ENERGINET

ENERGY ISLAND BORNHOLM

BIRDS

15-05-2024

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GENERAL INTRODUCTION

With the Climate Agreement for Energy and Industry of the 22nd of June 2020, the majority of the Danish Parliament decided that Denmark will become the first country in the world to develop two energy islands. One of these islands will be the island of Bornholm located in the Baltic Sea ("Energioe Bornholm"), with wind farms located south-west of Bornholm with an installed capacity of up to 3.8 GW. The planned wind farm areas consist of Bornholm I South (118 km^2), Bornholm I North (123 km^2) and Bornholm II (410 km^2). The island of Bornholm will house the transformer station and serve to distribute the produced energy.

Because of these political decisions, a series of biological and scientific investigations will be carried out for a well-defined pre-investigation area as part of the baseline mapping of this part of the Baltic Sea. This also includes a baseline investigation of birds, including resting and migrating birds (WP-G) in the pre-investigation area, which is presented in this technical report.

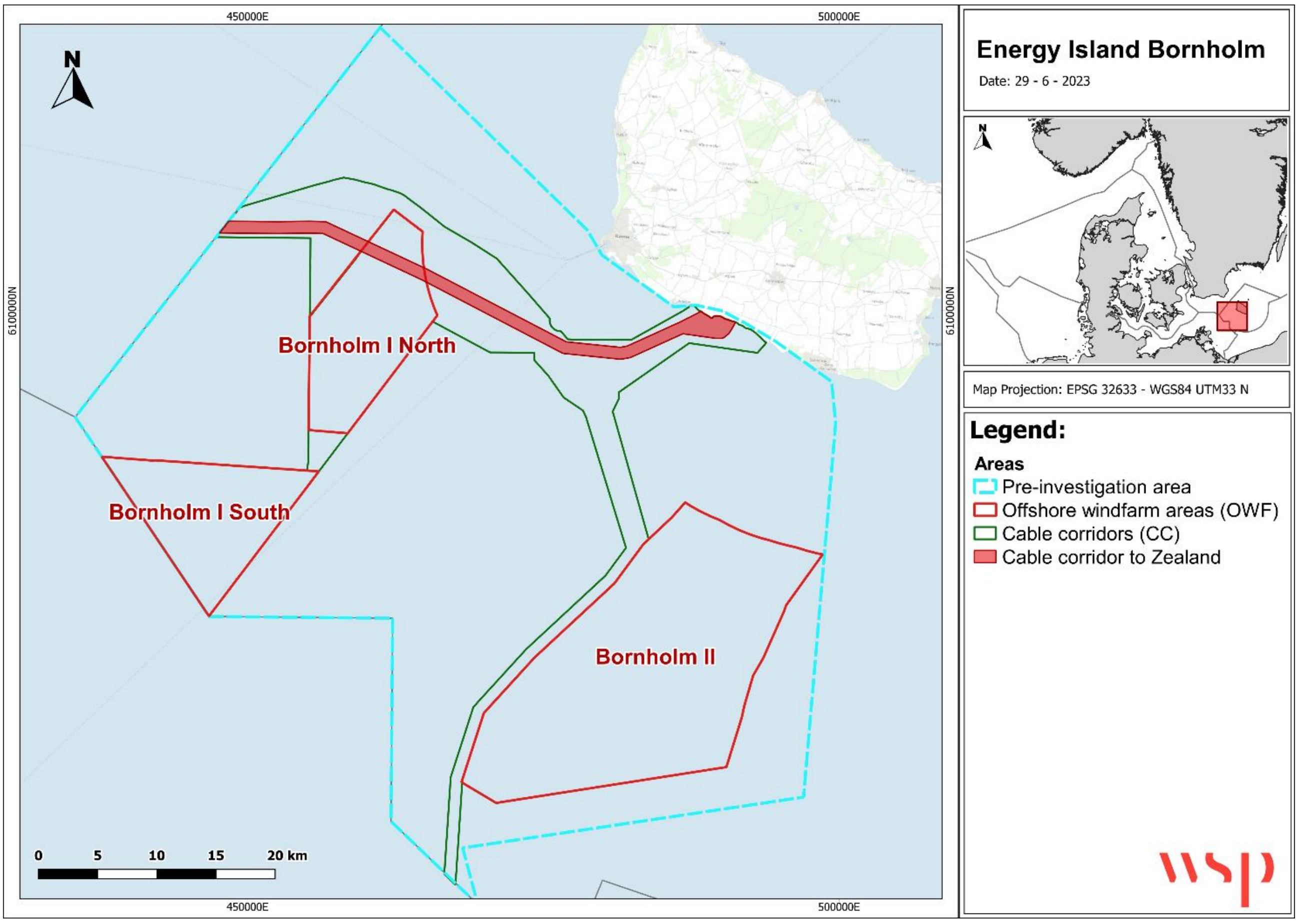

Figure 1. The pre-investigation area for Energy Island Bornholm.

Figure 1 shows the pre-investigation area for Energy Island Bornholm with the planned wind farm areas Bornholm I (OWF1) North and South (B1N and B1S), Bornholm II (OWF2) and the cable corridor area (CC).

The present report analyses the occurrence of birds in the pre-investigation area and is divided into two parts. Part A is focusing on seabirds resting and foraging in the pre-investigation area at least during periods throughout the year. Part B of this report is focusing on migrating birds and addresses species migrating through the pre-investigation area often twice a year on their seasonal movements between breeding and wintering grounds. For many of the terrestrial species, the sea is a biologically hostile habitat that needs to be crossed as quickly as possible to reach their breeding or wintering grounds. However, since many seabirds and other waterfowl are also migratory birds, the grouping is fluid and some of the species staying in the area but also crossing the pre-investigation area will occur in both parts of this report.

TWO SUBSECTIONS

The report is divided into two parts, dealing with resting (A) and migrating (B) birds respectively. The two subsections follow the same overall structure.

For both parts (resting as well as migrating birds), a compilation of data based on already available publications is given firstly, followed by a description of the methodological approach applied to attain new data. Finally, the new data are brought into context based on the existing knowledge. For those species, that are of either high conservation concern with respect to the expansion of offshore wind energy (e.g. cranes) or for which the pre-investigation area is of particular importance (e.g. long-tailed ducks), special programs or analyses are integrated into this report.

Each subsection also contains a list of references and an Appendix.

Abbreviation	Explanation
DCE	Danish Centre for Environment and Energy
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EIB	Energy Island Bornholm
F129	SPA (see below) number 129
EMODnet	European Marine Observation and Data Network (of the European Union)
HELCOM	Helsinki Commission = The Baltic Marine Environment Protection Commission
IBA	Important Bird Area
IUCN	International Union for the Conservation of Nature
OWF	Offshore wind farm
SAC	Special Area of Conservation
SCI	Sites of Community Interest
SPA	Special Protected Area
StUK4	German Standard Investigation of the Impacts of Offshore Wind Turbines in the marine environment
WP	Waypoint
WPG	Work Package G

PART A

RESTING BIRDS

CONTENTS

1 SUMMARY

1.1 INTRODUCTION

Resting birds include seabirds and other waterfowl species that remain in a non-breeding area during certain periods of the year. They are dependent on the local resources in these areas for moulting, overwintering, foraging etc. Approximately 38 different seabird species occur in the German part of the Baltic Sea, which lies south of the pre-investigation area. Among these, about 20 species are common or more abundant in offshore areas (Sonntag et al. 2006). These include divers, grebes, sea ducks, cormorants, gulls, terns, and auks.

Since these birds are strongly dependent on the existing resources of the areas they remain in, their abundance and presence are closely correlated with the presence/proximity of suitable (feeding and resting/wintering) habitats. Three important shallow sandbanks are found inside or close to the pre-investigation area: Rønne Banke, Adler Grund Banke and Oder Banke. Further south of the pre-investigation area within the German EEZ lies the SPA Pomeranian Bay (No. 1552-401), which is also a Natura 2000 site with a size of 200,000 ha. Rønne Banke is characterised by its shallow water depths ranging between 5-20 m. Since these banks are often covered by mussels they provide important habitats especially for sea ducks such as common and velvet scoters, common eiders and long-tailed ducks (Käppeler et al. 2012).

As the banks constitute important marine bird areas, some of them have been included in a protected area: SCI/SAC Natura-2000 site “Adler Grund” and “Rønne Banke” (site code: DK00VA261). This protected area with a size of 32,054 ha was designated specifically for two habitat types: (i) sandbanks slightly covered by water and (ii) reefs. Prior to the designation as a Natura 2000 site, “Rønne Banke” was considered an important bird area in Denmark, especially for the long-tailed duck and for the Black Guillemot (Rasmussen et al. 2000).

1.2 METHODOLOGY

To identify the resting bird species, which are most relevant for the pre-investigation area, either due to their frequent occurrence or their special conservation status, an extensive literature research was done. Based on the included publications, general information about e.g. distribution, geographic populations and potential anthropogenic impacts was accumulated.

The abundances, densities, and distribution patterns of resting bird species in the pre-investigation area were determined by 17 digital aerial surveys distributed between October 2021 and September 2023. As ”Rønne Banke” is of particular importance to long-tailed ducks, as well as auks and divers, special emphasis was placed on these species resulting in more surveys during winter/spring. The results of this report were considered in the context of other studies conducted for the already operating offshore wind farms “Arkona” and “Wikinger”, which are located south-west of Bornholm within the German EEZ.

Results show that during the 2-year survey period, a total of 32,749 resting birds was observed within the pre-investigation area comprising a total of 23 different species with a similar species composition during both years. Long-tailed ducks were by far the most common species with a total of 72.8 %, followed by velvet scoters (6.6 %), common guillemots (5.5 %) and herring gulls (3.0 %). While some species such as long-tailed ducks and other sea ducks were located mainly within the SPA in the center of the pre-investigation area, other species were spread across the entire pre-investigation area.

1.3 EXISTING DATA

Resting seabirds strongly depend on the resources existing in the areas they choose to spend the winter or rest on migration. Among these resources, the availability of prey is of utmost importance both for benthic feeders such as sea ducks (mostly on molluscs) and for piscivores such as divers and auks. Having to dive to the seabed, benthic feeders prefer shallow water depths for energetic reasons. Fish eaters also frequently concentrate in such shallow-water areas as reefs and mussel banks can provide ideal fish habitat.

Existing data as presented in published information was summarised for six groups of seabirds that represent the vast majority of the resting birds occurring in the pre-investigation area: divers, grebes, cormorant, sea ducks, gulls, and auks. Among these, two species of divers, four sea ducks, and three auk species constitute the most abundant taxa, especially between October and May, and are of highest conservation concern. The general biology, distribution, habitat, and prey preferences as well as population sizes and predominant threats are summarized from the literature for each of the six sea bird groups in the respective chapters.

1.4 SURVEY DATA

The occurrence of the same groups of sea birds was studied within the pre-investigation area by digital aerial surveys. Their temporal and spatial presence is presented in a variety of graphs. With over 70 % of all records, the long-tailed duck is by far the most numerous sea bird. From November to April, high densities of long-tailed ducks (>100 ind./km²) were observed in shallow waters including in the protected areas (Rønne Banke) and close to the coast of Bornholm.

Due to their numerical importance and their known sensitivity to offshore wind farms (OWFs), the occurrence of long-tailed ducks, divers and auks in existing OWFs was also studied via digital aerial survey. The two German OWFs "Wikinger" and "Arkona" are neighbouring the pre-investigation area to the southwest. Very few sea birds were detected in the operating OWFs, and the numbers were compared with monitoring results from 2016 and 2017. The results were lower than pre-construction surveys which was to be expected. Furthermore, long-tailed duck movements were recorded from six anchoring points. The local flights of long-tailed ducks in December and January concentrated around 8.00 h in the morning and took place mostly in altitude of less than 10 m.

1.5 CONCLUSION

The occurrence and distribution of wintering long-tailed ducks correlated well with high abundances of bivalves in the benthos, especially with the occurrence of blue mussel banks – one of their preferred prey species. Non-sea duck species were less concentrated along the reefs and mussel banks. Although there is some indication that some long-tailed ducks may utilize the operating wind farm areas for foraging during the night, the observed numbers are small compared to the total size of the wintering population of long-tailed ducks in the area, as revealed by the HighDef digital surveys. The occurrence within the planned wind farm areas for nocturnal foraging by wintering long-tailed ducks is likely rather limited.

2 INTRODUCTION

With the Climate Agreement for Energy and Industry dated 22nd of June 2020, the majority of the Danish Parliament decided that Denmark will become the first country in the world to develop two energy islands. One of these islands will be the island of Bornholm located in the Baltic Sea ("Energioe Bornholm"), with wind farms located south-west of Bornholm with an installed capacity of up to 3.8 GW. The planned future wind farm areas consist of Bornholm I South (118 km^2), Bornholm I North (123 km^2) and Bornholm II (410 km^2). The island of Bornholm will house the transformer station and serve to distribute the produced energy.

Due to these political decisions, a series of environmental pre-investigations were carried out for a well-defined pre-investigation area (Figure 2). The present report focuses on seabirds resting and foraging in the pre-investigation area. This report is separated from the report focusing on migrating birds, which deals with bird species crossing the pre-investigation area twice a year on their seasonal movements between breeding and wintering grounds. Since many species of seabirds are also migratory birds, the grouping is fluid and the present report considers all seabirds which use the pre-investigation area over longer periods for foraging, wintering, moulting or stopping over during migration.

The pre-investigations included a compilation of data based on already available publications, as well as several digital aerial transect surveys to determine distribution patterns and abundances of relevant resting bird species. Special emphasis was placed on long-tailed ducks. The new bird SPA "Rønne Banke" (F129/DK00FC373) in the Natura 2000 site "Adler Grund og Rønne Banke" (site no. 252/H261) is designated particularly for this sea duck species. Rønne Banke" is in the centre of the pre-investigation region between the offshore wind farm areas. Therefore, long-tailed duck distributions were investigated in more detail. Figure 2 shows the pre-investigation area for Energy Island Bornholm with the planned wind farm areas Bornholm I (OWF1) North and South (B1N and B1S), Bornholm II (OWF2) and the cable corridor area (CC). The cable corridor from Bornholm to Zealand is reported in a separate report and not included in this report, which concerns only the pre-investigation area for Energy Island Bornholm.

