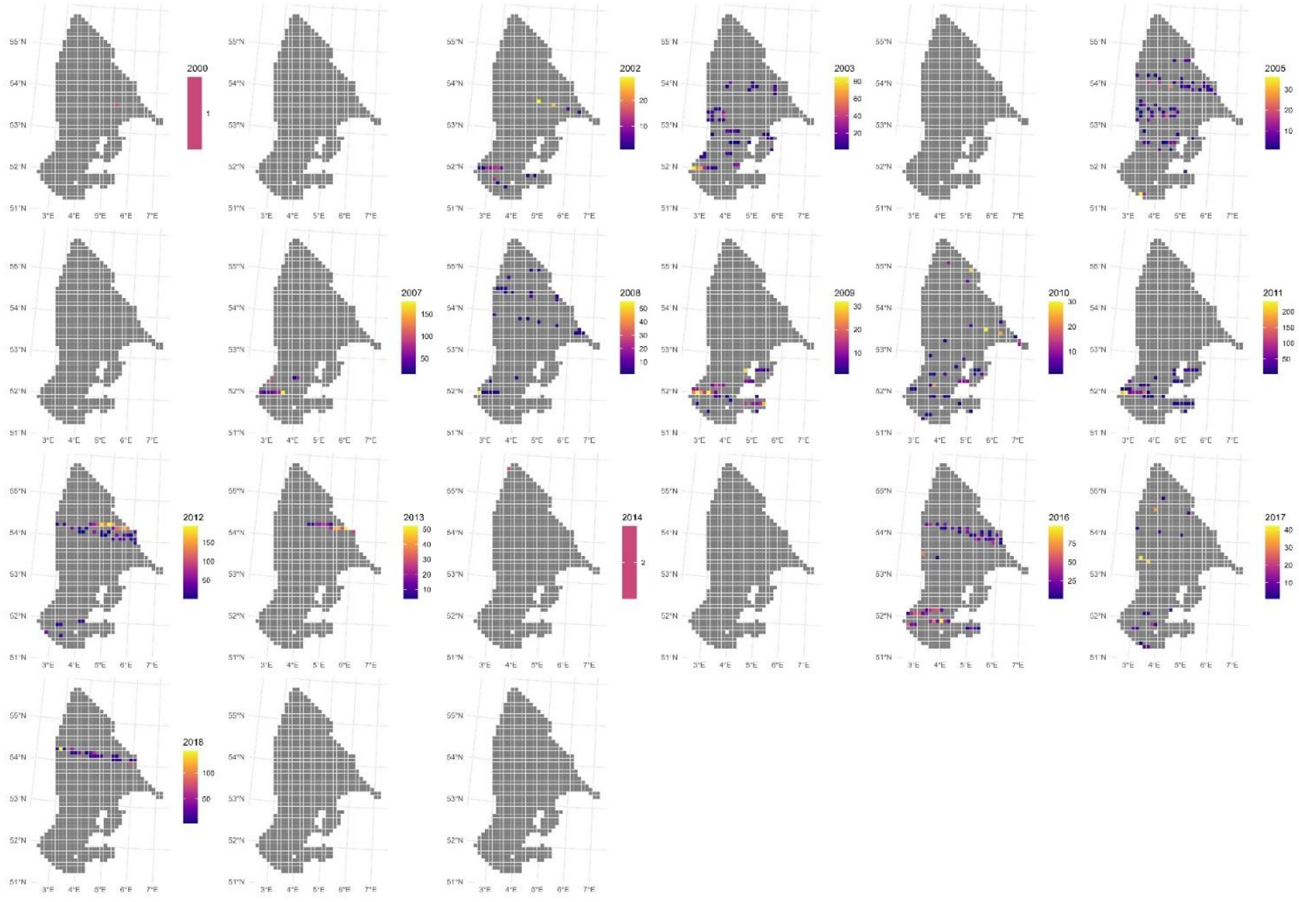


Figure S24. Ship-survey data collected from WOZEP repository > ship_base_observations > esas_export. Data from a ship-survey close to Borssele from 2020 to 2021 is shown.