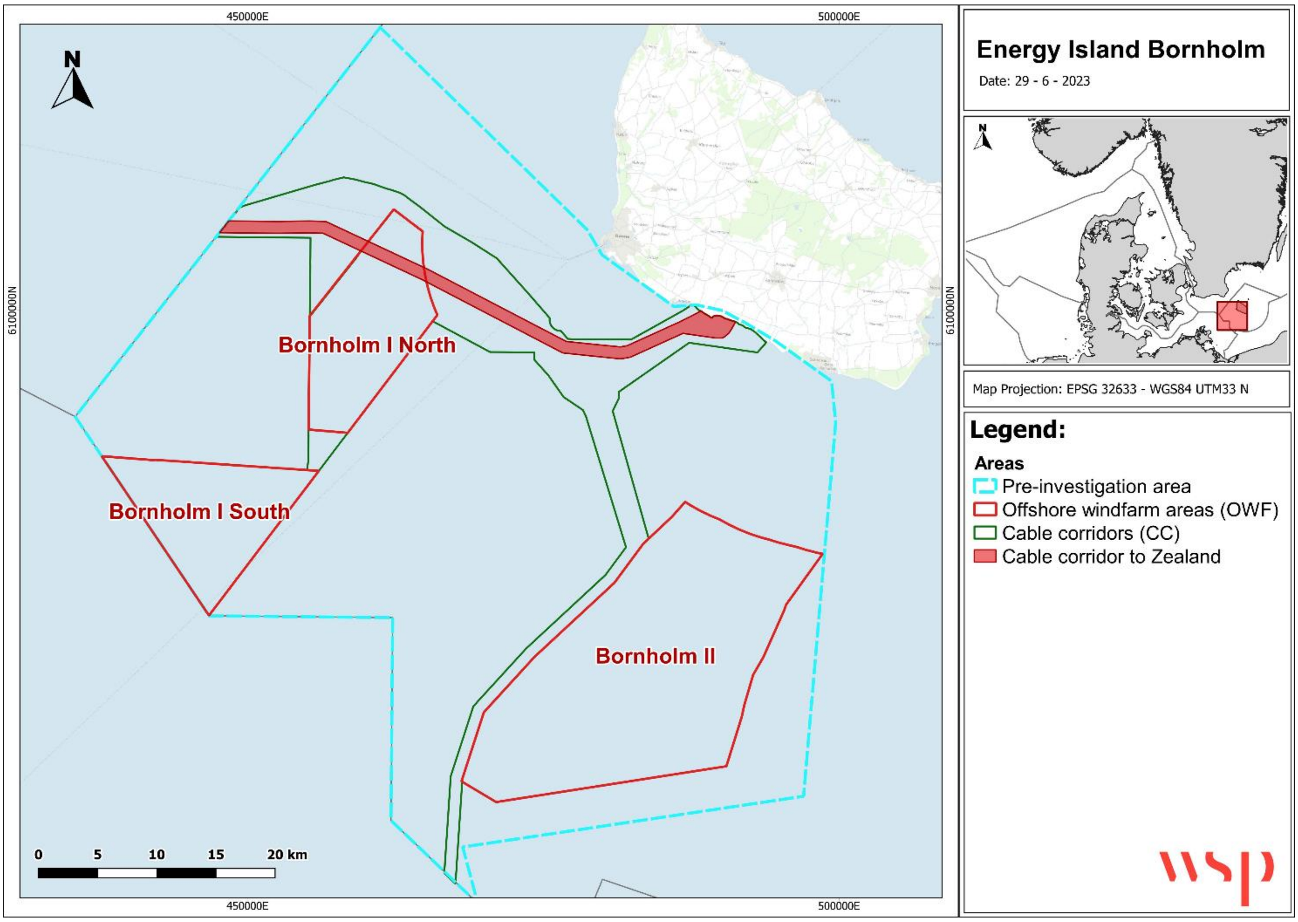

Figure 2. Pre-investigation area for Energy Island Bornholm.

3 METHODOLOGY

This chapter outlines the employed data collection methods and analytical approaches used to investigate the occurrence of seabirds within and around the pre-investigation area of Energy Island Bornholm.

3.1 EXISTING DATA

A desktop study has been conducted by reviewing relevant literature including both peer-reviewed journals as well as publicly available “grey literature”. The considered publications included information on the general distribution and biology, as well as the abundances of resting bird species in the pre-investigation area. Species were selected as relevant, if they either commonly occur in and around the pre-investigation area or have a special conservation status. A detailed description of available information for the most relevant groups of resting bird species, considered to be potentially present in the pre-investigation area is given, supplemented by a brief overview regarding potential threats of anthropogenic impacts.

The desktop study of resting birds also included a study carried out at the Kriegers Flak Offshore Wind Farm with the objective to estimate the abundance and density of wintering long-tailed ducks in the Kriegers Flak area, as well as to describe their spatial distribution (WSP 2023c).

3.2 SURVEY DATA

DIGITAL AERIAL SURVEYS

DATA COLLECTION

To determine abundances, densities, and distribution patterns of resting birds in the pre-investigation area, digital aerial video surveys using the HiDef-technology were conducted. The distribution of surveys followed the pre-agreed design with 7 surveys per year focused on surveying resting birds especially in autumn, winter and spring with a gap of at least 4 weeks between consecutive flights and two additional flights in the first year in June and July focused on surveying marine mammals. As the cameras also capture all objects on and above the sea surface during flights aimed at marine mammals, this data can also be used for bird surveys. These marine mammal flights in summer were omitted in the second year, but the programme was extended by one additional flight survey in September 2023, so that a total of 17 arial surveys were conducted in the period from November 2021 to the end of September 2023 (Table 2).

The surveys covered the pre-investigation area for Energy Island Bornholm and the two operating German OWFs “Wikinger” and “Arkona” (see Figure 3). A total of 13 transects varying between 28 and 66 km in length were covered during the study period, resulting in a total of 585.3 surveyed km (see Table 1 and Table 2 for information regarding single surveys). The transects ran parallel to each other in a north-south direction and were 5 km apart resulting in a total coverage of approx. 11 % of the total area. Compared to observer-based flights, 11 % coverage reflects an excellent resolution with the coverage of digital flights being several times than those of observer-based flights. For assessment studies some countries require a minimum coverage of 10 % so as not to extrapolate too much into the area not covered. In total, 2,859.9 km² were covered during each of the surveys.

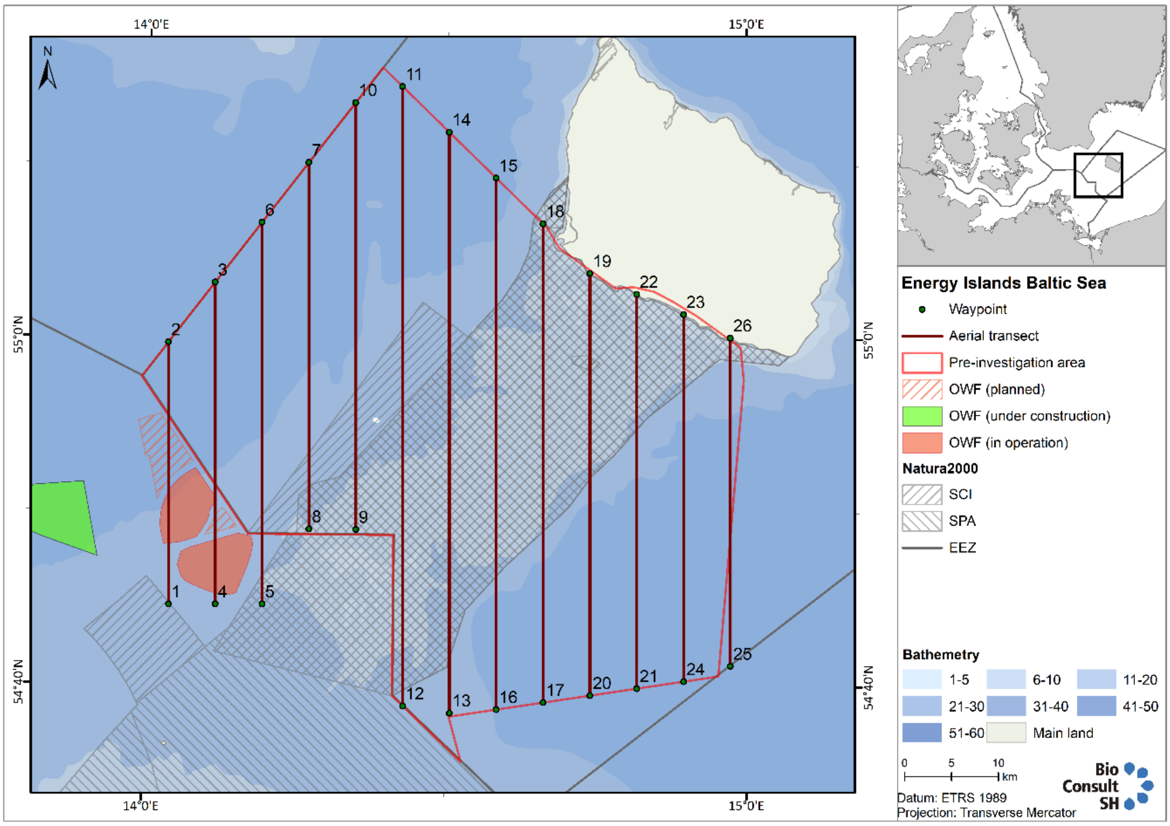

Figure 3. Aerial survey transect design for the pre-investigation area used during all flights. The figure includes the Natura 2000-sites (crosshatched). The aerial surveys also covered a small area within German waters outside the pre-investigation area.

Table 1. Geographical coordinates and length of aerial survey transects in the pre-investigation area for each flight. WP: Waypoint, marking starting and ending point of the transect.

Transect	Transect length (km)	Start of transect			End of transect		
		Wp	Latitude	Longitude	Wp	Latitude	Longitude
1	27.980	1	54° 44.61' N	14° 02.48' E	2	54° 59.69' N	14° 02.12' E
2	34.366	3	55° 03.17' N	14° 06.73' E	4	54° 44.64' N	14° 07.14' E
3	40.751	5	54° 44.67' N	14° 11.80' E	6	55° 06.65' N	14° 11.36' E
4	39.127	7	55° 10.12' N	14° 16.00' E	8	54° 49.02' N	14° 16.38' E
5	45.564	9	54° 49.02' N	14° 21.05' E	10	55° 13.59' N	14° 20.65' E
6	66.164	11	55° 14.55' N	14° 25.35' E	12	54° 38.87' N	14° 25.86' E
7	62.033	13	54° 38.48' N	14° 30.52' E	14	55° 11.93' N	14° 30.11' E
8	56.765	15	55° 09.31' N	14° 34.85' E	16	54° 38.71' N	14° 35.16' E
9	51.129	17	54° 39.12' N	14° 39.81' E	18	55° 06.69' N	14° 39.58' E
10	45.061	19	55° 03.83' N	14° 44.30' E	20	54° 39.53' N	14° 44.45' E
11	42.103	21	54° 39.94' N	14° 49.10' E	22	55° 02.65' N	14° 49.00' E
12	39.198	23	55° 01.49' N	14° 53.70' E	24	54° 40.35' N	14° 53.75' E
13	35.040	25	54° 41.24' N	14° 58.40' E	26	55° 00.13' N	14° 58.39' E

Table 2. Overview of the 17 digital aerial surveys carried out in the pre-investigation area between November 2021 and September 2023. Planned surveys (according to the agreed scope), survey dates, distance covered and survey effort as well as the covered area are given for every single flight.

Survey no.	Plan according to scope	Date	Distance (km)	Effort (km²)	Coverage (%)
1	1 bird survey between 09 and 11/2021	27.11.2021	587.41	315.7	11.0
2	5 bird surveys between 12/2021 and 05/2022	19.12.2021	586.4	317.14	11.1
3		10.01.2022	587.79	318.57	11.1
4		07.02.2022	588.38	319.17	11.2
5		01.03.2022	587.17	318.86	11.1
6		11.04.2022	586.94	316.73	11.1
7	1 bird survey + 2 marine mammals surveys between 06 and 08/2022	17.06.2022	587.15	318.56	11.1
8		11.07.2022	588.02	311.14	10.9
9		03.08.2022	588.61	318.87	11.1
10	1 bird survey between 09 and 11/2022	09.10.2022	578.67	308.29	10.8
11	5 bird surveys between 12/2022 and 05/2023	14.12.2022	587.52	318.26	11.1
12		28.01.2023	587.2	318.66	11.1
13		22.02.2023	572.08	310.68	10.9
14		12.03.2023	584.97	317.62	11.1
15		09.05.2023	586.79	318.52	11.1
16	1 bird survey between 06 and 08/2023	04.06.2023	600.78	325.18	11.4
17	1 extra bird survey between 09 and 11/2023	08.09.2023	588.31	318.97	11.2
			Total: 9,974.2	**Total: 5,390.9**	**Average: 11.1**

The recording of resting birds was performed using the digital video technology developed by the company HiDef (HiDef Aerial Surveying Ltd 2024).

A twin-engine, high-wing propeller-driven aircraft (Partenavia P 68) was used for the acquisition of digital videos, see Figure 4. This aircraft was equipped with four high-resolution video camera systems, which take approximately seven images per second and can achieve a resolution of two cm at sea surface. Since the camera system is not directed vertically downwards (depending on the sun position, it can be slightly inclined or even set against the flight direction), interferences arising from solar reflections (glare) can be effectively reduced. The external cameras (indicated by A and D, Figure 4) cover a strip of 143 m width while the internal ones cover a width of 129 m each, resulting in 544 m effectively covered. There is however about 20 m distance between each strip to avoid double counting of individuals detected by the cameras. Thus, the total recorded strip of 544 m is distributed over a width of 604 m.

The aircraft flew at an average speed of approx. 220 km/h (120 knots) at an altitude of 549 m. A GPS device (Garmin GPSMap 296) recorded the position every second, which permitted to geographically assign a location to the images and the individuals registered on them. The collected data was stored on mobile hard disks for subsequent review and analysis. For further details regarding the method, see Weiß et al. (2016).

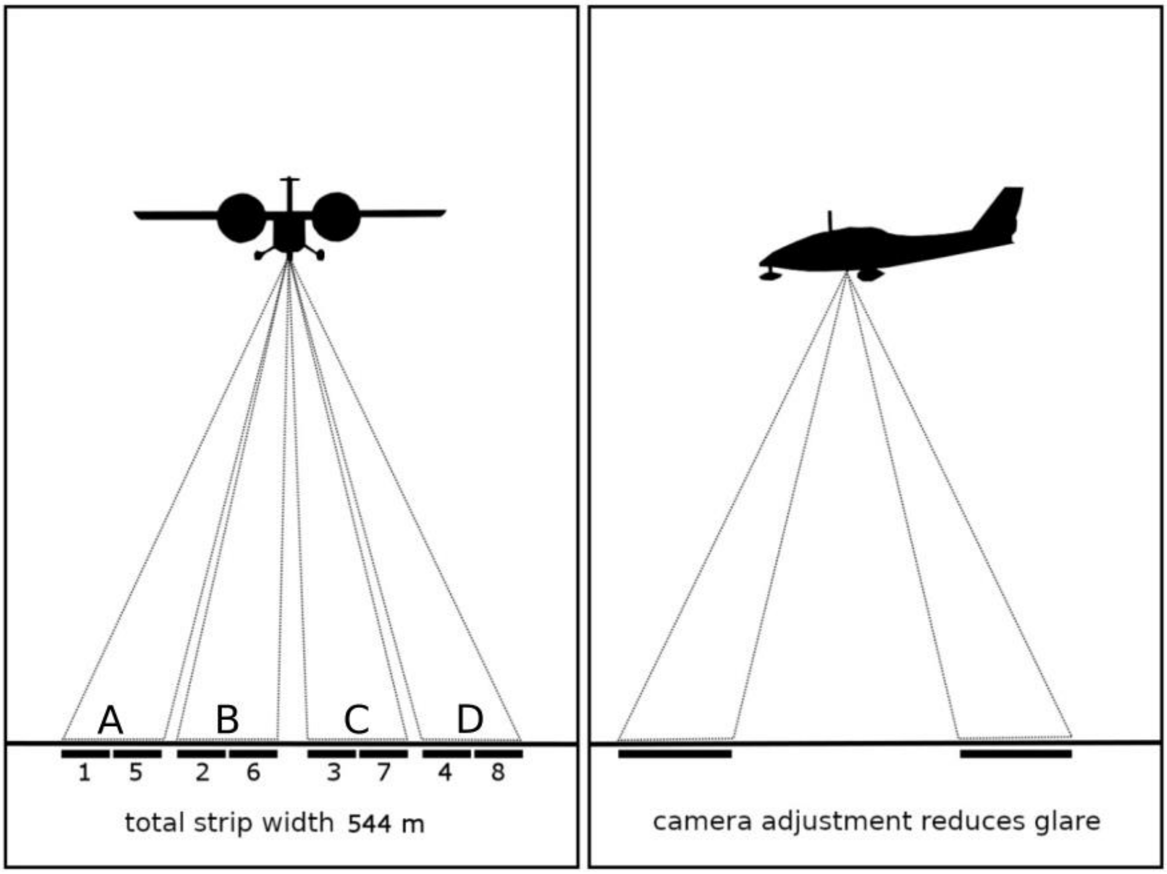

Figure 4. The HiDef Camera-System. The four cameras (A to D) cover an effective strip width of 544 m of the sea surface at a flight altitude of 549 m (left: frontal view; right: side view). The numbering indicates the camera images as they are used in the evaluation (the images from each camera are divided into two halves).