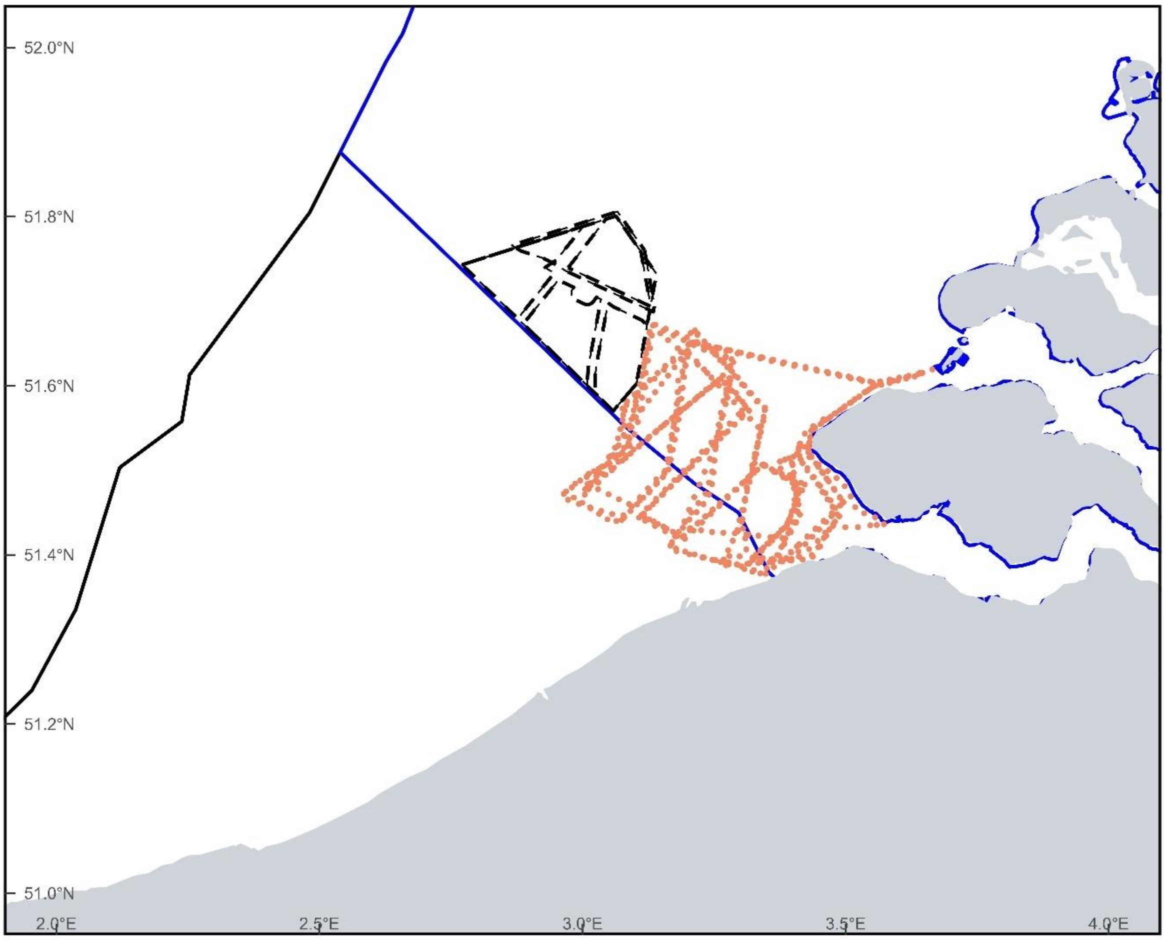


Figure S25. Ship-based survey data publicly available in the areas close to the Netherlands OWFs. Data from the ESAS database collected by other countries is shown. Countries are Belgium (BE), Ireland (IE), Great Britain (GB) and Germany (DE).