DATA ANALYSIS

To facilitate the detection of objects, the video sequences taken from each camera were split into halves, so that each fitted the width of a large monitor. The video files were then processed using an image capture and management software (StreamPix). Images were examined to mark all detected objects (birds, mammals, ships, etc.) and pre-sorted for subsequent identification. To guarantee a consistently high quality, 20 % of each film was randomly selected and processed again by another reviewer. If both reviewers reached a consensus of 90 % regarding object identification, discrepancies were rechecked, and the film afterwards approved for further analysis. If the consensus was below 90 %, the film was reanalysed entirely. Sections of the footage that could not be assessed due to backlight or the presence of clouds were not considered for further analysis.

Once the images were approved, the previously marked objects characterised as birds were identified by experienced observers. Due to strong similarities between some species (e.g. common guillemots and razorbills, common and arctic terns, red-throated and black-throated divers), an identification on species level was not always possible. However, it was usually possible to identify individuals as belonging to a species group formed by two or few closely related species, e.g. auks, which include common guillemots and razorbills. Relevant species as well as species groups were defined based on the frequency of occurrence in the pre-investigation area and the importance of the area as habitat for these according to reference literature. In addition to the identification, other information such as position, age, behaviour (swimming or flying) and flight direction were determined whenever possible.

Environmental parameters including air turbidity, sea state, solar reflection, and water turbidity were recorded every 500 images (approx. covering 4 km). To ensure quality control, 20 % of the objects identified were reassessed by a second observer. All discrepancies between the first and second identification process were checked again by a third expert. If there was a consensus of at least 90 %, the data collected was released for further analysis. If the consensus was below 90 %, systematic errors (e.g. problems in determining species groups) were corrected and all objects were re-identified.

Based on the number of detected individuals for each species or species group, monthly or seasonally mean densities given as ind./km² were calculated. As the survey effort differed among transects (see Table 2), densities were corrected by dividing them by the area covered for each transect. As the effect of the aircraft on resting birds is negligible, no correction factors are applied to the abundances of species (Zydelis et al. 2019).

Therefore, it is assumed that all birds present in the study during the time of the survey are captured by the images.

The spatial distribution was determined for all surveys together or seasonally according to the species-specific classification by GARTHE et al. (2007) and displayed using grid density maps. A grid was laid over the pre-investigation area with its grid cells aligned with the EEA grid (EEA 2019). For certain species also point sighting maps from single surveys are displayed to demonstrate distribution patterns at specific days.

DISTRIBUTION OF SEABIRDS IN EXISTING GERMAN OWFS

Before the start of the pre-investigation study, it was decided to extend the transect lines to cross the already operating OWFs on the German site “Wikinger” and “Arkona” (see Figure 3, areas bordered in green), which are directly connected to the pre-investigation area. The aim of this coverage of the wind farms was to gain more knowledge of the potential effect of the existing wind farms on the distribution of birds in the pre-investigation area.

As the bird SPA “Rønne Banke” (F129/DK00FC373), which is in the centre of the pre-investigation area between the planned offshore wind farm areas, is designated for the protection of long-tailed ducks in particular, their distributions were investigated in more detail. Point observation maps were created to illustrate the distribution along the transects. Buffer zones with a distance of 1 km, extending to a distance of 10 km, were drawn around the wind farm and the densities within each zone were calculated.

Water depth, which is closely related to available food resources has been included as well, to investigate to what extent these can explain long-tailed duck distribution.

The same analyses were performed for auks (including common and black guillemots, as well as razorbills), and divers (including red-throated and black-throated Divers), as the pre-investigation area provides an important habitat for these species as well.

LONG-TAILED DUCK OBSERVATION SURVEYS

In 2021 the Danish Environmental Agency designated a Special Protection Area (SPA) and internationally protected Natura 2000-site, ‘Rønne Banke’ (F129) inside the pre-investigation area for Energy Island Bornholm. The new SPA has been designated to protect the long-tailed duck (*Clangula hyemalis*).

The objective of the survey was to investigate whether the planned future wind farm areas (sub-sections inside the pre-investigation area) for Energy Island Bornholm OWF serve as night-resting areas for long-tailed ducks coming from the nearby Natura 2000-site and the SPA ‘Rønne Banke’ and to observe if there are movements of birds between the SPA and the planned future wind farm areas.

Vessel surveys were carried out at each 2 x 3 anchoring points between the boundary of the SPA (F129) and the two planned wind farm areas, Bornholm I (North & South) and Bornholm II (Figure 5 and Table 3). The surveys were conducted in December 2021 and January 2022 where the highest numbers of long-tailed ducks are expected to be present in the area.

Two observers registered all flying seabirds within 360° around the anchored vessel. For all observations, the number of individuals, distance to the vessel, direction of flight and estimated flight height were recorded. Both observers had to be in contact with each other to avoid double counts. All recordings were visually based, either with the naked eye or with a pair of binoculars (8 x magnification) and observed at a distance between 0 – 3,000 m from the vessel. Observations were carried out during the first three hours after sunrise and again during the last three hours before sunset. Details of the completed vessel surveys are found in Table 4.

Recordings were afterwards digitised and analysed with the programme R Studio (RStudio Team 2023) utilizing the Radarcircle tools within the FMSB package. Maps were created with the programme QGIS (QGIS.org 2024) for visualization of the area and anchoring points.

Table 3. Anchoring points for the long-tailed duck surveys. See also Figure 5. DD=Decimal degrees.

Anchor points	Latitude DD(y)	Longitude DD(x)
1 west	54.8620594908	14.2316927173
2 west	54.9296792891	14.3188851840
3 west	54.9984092216	14.4079263522
1 east	54.7415262456	14.5395696026
2 east	54.7959652075	14.6286409240
3 east	54.8518215550	14.7240373946

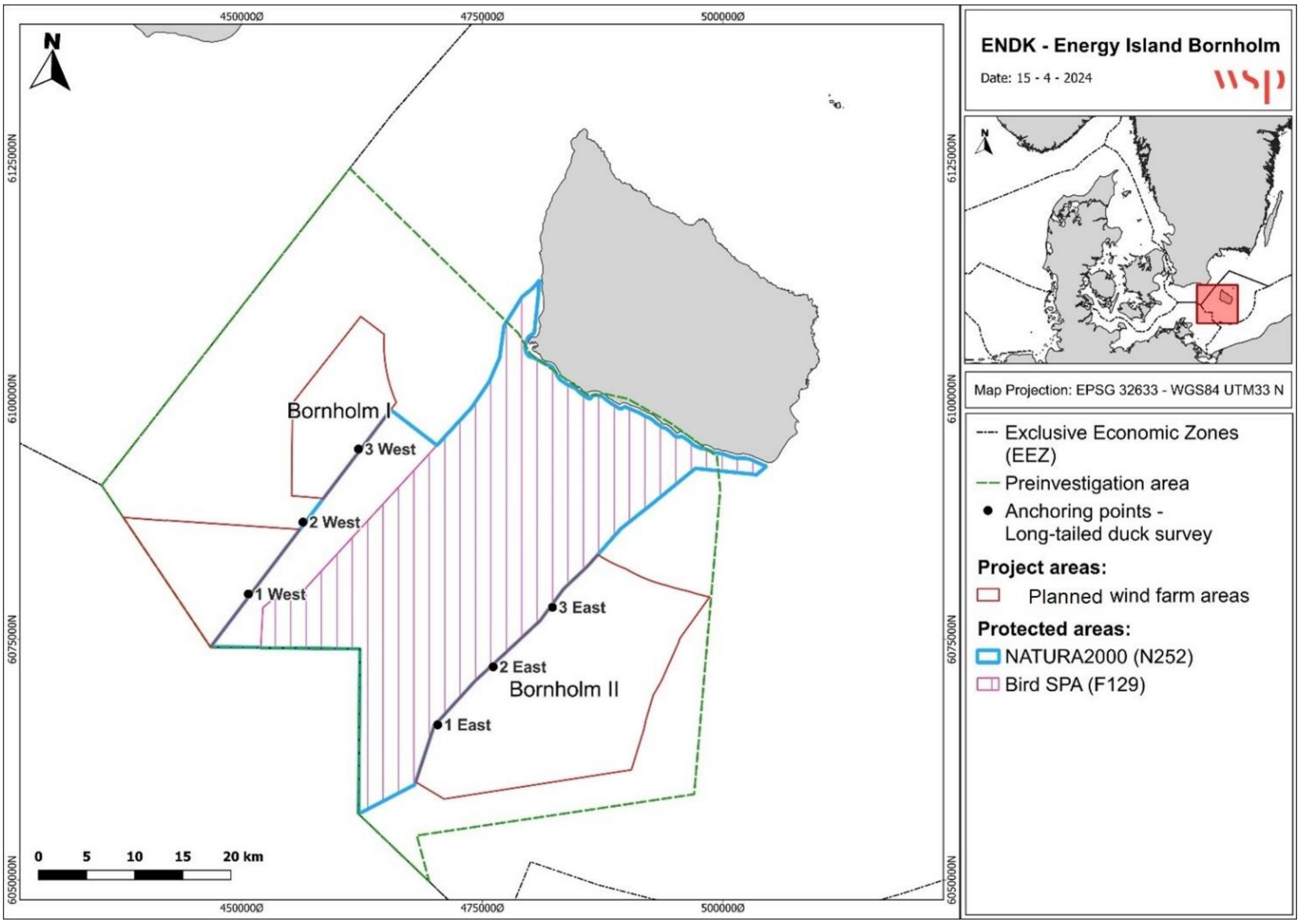

Figure 5. Location of the anchoring points in relation to the pre-investigation area and the Natura 2000 site 252 and SPA F129 Rønne Banke.

Table 4. Vessel surveys carried out at the six anchoring points. Coordinates can be found in Table 3.

Date	Anchor point	Wind	Temperature in degree Celcius	Precipitation	Wave height	Visibility	Note
07-12-2021	1 west	8-10 m/s from W	1	None	1-2 m	>10 km	
08-12-2021	2 west	18-20 m/s from S	0	None	3-4 m	>5 km	Survey not carried out due to weather conditions
09-12-2021	2 west	5-7 m/s from SE	0	None	0.5-1.5 m	>5 km	
10-12-2021	3 west	5-7 m/s from SE	0	None	0.5-1.5m	>5 km	
11-12-2021	3 east	5-7 m/s from SW	2	1mm	1 m	>10 km	
12-12-2021	2 east	5 m/s from SW	4	None	1 m	>10 km	
13-12-2021	1 east	1 m/s from S	5	None	0 m	>10 km	
06-01-2022	3 west	12 m/s from NW	4	None	1.5 m	>10 km	
07-01-2022	3 east	12 m/s from SW	4	None	1.5 m	>10 km	
08-01-2022	2 east	12 m/s from SW	4	None	1.5 m	>10 km	
09-01-2022	2 west	13 m/s from SE	5	None	2 m	>10 km	
24-01-2022	1 east	7-8 m/s from W	5-6	Light drizzle for a few hours	0.1-1 m	0.1-10 km	Low visibility from 7.30am to 8:45am.
25-01-2022	1 west	7.5-11 m/s from W	6	None	0.4-1.2	>10 km	

4 RESULTS

4.1 EXISTING DATA

Resting birds include seabirds and other waterfowl species that stay in the pre-investigation area or longer periods during certain times of the year. They are dependent on the local resources in these areas for moulting, overwintering, foraging etc. They typically tend to be very long-lived and have several adaptations that allow them to exploit resources even during harsh climate conditions. Around 38 different seabird species occur in the German part of the Baltic Sea, which lies south of the pre-investigation area. Among these, about 20 species are common or more abundant in offshore areas (Sonntag et al. 2006, Holm et al. 2023). These include divers, grebes, of sea ducks, cormorants, gulls, terns, and auks that are also common in the pre-investigation area as will be shown in the following.

Since these birds are strongly dependent on the existing resources of the areas they remain in, their abundance and presence are closely correlated with the presence/proximity of suitable (feeding and resting/wintering) habitats. Three important shallow sandbanks are found close to – or within the pre-investigation area: Rønne Banke, Adlergrund Banke and Ode Banke. Rønne Banke is characterised by its shallow waters (5-20 m). Both Adlergrund and Rønne Banke were formed by glaciers and have depths ranging between 5 and 25 meters of depth (Figure 13). Various sediment types ranging from sand to gravel or stones often covered by mussel beds can be found here (Käppeler et al. 2012). Ode Banke is distinguished by shallow waters and mostly sandy sediments (Käppeler et al. 2012). These banks provide important habitats especially for sea ducks such as common- and velvet scoters, common eiders and long-tailed ducks (Käppeler et al. 2012).

As the banks constitute important marine bird areas, some of them have been included in a protected area: SCI/SAC Natura 2000 area “Adler Grund og Rønne Banke” (site code: DK00VA261). This protected area with a size of 32,054 ha was designated specifically for two habitat types: (i) sandbanks slightly covered by water and (ii) reefs. Prior to the designation as a Natura 2000 site, Rønne Banke was considered an important bird area in Denmark, especially for the long-tailed duck and for the black guillemot (Rasmussen et al. 2000).

Further south of the pre-investigation area within the German EEZ lies the SPA Pomeranian Bay (No. 1552-401), which is also a Natura 2000 site with a size of 200,000 ha. Several of the species residing in this area are protected under various agreements. Among them are divers, three species of grebes, six species of gulls, four species of ducks, three species of auks and the great cormorant. All of these are expected to occur in the EIB pre-investigation area as well.

DIVERS (RED-THROATED DIVER AND BLACK-THROATED DIVER)

Divers, also called loons, include five species of fish-eating birds strongly linked to aquatic environments that inhabit the taiga and tundra regions of the Holarctic. All divers are migratory, breeding in freshwater lakes and spending the winter season at sea (Hemmer 2020). Two diver species are commonly found in the Baltic Sea, the red-throated diver (*Gavia stellata*) and the black-throated diver (*Gavia arctica*). While black-throated divers choose fish-rich inland lakes for breeding, red-throated divers prefer small fish-devoid water bodies and search for their food at larger waterbodies or at sea (Eriksson 2010, Hemmer 2020). Both species breed mainly in Scandinavia and in Russia (Durinck et al. 1994).

The diet of red-throated divers has been investigated in the Pomeranian Bay, which is one of their main wintering areas probably due to the suitability of the area as spawning, nursery and feeding ground for many fish species. Pikeperch (*Sander lucioperca*) and herring (*Clupea harengus*) constitute the majority of the consumed biomass of red-throated divers in winter and spring respectively (Guse et al. 2009).

Both species are widely distributed in the Baltic Sea. Most individuals occur in the Gulf of Riga at waters less than 30 meters of depth (Durinck et al. 1993). Other important areas are located off the coast of Lithuania and the Pomeranian Bay (Durinck et al. 1994). According to both studies, most divers are wintering offshore in areas with water depths ranging between 5 and 30 meters.

Estimates conducted almost two decades ago suggested an overall wintering population size of 150,000 to 450,000 red-throated divers and 250,000 to 500,000 black-throated divers for the population inhabiting northwest Europe (Mendel et al. 2008, Skov et al. 2011). Populations of both species show a declining trend. More recent evaluations estimate 210,000 – 340,000 wintering red-throated divers individuals (Wetlands International 2022, AEWA CSR 8, accessed on 23.02.2024). The population of black-throated divers inhabiting northern and western Europe and Siberia is estimated at 390,000 – 590,000 individuals (Wetlands International 2022, AEWA CSR 8, accessed on 23.02.2024).

Whereas the largest densities are reported for the Gulf of Riga (> 10 ind./km^2, Durinck et al. 1994), densities at Rønne banke (close to the pre-investigation area) have been estimated as intermediate (1-2 ind./km^2, Durinck et al. 1993). Both diver species are also often found at the Adlergrund and Ode banke (Durinck et al. 1993). A monitoring study conducted for the preliminary site O-1.3 (southwest of Bornholm I) found that the highest densities of divers occurring at areas that were relatively shallow and located closely to the banks (BioConsult SH et al. 2020a).

During the year, divers are expected in the pre-investigation area from November to June. Large densities are expected in winter (January and February), followed by a decrease as individuals will leave the pre-investigation area to migrate to their breeding grounds. From July to September both divers are expected to occur in the area only sporadically. According to Holm et al. (2023), the waters southwest of the island of Bornholm are of major importance to resting divers in Denmark. For 2020, this situation is confirmed by Nielsen et al. (2023) when a large portion of the 5400 individuals were recorded overwintering west of Bornholm.

Besides very few black-throated divers also present during summer in the SPA Pomeranian Bay south of Bornholm (Mendel et al. 2008), both species use the Baltic Sea almost exclusively as wintering and staging grounds and as a migration corridor to wintering areas further south and west, such as the North Sea or Atlantic coastal waters. These are predominantly divers breeding in northern Russia (Mendel et al. 2008, Dorsch et al. 2019) which will arrive in or cross the pre-investigation area from October to January and leave until June. Bellebaum and colleagues (2010a) report higher numbers of migrating red-throated divers near the coast as opposed to areas further offshore, assuming a more southward concentration of spring migration along the German coast and an autumn migration further north with counts of 4,000 individuals passing between the Swedish Skåne coast and Bornholm. GPS tracks of about 20 tagged red-throated divers (Dorsch et al. 2019) suggest that individuals are rather evenly spread across the pre-investigation area and did not confirm these patterns.

Flight heights of both diver species are generally estimated to be low. Especially during headwind situations divers tend to fly close to the water surface. They will usually not be observed flying at heights surpassing 50 meters and often fly at heights of up to 10 meters off the water surface (Krüger & Garthe 2001, Bellebaum et al. 2010b, BioConsult SH et al. 2020b).

Both species of divers are not considered threatened on a global scale. The IUCN categories and the recent Birdlife International Red List for Europe (BirdLife International 2021) considered them as species of least concern. Nevertheless, their populations have decreased and since they are among the seabird species most vulnerable to many anthropogenic factors, they are included in the Annex I of European Union (EU) Birds Directive (Council Directive 2009/147/EC on the conservation of wild birds, European Union 2010) and in the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA, UNEP/AEWA Secretariat 2019). Moreover, their wintering populations are considered to be critically endangered (CR) by HELCOM (HELCOM 2013b).

Oil spills, habitat degradation and being caught as bycatch in fishing nets are the most common threats to divers (Mendel et al. 2008). Additionally, contamination of breeding lakes, for example by mercury pollution, may affect their reproductive success (e.g., Eriksson 2015). Furthermore, it has been shown that ship traffic and offshore wind farms are known to have detrimental effects on divers. They display a strong avoidance of OWFs (Dierschke et al. 2016), which can be noticeable at distances of up to 16 km from an OWF (Mendel et al. 2019).

GREBES

Grebes occur in coastal areas with shallow waters. The most important species of grebes which may be found in the pre-investigation area are red-necked grebes (*Podiceps grisegena*), great crested grebes (*Podiceps cristatus*), and Slavonian grebes (*Podiceps auritus*). All occur in the Pomeranian Bay and might be found south and west of Bornholm (Durinck et al. 1993). However, they are not expected in large numbers in the pre-investigation area. Previous baseline studies on the O-1.3 site directly west of the pre-investigation area found only small numbers of grebes (BioConsult SH et al. 2020a).

An estimated total of 3.500-4,000 pairs of great-crested grebes breeds in Denmark. Many of these concentrate in lakes and coastal waters during July-September (Meltofte 1996). Based on the IUCN categories and the recent Birdlife International Red List for Europe, the European populations of Slavonian grebes are considered near threatened, those of red-necked grebes are categorised as vulnerable and those of great-crested grebes are considered to be of least concern (BirdLife International 2021).

GREAT CORMORANT

Two of the six subspecies of the great cormorant (*Phalacrocorax carbo*) may occur in north Europe: *P. carbo carbo* and *P. carbo sinensis*, the latter is the subspecies that may occur in the pre-investigation area. In general, cormorants are diving coastal birds feeding on fish and small eels.

According to population estimates by Birdlife, 828,000 – 1,030,000 great cormorant individuals are found across Europe (BirdLife International 2021). In the Baltic Sea, they occur during the whole year, however they are mainly associated with coastal habitats. Great cormorants can be attracted to OWFs and other man-made structures, as these provide them with resting sites, thus allowing them to expand their foraging grounds further offshore (Dierschke et al. 2016).

During the 19th century, the species went almost extinct. After protection measures established in the mid-20th century, the population has increased in the Baltic with a total of 190,000 – 210,000 breeding pairs occurring in the entire region, and around 27,000 breeding pairs in Denmark in 2012 (Herrmann et al. 2014). Recent IUCN assessments consider them as least concerned (BirdLife International 2021). Besides the common threats affecting most seabirds like oil spills, habitat degradation and fishing nets, great cormorants may suffer from conflicts with the fishing industry. Since their diet includes fish also utilised by humans, they have been blamed for potentially reducing fish stocks. Although a reduction of pikeperch was associated to the colony size of cormorants, no significant results were observed for other species (Östman et al. 2012). Most likely, the relationship between cormorants and fish is more complex and requires further research (Ovegård et al. 2021).

SEA DUCKS

Sea ducks spend their non-breeding season in marine environments feeding mainly on bivalves (e.g. Madsen 1954; Meissner & Bräger 1990; Mendel et al. 2008). The Baltic Sea offers important moulting and wintering sites for sea ducks with individuals mainly located in coastal waters and shallow offshore banks, where they can easily dive to obtain their food (e.g. Bräger et al. 1995). Among the most common and abundant sea ducks that may occur in the pre-investigation area are long-tailed ducks, common eiders, common scoters and velvet scoters. In general, all sea duck populations have suffered from declines in recent years (e.g., Durinck et al. 1993, Mendel et al. 2008, Bellebaum et al. 2012, Nilsson & Haas 2016). They are subject to many anthropogenic threats including oil pollution, being caught as bycatch in fishing nets and habitat degradation (Mendel et al.

2008, Bellebaum et al. 2012, Nilsson 2016). In addition, breeding populations may suffer predation from gulls and other raptor species (Bellebaum et al. 2012). Some sea duck species such as common scoters are strongly disturbed by ship traffic showing long escape distances, while others may be less disturbed (Fliessbach et al. 2019). The same applies to the disturbance caused by OWFs, as the reaction differs among species as well (Petersen & Fox 2007, Petersen et al. 2014, Dierschke et al. 2016).

LONG-TAILED DUCK

Long-tailed ducks (*Clangula hyemalis*) have a circumpolar distribution range and migrate between artic breeding grounds and temperate wintering areas. They mainly breed in freshwater habitats located in the artic tundra areas, or in areas that provide similar conditions – e.g., the alpine areas of the Norwegian west coast (Glutz von Blotzheim & Bauer 1992). During the breeding season long-tailed ducks forage on a variety of organisms including insect larvae, fish spawn, crustaceans, and molluscs (Glutz von Blotzheim & Bauer 1992). During the non-breeding season, long-tailed ducks are gregarious, and often seen in flocks at temperate marine coastal areas and offshore banks, where they mainly feed on bivalves supplemented by polychaeta worms, echinoderms, and fish spawn (Madsen 1954, Kirchhoff 1979, Stempniewicz 1995, Evert 2004, Žydelis & Ruskyte 2005).

Long-tailed ducks wintering in the pre-investigation area are part of the Fennoscandian-West Siberian population. They arrive from the breeding grounds from October, being most numerous during winter (January-February) and leave in April to migrate to their breeding grounds (Mendel et al. 2008). Observations of long-tailed ducks in the pre-investigation area in summer are thus unlikely except for sporadically appearing young non-breeding individuals. The most important areas in the Baltic Sea include the Pomeranian Bay, the Gulf of Riga, and Midsjö Banks south of Gotland. According to Holm et al. (2023), the waters southwest of the island of Bornholm are of major importance to resting long-tailed ducks in Denmark.

A considerable number of long-tailed ducks have been observed at Rønne Banke within the pre-investigation area (see Table 5). The Danish Center for Environment and Energy (DCE) has regularly conducted aerial surveys of the region and has estimated a total of 18,000-30,000 wintering individuals at Rønne Banke (Petersen et al. 2016).

Table 5. Number and densities of long-tailed ducks in IBA Rønne Banke during the national Danish winter bird census (elaborated from Petersen et al. 2016, Petersen et al. 2021, and Nielsen et al. 2023).

Year	Estimated number	Estimated number within IBA	Percent within IBA	Density in IBA (birds/km^2)
2004	27,556	26,421	96 %	22
2008	8,776 (Partial survey)	8,155 (Partial survey)	93 % (Partial survey)	7
2013	24,000-39,000	16,000-24,000	66.7 % / 61.5 %	13-20
2016	28,000-45,000	18,000-30,000	64.3 % / 66.7 %	15-25
2020	33,200	Not available (unpublished)	27.2 %-	-

Based on a coordinated Baltic Sea survey from 2007 to 2009 roughly 1.5 million long-tailed ducks were estimated to winter in the Baltic Sea (Skov et al. 2011). This is a decline of 65 % compared to the census in 1988-1993, where a number of 4.7 million individuals was estimated (Wetlands International 2006). The distribution and density of wintering long-tailed ducks based on the joint survey between 2007 and 2009 are shown in Figure 6.

The average number of wintering long-tailed ducks estimated by spatial modelling based on this data is summarized in Table 6.

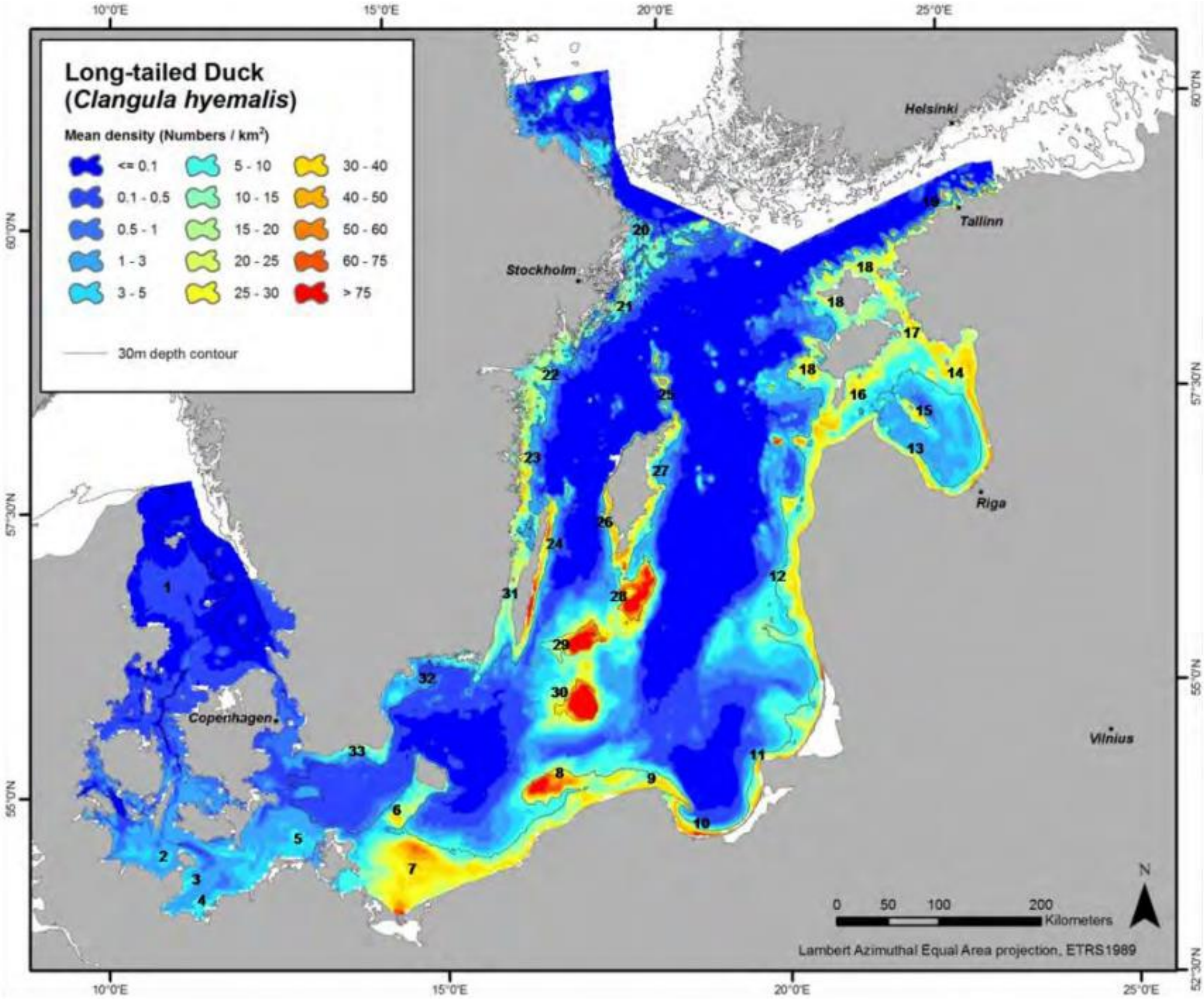

Figure 6. Distribution and density of wintering long-tailed ducks in the Baltic Sea from 2007 to 2009 (Skov et al. 2011).

Table 6. The average number of wintering long-tailed ducks *Clangula hyemalis* estimated by spatial modelling for key areas of the Baltic Sea, 2007–2009 (Skov et al. 2011).

	Locality	Area	Number	Mean density	Std density	%
1	NW Kattegat	3,353	440	0.13	0.05	0.03
2	Kiel Bay	2,537	4,970	1.96	1.12	0.33
3	Sagas Bank	267	890	3.34	1.07	0.06
4	Wismar Bay	434	1,980	4.55	1.57	0.13
5	Darss & Plantagenet Ground	1,642	5,550	3.38	1.16	0.37
6	Rønne Bank & Adler Ground	722	12,000	16.60	9.83	0.81
7	Pomeranian Bay	7,316	186,000	25.45	11.54	12.51
8	Slupsk Bank	1,402	61,200	43.67	24.16	4.12
9	Central Polish coast	2,628	51,500	19.58	10.34	3.47
10	Gulf of Gdansk	1,053	26,000	24.73	19.62	1.75
11	Kaliningrad – Lithuania S	1,314	22,900	17.44	10.58	1.54
12	Lithuania N – Latvia S	1,317	35,800	27.18	8.92	2.41
13	Gulf of Riga, southwest	1,751	30,800	17.58	11.49	2.07
14	Kihnu offshore	3,316	73,300	22.09	12.22	4.93
15	Ruhnu offshore	615	8,160	13.27	10.31	0.55
16	Gulf of Riga, northwest	2,982	60,700	20.36	12.64	4.08
17	Muhu Strait	375	9,710	25.86	7.65	0.65
18	Hiiumaa & Saaremaa coast	4,973	69,000	13.89	9.59	4.64
19	Estonia N coast	1,524	15,000	9.99	12.15	1.01
20	Stockholm archipelago N	3,349	20,700	6.18	5.06	1.39
21	Stockholm archipelago S and Södermanland Archipelago	1,248	10,700	8.57	7.51	0.72
22	Östergötland Archipelago	1,515	22,300	14.70	7.87	1.50
23	N Kalmar Archipelago	1,130	21,000	18.56	11.81	1.41
24	Öland E	1,486	43,600	29.35	22.16	2.93
25	Fårö & Gotska Sandøn	720	6,100	8.42	10.55	0.41
26	Gotland SW	630	16,000	25.47	15.36	1.08
27	Gotland E	1,896	28,000	14.95	11.27	1.88
28	Hoburgs Bank	3,198	113,800	35.58	30.60	7.66
29	N Midsjö Bank	2,767	93,600	33.81	42.25	6.30
30	S Midsjö Bank	2,428	153,900	63.38	80.96	10.35
31	Kalmar Sound	2,292	27,100	11.83	6.84	1.82
32	Hanö Bay	1,937	6,980	3.60	3.13	0.47
33	Skåne S coast	913	6,570	7.19	4.90	0.44
	Key areas		1,246,000			83.85
	Residual		240,000			16.15
	Total		**1,486,000**			**100.00**

Rønne Banke, also designated as an Important Bird Area (IBA) by BirdLife International, has been known as an important resting ground for long-tailed ducks for decades (Petersen et al. 2016). It was officially designated as a Special Protection Area (SPA) under the EU Birds Directive in 2021 by the Danish Authorities. The distribution and the estimated number of birds in the IBA based on aerial surveys carried out by DCE are shown in Figure 7 to Figure 10 (Petersen et al. 2016, 2021). This information is confirmed by Holm et al. (2023) and Nielsen et al. (2023).