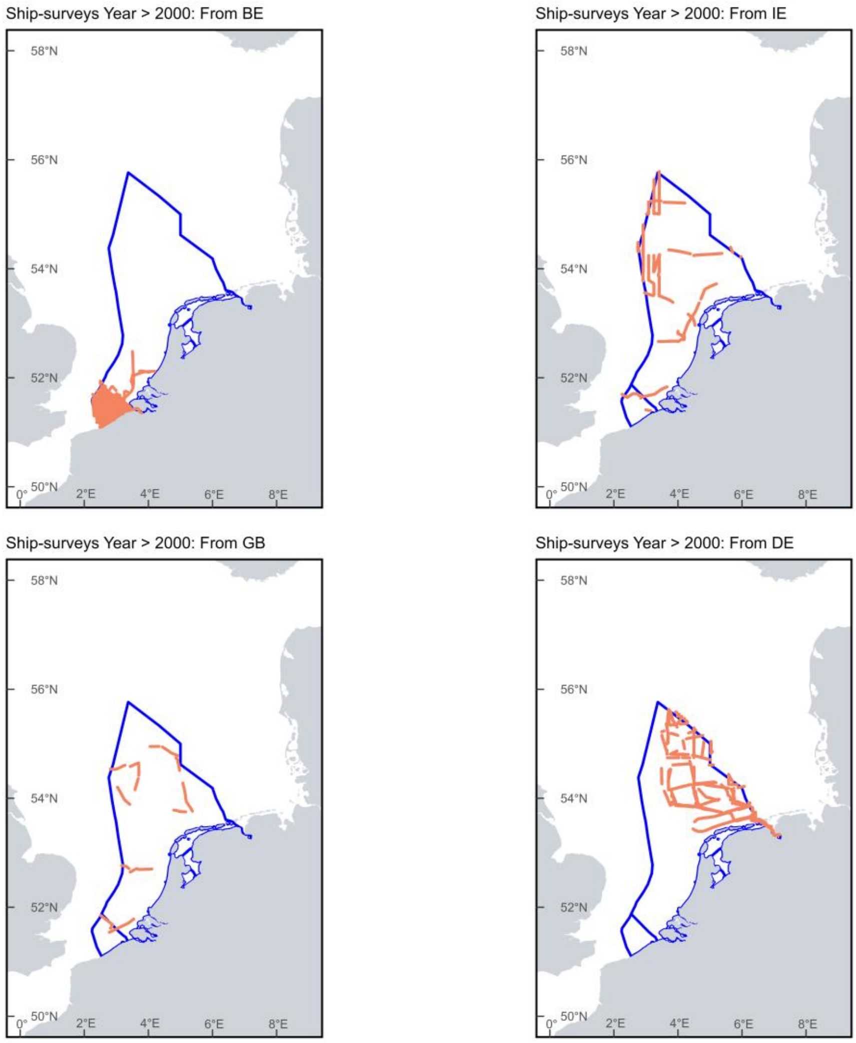


Figure S26. Plane survey data publicly available in the ESAS database collected by other countries. Only data from Germany (DE) was found. No publicly available plane data was found for Belgium or any other country inside the Dutch or Belgian EEZ.