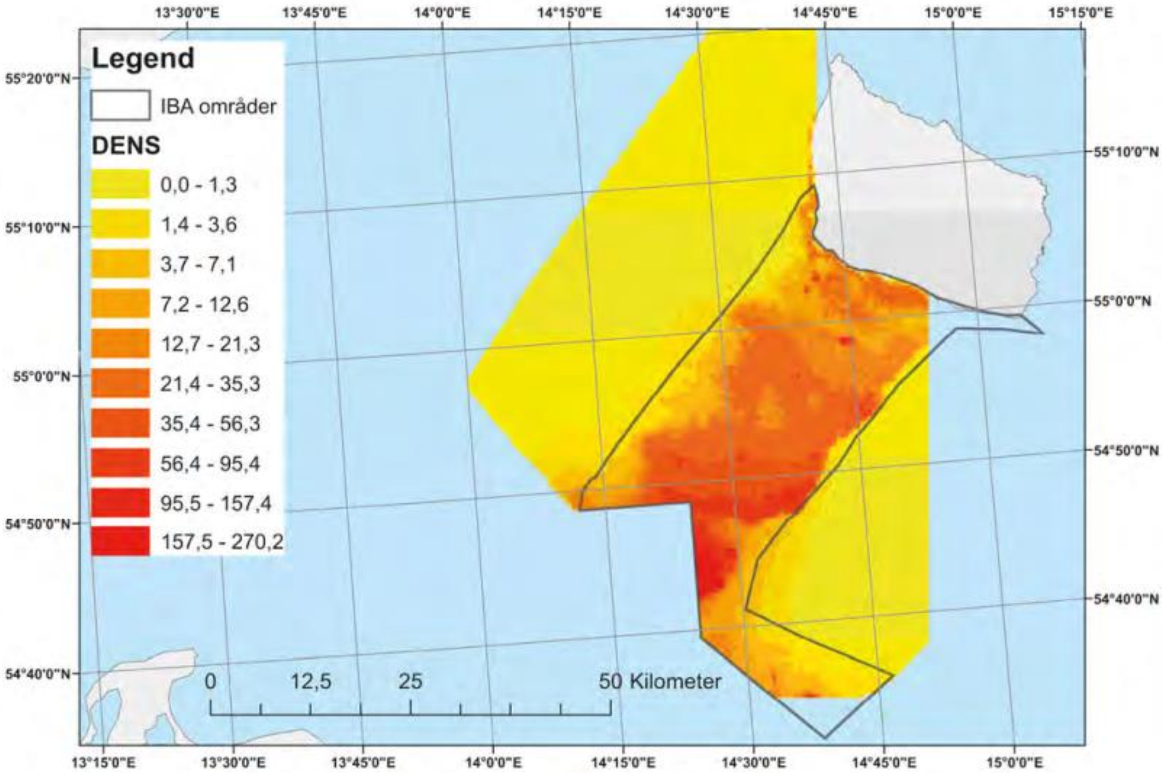

Figure 7. Modelled distribution of 27,556 long-tailed ducks in the waters west of Bornholm in winter 2004. 26,421 (96 %) individuals were located within the IBA (Petersen et al. 2016).

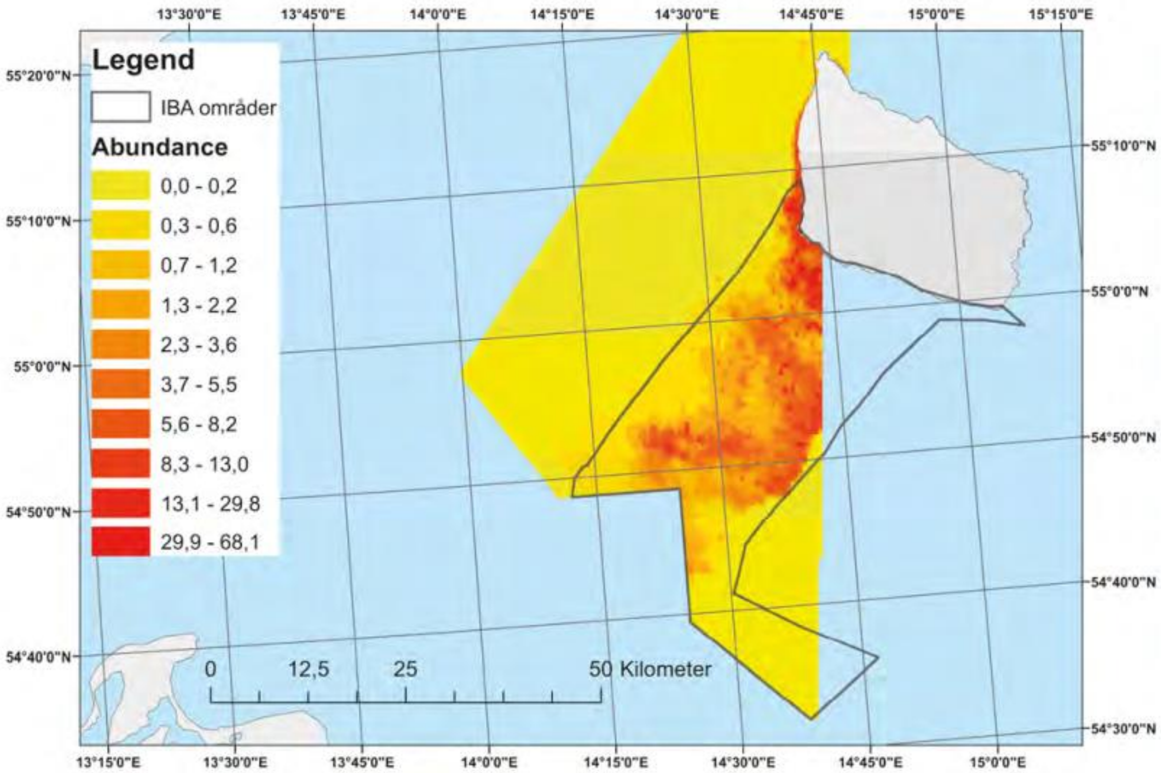

Figure 8. Modelled distribution of 8,776 long-tailed ducks in the waters west of Bornholm in winter 2008. 8,155 (96 %) individuals were located within the IBA (Petersen et al. 2016).

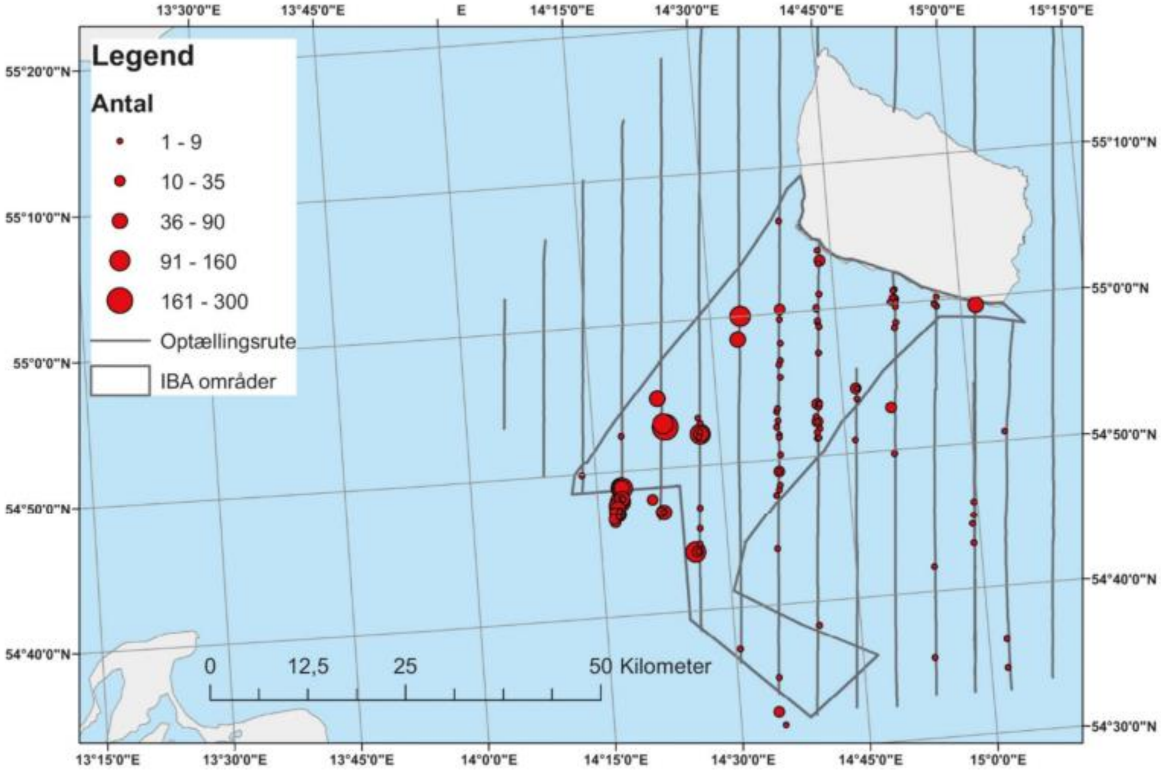

Figure 9. Distribution based on observations of 2,377 long-tailed ducks in the waters west of Bornholm in winter 2013. 1,524 (64 %) individuals were located within the IBA (Petersen et al. 2021).

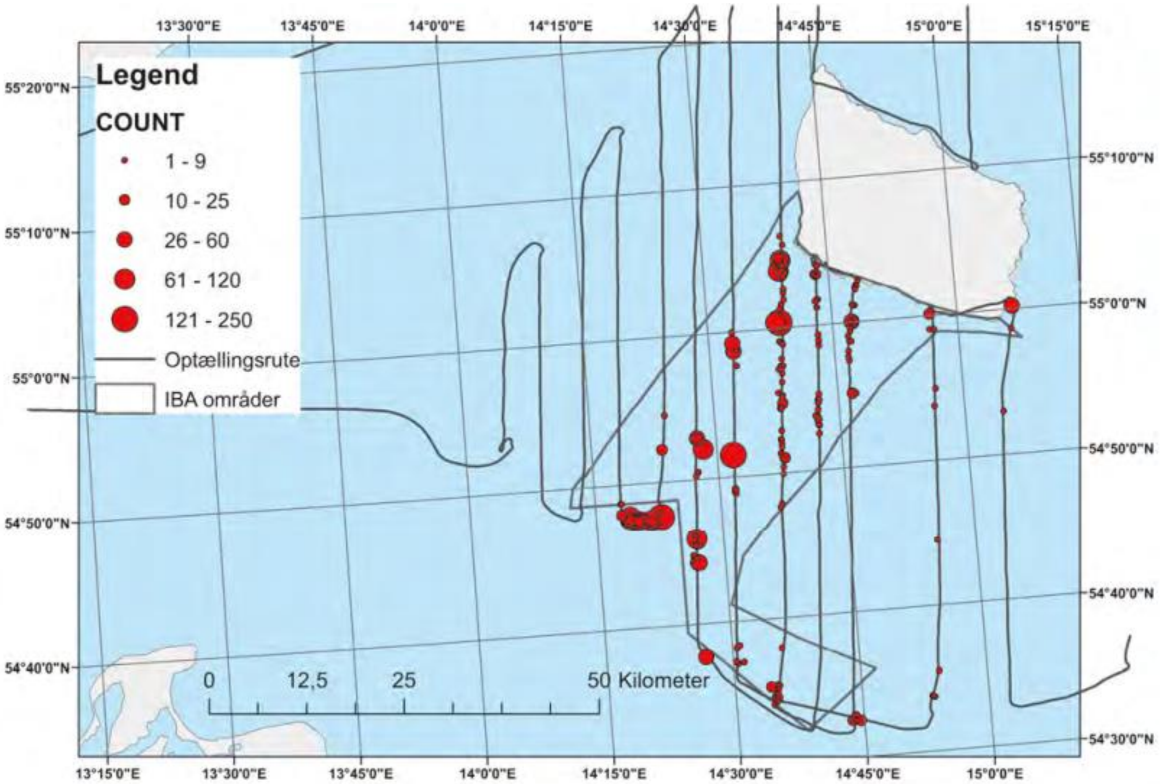

Figure 10. Distribution based on observations of 2,724 long-tailed ducks in the waters west of Bornholm in winter 2016. 1,797 (66 %) individuals were located within the IBA (Petersen et al. 2016).

Digital aerial surveys (HiDef) conducted for the environmental baseline monitoring for the German OWF area O-1.3

revealed long-tailed duck densities at Adlergrund partly overlapping with the pre-investigation area (IfAÖ et al. 2020; Figure 11).

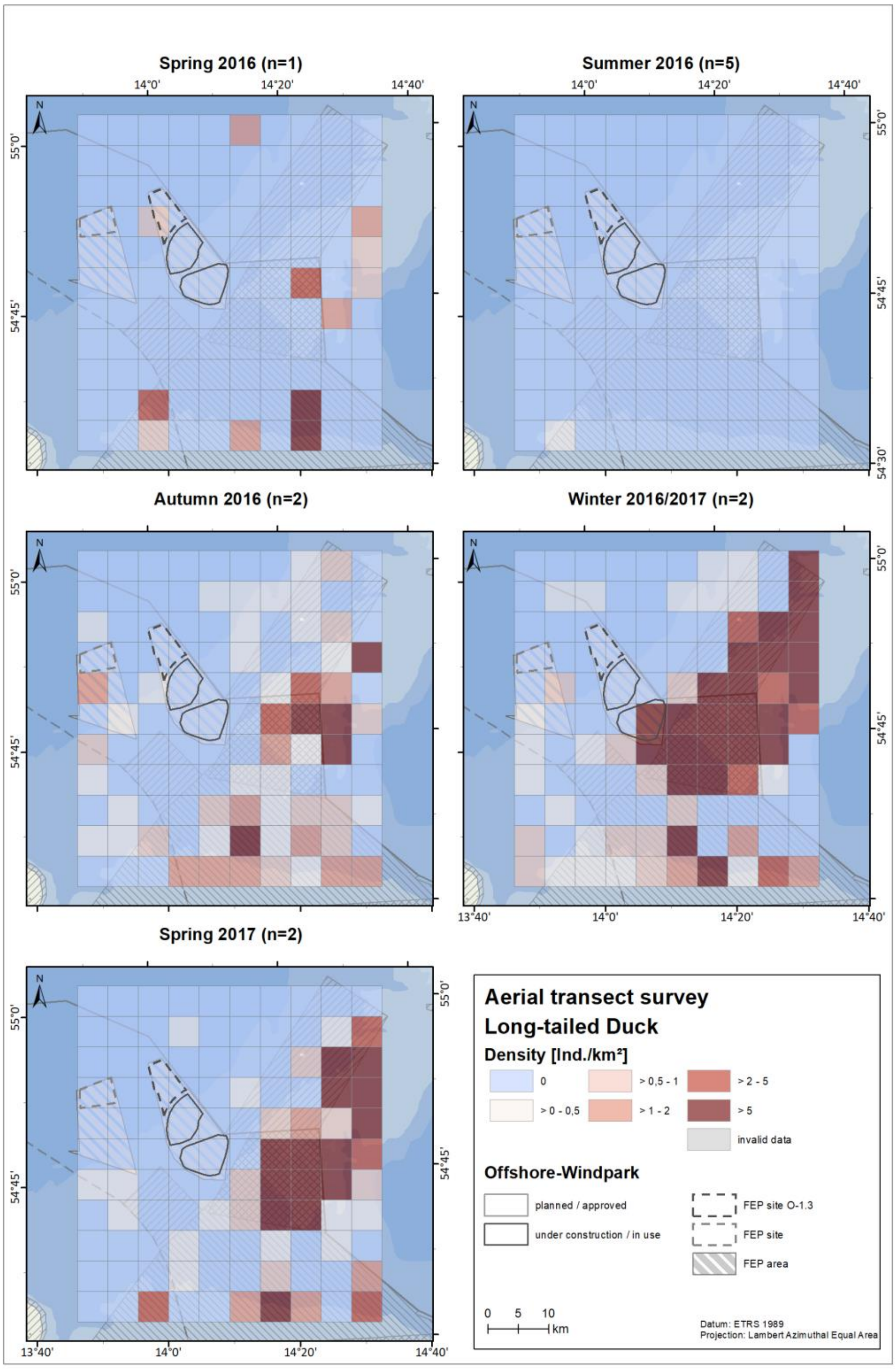

Figure 11. Spatial distribution of long-tailed ducks during aerial surveys in the survey area O-1.3 between spring 2016 and spring 2017. Source: IfAÖ et al. 2020.

The distribution of long-tailed ducks in winter partly coincides with the at that time still planned OWF “Arkona” and thus also corresponds to the high numbers of long-tailed ducks in the area of the German/Danish border, which were shown in 2004, 2013 and 2016 (Figure 7, Figure 9, Figure 10). The overall distribution pattern remains stable confirming previous findings showing that this species is focused on the shallow areas of Rønne Banke.

Water depths of the SPA Rønne Banke vary from 1 to 37 m, with 65 % of the water depths being between 13-20 m. The national Danish midwinter counts have previously shown that 65 % of the resting long-tailed ducks were located at water depths between 14 and 24 m (Petersen et al. 2006).

Long-tailed duck populations have decreased in the last decades due to various anthropogenic factors, especially oil pollution (Skov et al. 2011). Various anthropogenic factors are suspected to have influenced this decline (e.g Skov et al. 2011; Nilsson 2016; Nilsson & Haas 2016). Due to this drastic population decline, they are considered as vulnerable under the IUCN and are listed in Appendix II B of the European Birds Directive (European Union 2010).

To measure and evaluate the distribution of long-tailed ducks in an area with an existing offshore wind farm, a vessel-based survey was carried out in the Kriegers Flak area in 2022-2023 (WSP 2023c).

The survey was carried out from vessel-based transect lines that were approximately three kilometres apart and their mutual distance and overall layout were governed by the presence of the wind turbines in the surveyed area.

In total, four separate surveys were conducted on the following dates: 21/12/2022, 07/01/2023, 08/02/2023 and 28/02/2023. The applied methodology and analysis are outlined in more detail in WSP 2023c.

The collected data was used to create maps of the distribution of long-tailed ducks inside the pre-investigation area. Moreover, extrapolation of the transect observations by means of Distance Sampling was used to estimate the total numbers of long-tailed ducks in the area at the time of the four surveys conducted during the winter 2022/2023 (Figure 12).

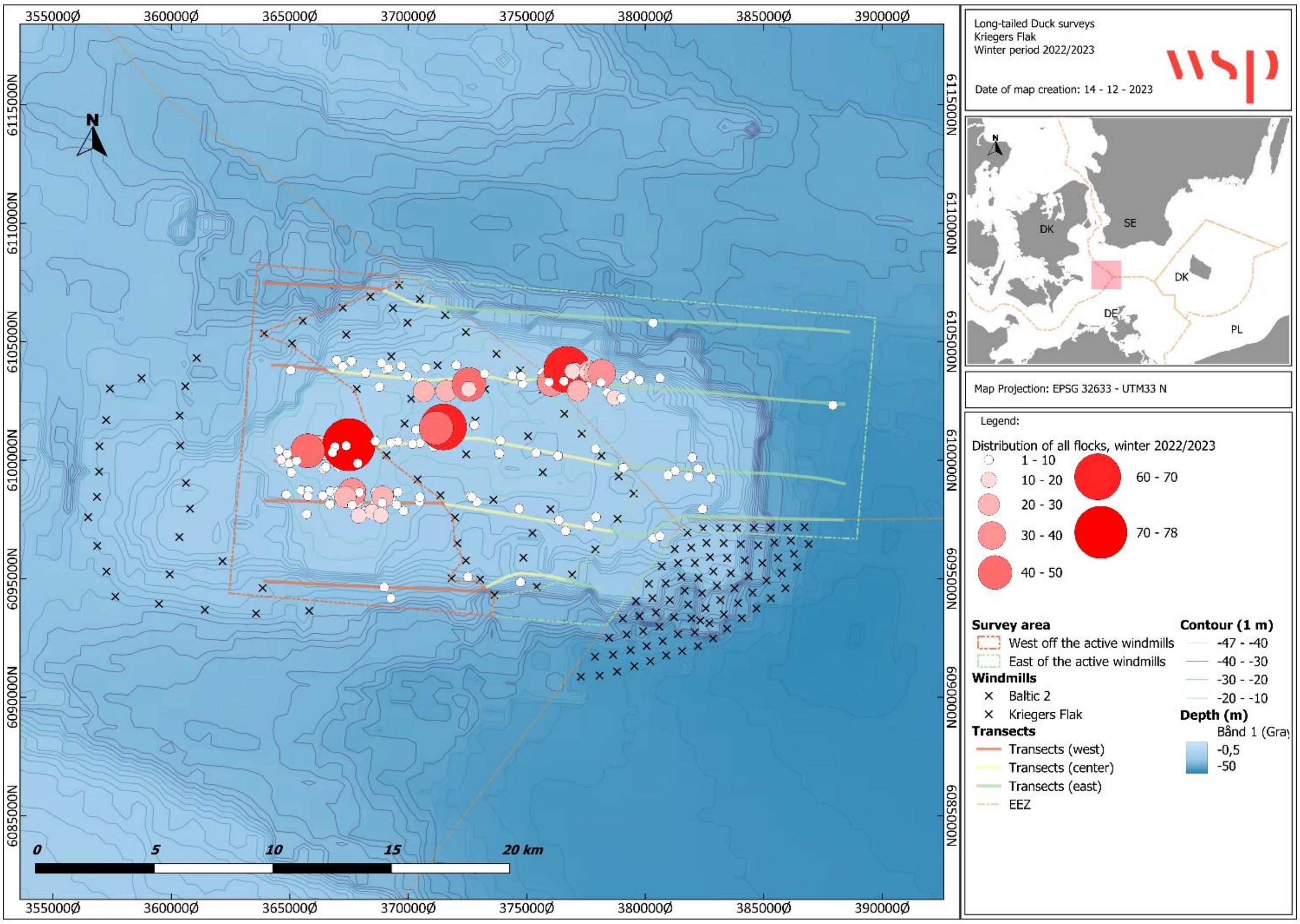

Figure 12. Distribution of all recorded flocks of long-tailed ducks on the four surveys during winter 2022/2023.

The collected survey data showed a notable temporal trend in long-tailed duck density, with a gradual increase from December to February. The average and maximum density of wintering long-tailed ducks were estimated at approximately 4 and 12 individuals per square kilometer, respectively.

The observed increase in long-tailed duck density from December to February may be influenced by various factors, including food availability, weather conditions, and migration patterns.

The presence of the wind turbines in the centre area could also be affecting the distribution patterns of the species. Because this specific area had not previously been investigated using the same methods employed in this survey, we compared our findings with data from similar ship-based surveys from nearby locations, as well as aerial surveys from the Kriegers Flak area.

To address the possible influence from the wind turbines on the spatial distribution of long-tailed ducks, the survey-area was divided into three parts: west of the active wind turbines (A1), in-between the operating wind turbines (A2) and east of the active wind turbines (A3).

The highest densities of long-tailed ducks were found in the western part (A1). One plausible explanation is the presence of shallower waters in the western region, providing favourable foraging conditions for the sea ducks during their resting periods. Likewise, relatively low densities observed in the eastern area (A3) could be attributed to the fact that water depth in this area ranges from 30-50 meters in most of the area, which is well above the species' preferred range of water depths.

Based on total numbers, estimated densities and the spatial distribution of the long-tailed duck observations found in this study, there seems to be no clear and consistent sign of habitat displacement caused by the Kriegers Flak Offshore Wind Farm.

The pronounced preference for the western pre-investigation area suggests specific habitat characteristics that are particularly favourable to long-tailed ducks during the winter months, such as shallow waters ideal for foraging.

Even though the western area (A1) had the highest numbers of long-tailed ducks overall, it is worth noting that the greatest count on any of the four surveys was recorded inside the wind farm array (A2).

However, the results must be interpreted with caution as there is no baseline data available for the specific area, which could have provided a base for comparison and opportunity to consider the effect of the wind farm in isolation. Nonetheless, the spatial distribution patterns of long-tailed ducks found in this study do not indicate any clear effects of habitat displacement due to the turbine array of the Kriegers Flak wind farm. This may, however, be influenced by the quite large mutual spacing of individual turbines in the array.

The methodology, results and implications of the displacement study have been outlined in detail in a separate publication (WSP 2023b).

The benthic communities in the pre-investigation area were investigated by WSP (2023a). They showed that the areas had high abundances of blue mussels (*Mytilus edulis*) and some other bivalve species such as the Baltic tellin (*Limecola balthica*) and the Icelandic cyprine (*Artica islandica*). Especially blue mussels are usually occurring on hard substrates, sometimes forming large mussel banks. Also, smaller, mobile mussel “clumps” were found on the seabed in the pre-investigation area. The study showed that the Natura 2000 area designated for long-tailed ducks had the highest abundance of food sources such as blue mussels, and less so in the planned wind farm area Figure 13.

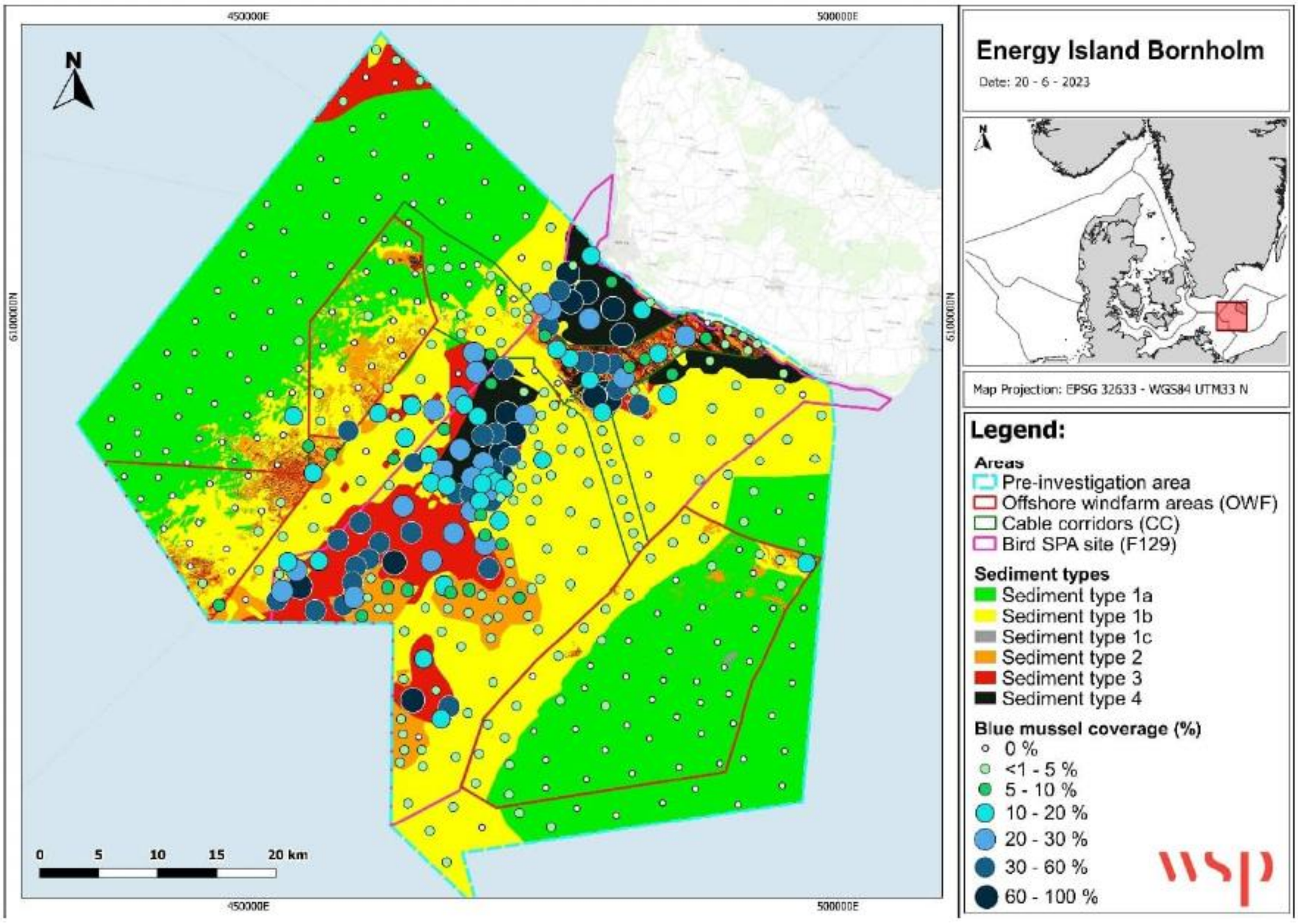

Figure 13. Overall coverage of blue mussel (*Mytilus spp*.) in the pre-investigation area as well as sediment types. Sediment types: 1a= Silt, 1b= Sand, 1c= Clay, 2= Mixed, 3= Hard bottom, 4= Stone reef/rock. Map taken from WSP (2023).

COMMON EIDER

The population of common eiders (*Somateria mollissima*) in Denmark has increased during the 20th century (Lyngs 2000). The performed censuses indicate a population of about 23,000 eiders between 1988 and 1993. The last censuses of 2000-2002 reported a similar number of eiders, indicating that the population in Denmark remained stable (Lyngs 2008). The archipelago Ertholmene northeast of Bornholm, where these ducks breed, held the second largest colonies in Denmark in the late 1980s (Lyngs 1992). With 2,400 females, the colony of Ertholmene was still the second biggest colony in Denmark at the beginning of the 2000s, despite a recent reduction in breeding pairs (Lyngs 2008).

Breeding individuals usually arrive to the island from late February until late March. The laying of eggs starts by the beginning of April and continues until mid-June. From late May, adult males leave the breeding colonies migrating to moulting areas elsewhere, while females swim with their ducklings to Bornholm (Lyngs 1992).

Common eiders are considered as near threatened under the IUCN. In Europe, they are generally considered endangered (BirdLife International 2021). Like other sea duck species, they are also listed in the Annex IIB of the European Birds Directive (European Union 2010).