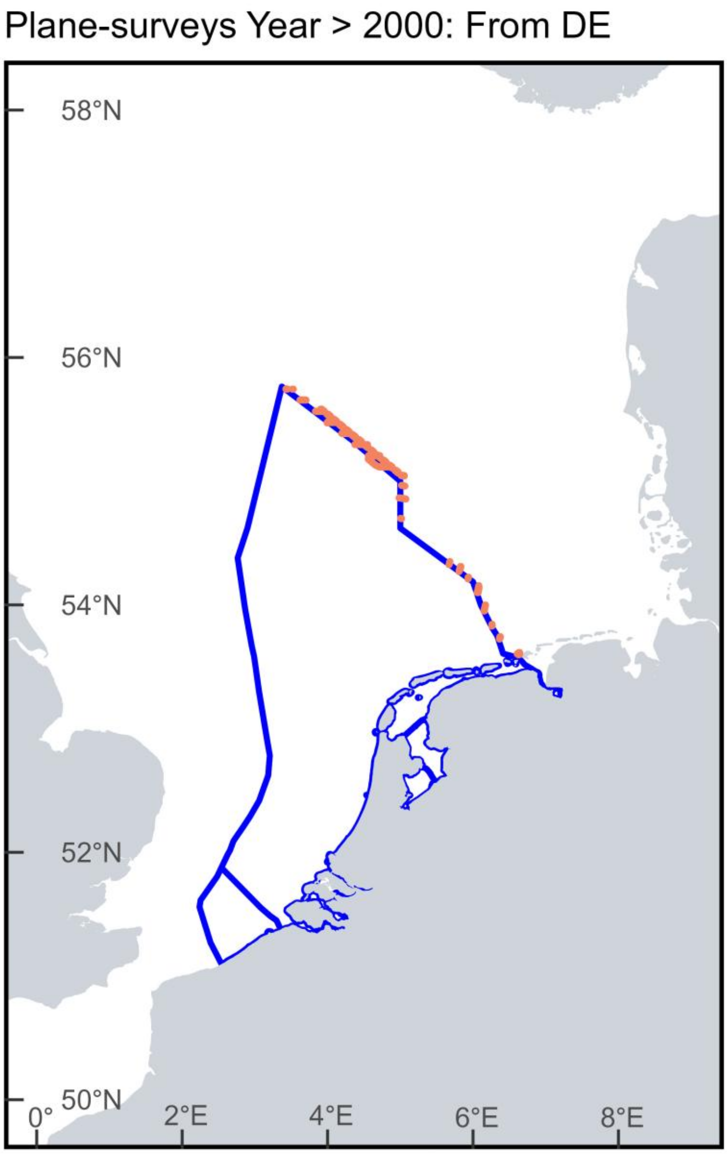


Figure S27. Ship surveys on the Belgium area, showing OWF in black polygons. Belgian offshore wind farms include: (a) Norther, Thorntonbank Part 2, C-Power, Rentel, Northwind, Seamade (SeaStar), Belwind Phase 1, Belwind I & II, Northwester 2, and Mermaid. (b) Princess Elisabeth Zone Lot 1, Lot 2.2, Lot 2.1, and Lot 3. OWF shapefiles from EMODnet accessed October 2025.

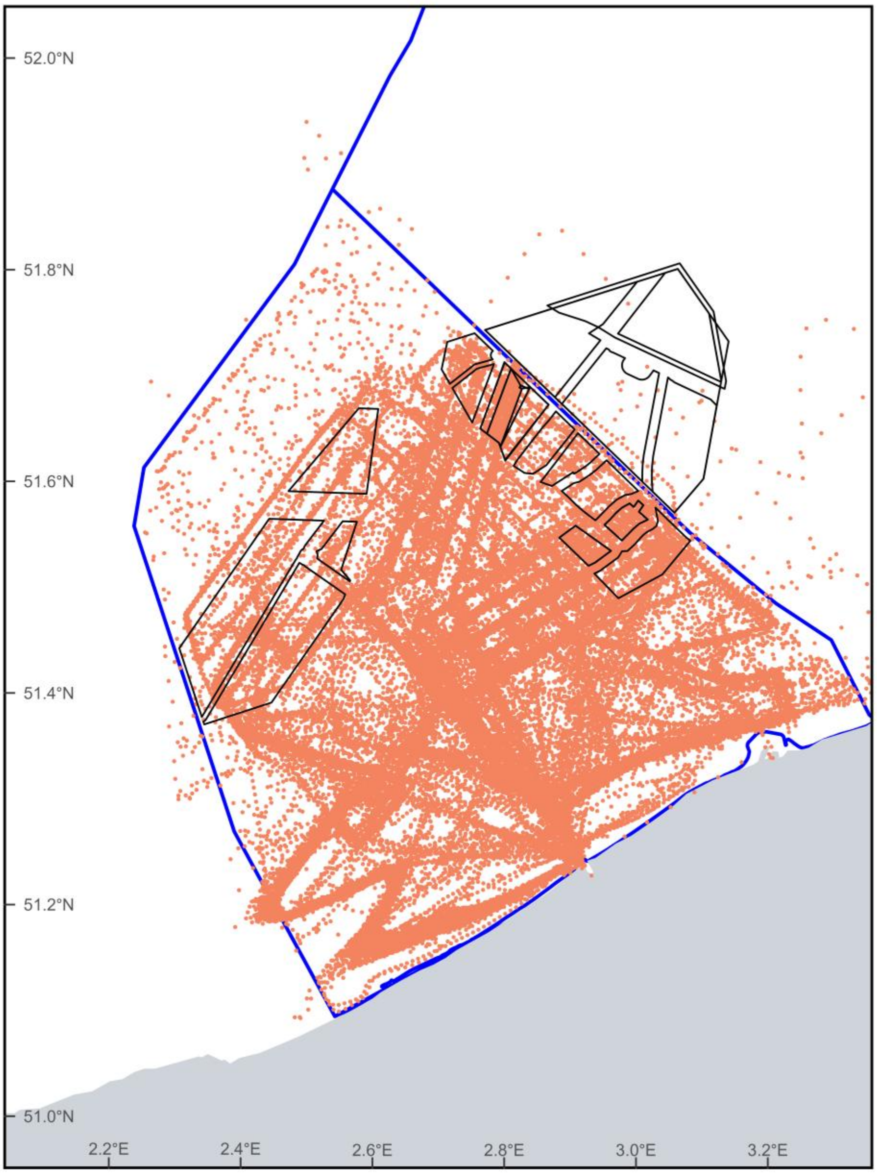


Figure S28. Surveys including Belgium areas, separated by year.