COMMON AND VELVET SCOTER

In winter, most common scoters (*Melanitta nigra*) occur in the western Baltic Sea (Durinck et al. 1993). The Pomeranian Bay and the Kattegat are also important moulting areas from June to September. Thus, in the German Baltic Sea, they may be found during the whole year, especially in the Pomeranian Bay and its surrounding areas (Mendel et al. 2008). They tend to be most abundant during spring. Since the pre-investigation area lies not far from the Pomeranian Bay, common scoters and the less abundant Velvet Scoters (*Melanitta fusca*) may be found regularly. In the Baltic Sea, common scoters show a preference for areas with water depths between 5 and 15 meters (Skov et al. 2011). In the wintering areas the diet consists largely of marine bivalves, which are harvested on or up to three cm below the sea floor. Thereby, common scoters are assumed to choose their diet according to abundance, availability and energetic content of prey items rather than being restricted to certain prey species (Fox 2003).

The results of the Baltic coordinated survey in 2007 to 2009 indicates that the winter population of common scoters has declined markedly from 783,310 birds in 1988–1993 to 412,000 birds in 2007–2009, equivalent to 47 % over 16 years (HELCOM HELCOM 2019b).

Velvet scoters breed along the Baltic Sea coast of Sweden, Finland, Russia and Estonia. The species is a regular and common winter and migration visitor in the Baltic Sea area from September to May. Besides, there is a small moulting area in the Pomeranian Bay around the Odra Bank. Thus, velvet scoters can be found in the Baltic Sea area throughout the year (Durinck et al. 1994, Sonntag et al. 2006). A study of velvet scoters wintering along the Lithuanian coast demonstrated a preference for marine areas with sandy substrates at depths between 2 and 30 meters of depth (Zydelis 2000). In the Pomeranian Bay the species occurred in waters with sandy sediments up to 30 meters of depth but was most frequently found up to 15 meters of depth (Sonntag 2009).

While the common scoter is listed as a species of least concern by the IUCN, the Velvet Scoter is considered vulnerable (BirdLife International 2021).

GULLS

The general term ‘gulls’ groups different species of small-bodied and larger gulls (genus *Larus*). The first include two species that may occur frequently in the pre-investigation area: the black-headed gull (*Chroicocephalus ridibundus)* and the little gull (*Hydrocoloeus minutus*). All gull species are opportunistic and omnivore feeders. Little and black-headed gulls feed mainly on insects and crustaceans whereas large gulls feed mainly on small or medium-sized fish (Mendel et al. 2008). Except for the great black-backed gull (L*arus marinus*) they tend to be gregarious.

While little gulls may be slightly affected by offshore wind farms avoiding these areas, other species are known to be attracted by OWF structures (Dierschke et al. 2016).

COMMON GULL

In the Baltic Sea, common gulls (*Larus canus*) breed along the coast mainly in Sweden and Finland. These gulls are mainly migratory, some birds winter in the northeast and southern Baltic Sea, but most overwinter in the North Sea (Durinck et al. 1994). They feed on terrestrial and aquatic invertebrates as well as fish, but also on fish discards and garbage dumps (Durinck et al. 1994). In fact, they are typical ship followers (Walter & Becker 1997, Kubetzki 2002). They are observed in large flocks of up to 100 birds (Durinck et al. 1994).

Common gulls may occur in the pre-investigation area throughout all year but might be more numerous in winter. West of Bornholm they may be found at mid to high densities (1-5 ind./km^2, Durinck et al. 1994), but south of it and in most part of the pre-investigation area they may not be so numerous (BioConsult SH et al. 2020a). Previous surveys indicated they were distributed over most of the Baltic Sea (Durinck et al. 1993). On Graesholm for example, there were colonies with around 5,000 pairs of common gulls by the 1920s. Forty years later no more breeding individuals could be found in this region. The decline was probably caused by competition with Herring Gulls for nesting sites (Lyngs 1992). They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021).

LESSER BLACK-BACKED GULL

Lesser black-backed gulls are distributed throughout Europe. Three subspecies exist: the eastern variation *Larus fuscus fuscus,* which breeds from Sweden to northern Norway and eastwards to Russia. The western variation *L. f. graelssii* breeding from SW Greenland to Iceland to Spain and the intermediate form *L. f. intermedius* mainly occuring in the Netherlands and Denmark (Mendel et al. 2008). In Denmark, two of these subspecies may occur (*L. f. fuscus* and *L. f. intermedius*). Almost two decades ago, estimates suggested a population of 300,000 to 350,000 breeding pairs of lesser black-backed gulls (Mendel et al. 2008).

In the Baltic Sea, close to the pre-investigation area, comparatively fewer lesser back-backed gulls are expected than along the coasts of the North Sea. In the Pomeranian Bay, they may be seen mainly in summer and autumn (Mendel et al. 2008). They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021).

GREAT BLACK-BACKED GULL

The great black-backed gull *(Larus marinus*) occurs in small numbers in the Baltic Sea east of Rügen throughout the year. The highest populations are observed in winter when birds migrate southward from northern sites. Great black-backed gulls feed mainly on fish and are solitary or observed in small loose flocks (Durinck et al. 1994). They also gather near fishing ships to forage on discard (Durinck et al. 1994, Garthe & Scherp 2003, Mendel et al. 2008). One of the important wintering areas for this species is the Bornholm deep, located west of the island of Bornholm (Durinck et al. 1994). In the preliminary site O-1.3 directly west of the pre-investigation area, densities of around 0.1 ind./km² were observed during digital aerial surveys flown in winters (BioConsult SH et al. 2020a). They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021).

HERRING GULL

The numbers of herring gulls have increased in Denmark during the last decades. While the first censuses of 1920 estimated a population of around 3,000 pairs, more recent counts in 2010 estimated roughly 87,000 pairs. Currently, declining population trends of partially significant magnitude in the Baltic region for example in Finland have been reported (Hario & Rintala 2016, Wetlands International 2022, retrieved on 03.03.2022). Most of the growth of the population occurred after the 1960s and parallels the growth observed in north-western Europe, apparently linked to an increase due to protection measures and the availability of additional food resources for example by garbage dumps and fisheries discards (Bregnballe & Lyngs 2014).

The development of the population of herring gulls differed between eastern and western Denmark. Before the mid-seventies, most herring gulls bred in the eastern part of Denmark (61 %, Bregnballe & Lyngs 2014), with the colony of Ertholmene being the second largest colony in Denmark (Lyngs 1992). Around 1974, the government installed culling programmes in the largest colony, which resulted in a decline of the entire breeding population and shifted their centre of distribution towards the western part of the country (Bregnballe & Lyngs 2014). Although herring gulls breeding at Ertholmene have reduced from about 20,000 pairs in 1970s (Lyngs 1992) to about 9,000 pairs (Bregnballe & Lyngs 2014), the breeding colony is still important. They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021), but listed as vulnerable in the HELCOM Red List (2013a).

Herring gulls arrive to the colony between mid-January and late February. Egg laying starts in April peaking at the end of the month and individuals leave the colony from mid to late August (Lyngs 1992). Herring gulls are regarded as the most common gull species in the offshore sites of the German Baltic Sea. In a previous study of the preliminary site O-1.3, herring gulls were widely distributed over the pre-investigation area during all seasons with the exception of one summer (BioConsult SH et al. 2020a). Thus, their occurrence is expected in the pre-investigation areas of the OWFs of Energy Island.

AUKS

Auk species typically found in the pre-investigation area are common guillemots (*Uria aalge*) and razorbills (*Alca torda*). Occasionally, other auks such as the Atlantic puffin (*Fratercula arctica*) and the black guillemot (*Cepphus grylle*) may appear as well. The black guillemot is one of the species for which Rønne Banke is considered an important bird area (Rasmussen et al. 2000). Over two thirds of the population of common guillemots and 30 % of the populations of razorbills breed on Störa Karlso (and Lilla Karlsö), two small islands located west of the island of Gotland, which are famous for hosting the largest fish-eating seabird colonies of the Baltic Sea (Olsson & Hentati-Sundberg 2017). Other colonies are located in different areas of the Baltic Sea, but most are relatively small. The second largest colony of common guillemots in the Baltic Sea is found on Græsholmen, a very small island north of the island of Bornholm, which hosts about 2,000-3,000 breeding pairs (Olsson et al. 2000). Lyngs (1992) suggests that there were 2,000 pairs of common guillemot and around 450 pairs of razorbills breeding in Graesholmen in the 1980s. In the early 2000s, the breeding pairs of razorbills had increased to 780 pairs (Lyngs 2001). The archipelago of Ertholmene is one of the Danish important bird areas and the only site in Denmark known to have breeding colonies of both auk species (Rasmussen et al. 2000). According to , the waters south (and east) of the island of Bornholm are of major importance to resting razorbills and common guillemots in Denmark. This situation is confirmed by Nielsen et al. (2023).

Guillemots reach the colonies earlier than razorbills. While they may arrive as early as December, razorbills arrive by late February and early March. Common guillemots therefore occupy the breeding site earlier and start breeding earlier, too. Lyngs (1992) also mentions that chicks of common guillemots leave the colony from mid to late June, while razorbill chicks may remain until mid-July. It is therefore highly possible that these birds will occur in the pre-investigation area in noticeable densities, especially in deeper waters. Previous digital aerial surveys conducted at the preliminary site O-1.3 south of Bornholm I found low to mid-densities of auks in the area. Especially during winter, they were widely spread throughout the pre-investigation area (BioConsult SH et al. 2020a).

Black guillemots may also concentrate in the area of Rønne Banke, although they were only observed in relatively low numbers during the national Danish midwinter surveys (Petersen et al. 2016). An old census found areas with mid densities of black guillemots at Rønne Banke (1.6 ind./km²) during winter (Durinck et al. 1993). Even larger densities of this species may occur in the Pomeranian Bay and south of Rønne Banke (Ode Bank, Adlergrund bank; Durinck et al. 1994; Mendel et al. 2008). Compared to the other two auk species, black guillemots prefer shallower waters (depths < 25 meters, Durinck et al. 1994). During the surveys conducted for the baseline study of preliminary site O-1.3, 25 and 74 individuals of black guillemots were counted on the digital aerial surveys of 2016/2017 and 2017/2018 respectively (BioConsult SH et al. 2020a).

While the two most common auk species have relatively stable populations or are increasing, other auk species are threatened (HELCOM HELCOM 2019a). In general, auks are long-lived, but start reproducing only after several years of life. Moreover, these species were heavily hunted by humans, and their populations almost got extinct. Both the common guillemot and the razorbill are listed a species of least concern under the IUCN Red List (BirdLife International 2021). Among the two other species that may rarely occur in the pre-investigation area, the black guillemot is listed as a species of least concern as well, whereas the Atlantic puffin is considered endangered (BirdLife International 2021).

4.2 SURVEY RESULTS

RESULTS FROM DIGITAL AERIAL SURVEYS

Since not all species were equally common in the pre-investigation area, a threshold was introduced. Species had to account for a minimum of 0.3 % of the total species composition to be included in the analysis. This ensured that species, which were defined as relevant but are typically present in low numbers, could still be incorporated.

During the 2-year survey period lasting from November 2021 to September 2023, a total of 32.749 resting birds was observed within the pre-investigation area comprising a total of 23 different species Table 7. Species composition and abundance were similar during both survey years. The overall species composition during the surveys are shown in Figure 14 and Figure 15, respectively. In both years, 23 different species were counted with a total of 16,141 resting birds during the first year and a total of 16,608 resting birds in the following year.

Regarding species groups, sea ducks comprised most of the resting bird community in each of the two years (see Figure 14 and Figure 15). With a total of 72.80 %, long-tailed ducks were the most common among all observed species in the pre-investigation area during both survey years, followed by velvet scoters (6.62 %).

Auks were the second most common group in both years with common guillemots being the most abundant (a total of 5.45 %), followed by razorbills (a total of 1.56 %) and black guillemots (a total 0.35 %). Gulls represented 6.8 % and 3.8 % of the total resting birds in each year of study and were thus the third most abundant species group. The most frequently observed gull species were herring gulls with a total of 2.99 %. Total numbers as well as proportions per survey period for all species are given in Table 7. Since the number of resting birds residing in an area can vary interannually, the results presented in Table 7 are given per survey year (lasting from October to September).

Calculating average monthly densities for both study years showed that species or species groups were not observed in equal numbers across time (see Table 8 and Table 9).

During the first survey year, highest mean densities of sea ducks and gulls were observed in December 2021, whereas highest values in the second period were observed in March 2023 for divers and February 2023 for sea ducks respectively. For gulls and auks, highest mean densities were noted in November 2021 in the first study year, but in December 2022 during the second study year.

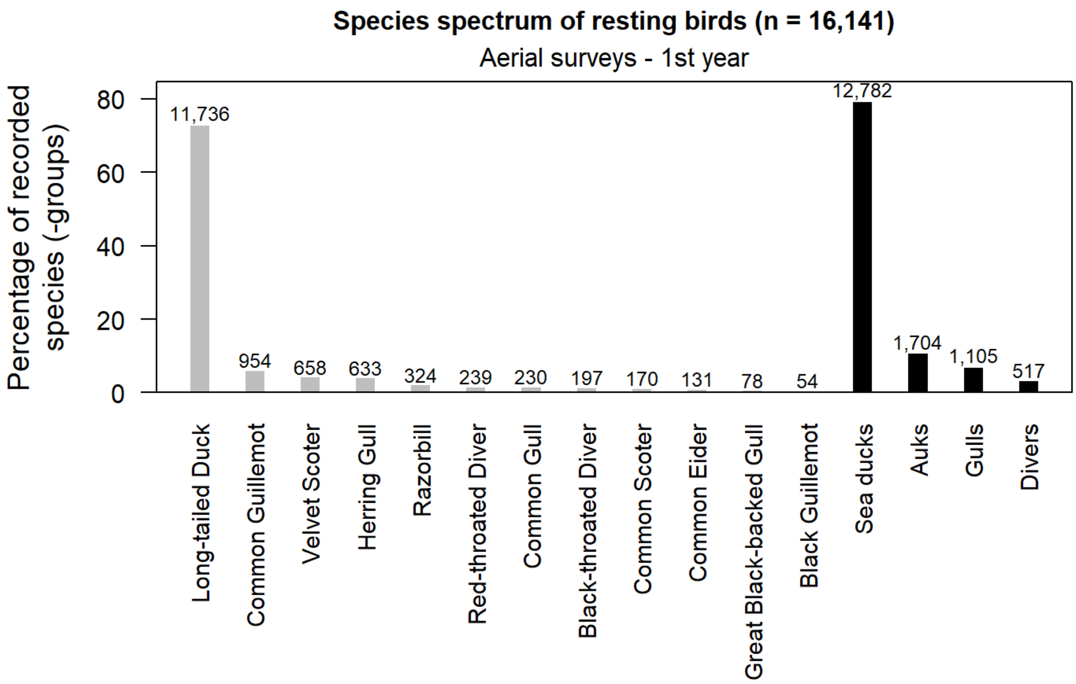

Figure 14. Percentage of the most common species or species groups representing crossing the 0.3 % threshold recorded during aerial surveys in the pre-investigation area between October 2021 and September 2022. The total number of observed individuals is given as *n*. Species are depicted in grey, species groups in black. The number of individuals counted per species or species group is given above each bar.

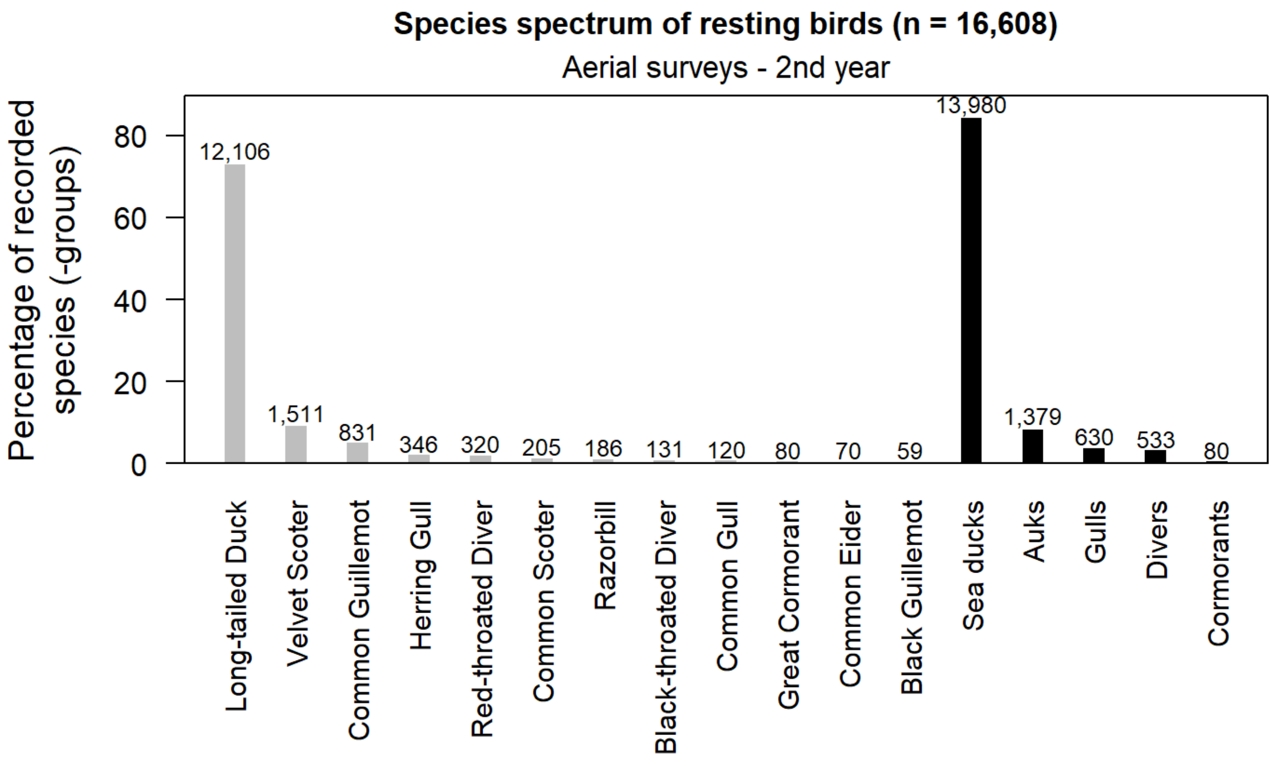

Figure 15. Percentage of the most common species or species groups representing crossing the 0.3 % threshold recorded during aerial surveys in the pre-investigation area between October 2022 and September 2023. The total number of observed individuals is given as *n*. Species are depicted in grey, species groups in black. The number of individuals counted per species or species group is given above each bar.

Table 7. Total number of individuals per species or species group observed during the 17 digital aerial surveys conducted from November 2021 until September 2023. The total number of observed individuals (N° Ind) as well as their proportion of the overall species composition (%) is given for each survey period. Combined results from both study years are given as a total, again including the number of individuals as well as their proportion. The total of species crossing the 0.3 % threshold is given in bold (far-right column). Species listed as critically endangered (*CR*), near threatened (*NT*), vulnerable (*VU*) or endangered (*EN*) under the IUCN or HELCOM red list are given in red.

Species / Species group	Scientific name	Nov 2021- Sep 2022		Oct 2022 – Sep 2023		Total	
		N° Ind	%	N° Ind	%	N° Ind.	%
Red-throated diver[CR]	*Gavia stellata*	239	1.48	320	1.93	559	**1.71**
Black-throated diver[CR]	*Gavia arctica*	197	1.22	131	0.79	328	**1.00**
Great northern diver	*Gavia immer*	3	0.02	3	0.02	6	0.02
Yellow-billed diver[VU]	*Gavia adamsii*	1	0.01			1	0.00
Unidentified diver	*Gavia sp.*	77	0.48	79	0.48	156	**0.48**
Great crested grebe	*Podiceps cristatus*	1	0.01	5	0.03	6	0.02

Species / Species group	Scientific name	Nov 2021- Sep 2022		Oct 2022 – Sep 2023		Total	
		N° Ind	%	N° Ind	%	N° Ind.	%
Red-necked grebe[VU]	*Podiceps grisegena*			11	0.07	11	0.03
Slavonian grebe[NT]	*Podiceps auritus*	4	0.02	4	0.02	8	0.02
Red-necked/great crested grebe	*Podiceps grisegena/Podiceps cristatus*	3	0.02	12	0.07	15	0.05
Unidentified grebe	Podicipedidae *sp.*	4	0.02	15	0.09	19	0.06
Great cormorant	*Phalacrocorax carbo*	26	0.16	80	0.48	106	**0.32**
Common eider[EN]	*Somateria mollissima*	131	0.81	70	0.42	201	**0.61**
Long-tailed duck[VU]	*Clangula hyemalis*	11,736	72.71	12,106	72.89	23,842	**72.80**
Common scoter	*Melanitta nigra*	170	1.05	205	1.23	375	**1.15**
Common scoter / velvet scoter	*Melanitta sp.*	87	0.54	88	0.53	175	**0.53**
Velvet scoter[VU]	*Melanitta fusca*	658	4.08	1511	9.10	2169	**6.62**
Arctic skua[EN]	*Stercorarius parasiticus*	1	0.01	1	0.01	2	0.01
Little gull	*Hydrocoloeus minutus*	7	0.04	42	0.25	49	0.15
Black-headed gull	*Chroicocephalus ridibundus*	47	0.29	25	0.15	72	0.22
Common gull	*Larus canus*	230	1.42	120	0.72	350	**1.07**
Unidentified small gull	*Larus* small *sp.*	5	0.03	8	0.05	13	0.04
Lesser black-backed gull	*Larus fuscus*	8	0.05	4	0.02	12	0.04
Herring gull[VU]	*Larus argentatus*	633	3.92	346	2.08	979	**2.99**
Common/herring gull	*Larus canus / Larus argentatus*	17	0.11	6	0.04	23	0.07
Great black-backed gull	*Larus marinus*	78	0.48	46	0.28	124	**0.38**
Unidentified large gull	*Larus (magnus) sp.*	62	0.38	16	0.10	78	0.24
Great / lesser black-backed gull	*Larus fuscus/Larus marinus*	1	0.01	8	0.05	9	0.03
Unidentified Larus gull	*Larus sp.*	2	0.01			2	0.01

Species / Species group	Scientific name	Nov 2021- Sep 2022		Oct 2022 – Sep 2023		Total	
		N° Ind	%	N° Ind	%	N° Ind.	%
Black-legged kittiwake[VU]	*Rissa tridactyla*	2	0.01	1	0.01	3	0.01
Unidentified gull	Laridae *sp.*	13	0.08	8	0.05	21	0.06
Common/arctic tern	*Sterna hirundo/Sterna paradisaea*	5	0.03			5	0.02
Tern/small gull	*Sterna spp / Larus spp.*	1	0.01	3	0.02	4	0.01
Unidentified tern	Sternidae *sp.*			2	0.01	2	0.01
Common guillemot	*Uria aalge*	954	5.91	831	5.00	1,785	**5.45**
Common guillemot/razorbill	*Uria aalge / Alca torda*	359	2.22	293	1.76	652	**1.99**
Razorbill	*Alca torda*	324	2.01	186	1.12	510	**1.56**
Black guillemot	*Cepphus grylle*	54	0.33	59	0.36	113	**0.35**
Unidentified auk	Alcidae *sp.*	13	0.08	10	0.06	23	0.07
TOTAL		**16,141**	**100**	**16,608**	**100**	**32,749**	**100**

Table 8. Monthly mean densities (ind./km²) of selected species/species groups recorded in the pre-investigation area during digital aerial surveys from November 2021 to August 2022. The indication "0" means that no individual of this species was detected. Months with highest calculated densities are given in bold. Numbers are based on one aerial survey conducted per month.

Species/Species-group	Survey month								
	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	Jun 2022	Jul 2022	Aug 2022
Red-throated diver	0.124	**0.221**	0.094	0.094	0.147	0.066	0.006	0	0
Black-throated diver	0.101	**0.136**	0.11	0.097	0.069	0.095	0	0	0.013
Great-crested grebe	0	0	0	0	0	0	**0.003**	0	0
Great cormorant	0	0	0.013	0.003	**0.025**	0	0.006	0.013	0.022
Common eider	0	0.003	0	0.006	0.016	**0.249**	0.138	0	0
Long-tailed duck	**8.695**	7.057	6.272	6.47	4.971	3.489	0	0	0
Common scoter	0.022	0.06	0	0.028	0.025	**0.287**	0	0.116	0
Velvet scoter	0.133	0.429	0.518	0.204	**0.756**	0.028	0	0	0
Little gull	0.006	**0.013**	0	0	0.003	0	0	0	0
Black-headed gull	0	0.006	0.003	0	0	0	0	**0.122**	0.019
Common gull	0.073	**0.218**	0.154	0.091	0.016	0.019	0.006	0.077	0.072
Lesser black-backed gull	0.006	0	0	**0.009**	0	0.003	0.003	0	0.003
Herring gull	0.485	0.347	**0.493**	0.135	0.072	0.234	0.022	0.09	0.119
Great black-backed gull	**0.098**	0.032	0.094	0.006	0.003	0.003	0	0.006	0.003
Black-legged kittiwake	0	**0.003**	0	0	0	**0.003**	0	0	0
Arctic / common tern	0	0	0	0	0	0	0	0	**0.016**
Common guillemot	**0.865**	0.353	0.512	0.689	0.169	0.12	0.035	0.071	0.191
Razorbill	**0.513**	0.155	0.182	0.025	0.038	0.111	0	0	0
Black guillemot	0.022	0.025	0.044	0.003	**0.075**	0	0	0	0
Divers	0.298	**0.366**	0.245	0.229	0.241	0.221	0.006	0.006	0.016
Ducks	0.054	**0.189**	0.163	0.056	0.075	0.129	0.013	0	0
Gulls	**0.697**	0.609	0.854	0.26	0.107	0.259	0.031	0.177	0.201
Auks	**1.973**	0.709	0.979	0.811	0.342	0.259	0.035	0.071	0.191

Table 9. Monthly mean densities (ind./km²) of selected species/species groups recorded in the pre-investigation area during digital aerial surveys from October 2022 to September 2023. The indication "0" means that no individual of this species was detected. Months with highest calculated densities are given in bold. Numbers are based on a maximum of one aerial survey conducted per month.

Species/Species-group	Survey month							
	Oct 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	May 2023	Jun 2023	Sep 2023
Red-throated diver	**0.032**	0.302	0.132	0.238	0.271	0.028	0	0.009
Black-throated diver	0.068	0	0.035	0.09	**0.116**	0.047	0.04	0.019
Great-crested grebe	0.003	0	**0.006**	0	**0.006**	0	0	0
Great cormorant	**0.065**	0	0.028	0.042	0.044	0.013	0.025	0.038
Common eider	**0.165**	0	0	0.006	0.016	0.016	0.022	0
Long-tailed duck	0.049	**11.18**	9.797	8.71	8.516	0	0	0
Common scoter	0	0.145	**0.27**	0.003	0.11	0	0	0.116
Velvet scoter	0.039	0.408	0.527	**2.369**	1.464	0	0	0
Little gull	0.006	0	0.006	**0.087**	0.006	0	0	0.028
Black-headed gull	0.019	0.003	0.003	0	0.003	0	0	**0.05**
Common gull	**0.127**	0.072	0.047	0.051	0.035	0.016	0.003	0.031
Lesser black-backed gull	0	0	0	0	0	**0.006**	0	**0.006**
Herring gull	0.165	**0.245**	0.204	0.109	0.069	0.05	0.148	0.1
Great black-backed gull	0.029	0.041	**0.047**	0.01	0.013	0	0	0.006
Black-legged kittiwake	0	**0.003**	0	0	0	0	0	0
Arctic / common tern	0	0	0	0	0	0	0	0
Common guillemot	0.418	0.471	**0.653**	0.328	0.343	0.129	0.117	0.169
Razorbill	0.045	**0.38**	0.078	0.035	0.016	0.009	0	0.022
Black guillemot	0.013	0.003	0.041	**0.093**	0.028	0	0	0.009
Divers	0.12	0.339	0.226	0.393	**0.444**	0.088	0.043	0.034
Ducks	0.058	0.154	0.129	**0.164**	0.123	0.025	0.012	0.27
Gulls	0.321	**0.358**	0.298	0.183	0.12	0.078	0.157	0.166
Auks	0.584	**1.15**	1.02	0.669	0.416	0.166	0.117	0.241

In the following, results for the selected relevant species and species groups crossing the previously defined 0.3 % threshold will be presented in more detail.

DIVERS (RED-THROATED DIVER AND BLACK-THROATED DIVER)

With 239 individuals observed in the first and 320 individuals in the second survey period, red-throated divers were the fifth and sixth most common species of resting birds observed. Highest abundances for this species were observed during spring and winter with highest calculated densities in December (0.22 ind./km² in December 2021 and 0.30 ind./km² in December 2022, see Figure 16. Only few individuals were encountered during the summer months when the adult birds are breeding in the arctic. Higher densities were generally detected in shallower waters. Most grid-cells with densities of >2 ind./km² were located within the protected area Adler Grund and Rønne Banke (see Figure 17 and Figure 18).

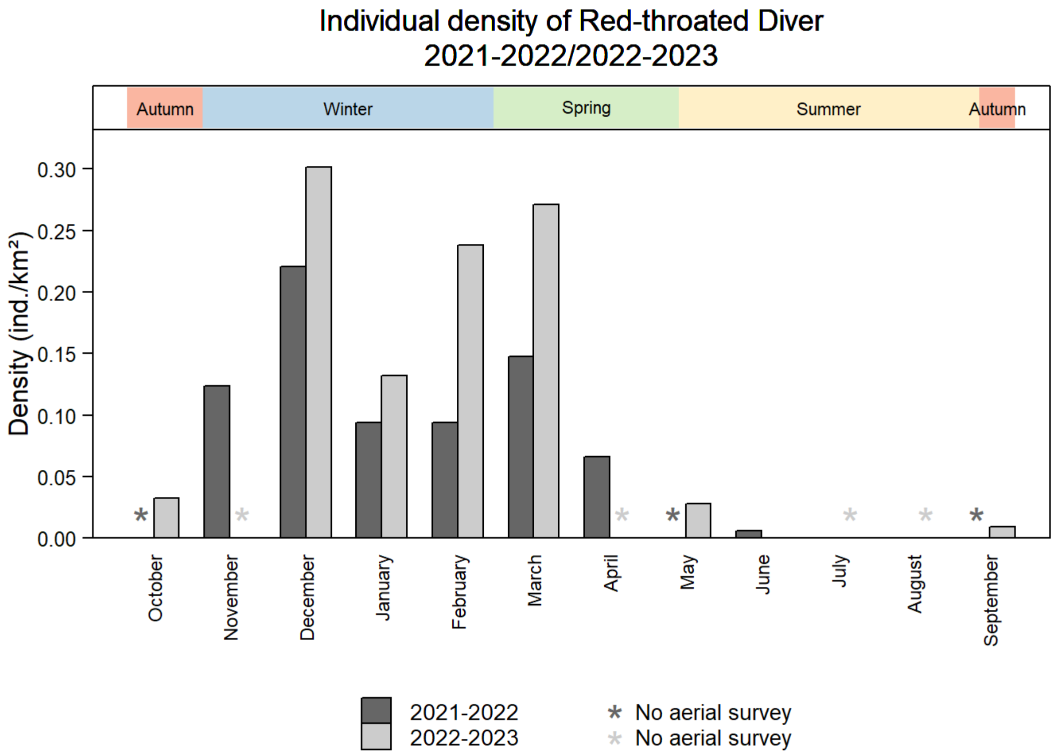

Figure 16. Monthly densities of red-throated divers given as individuals per km^2 calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey period (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

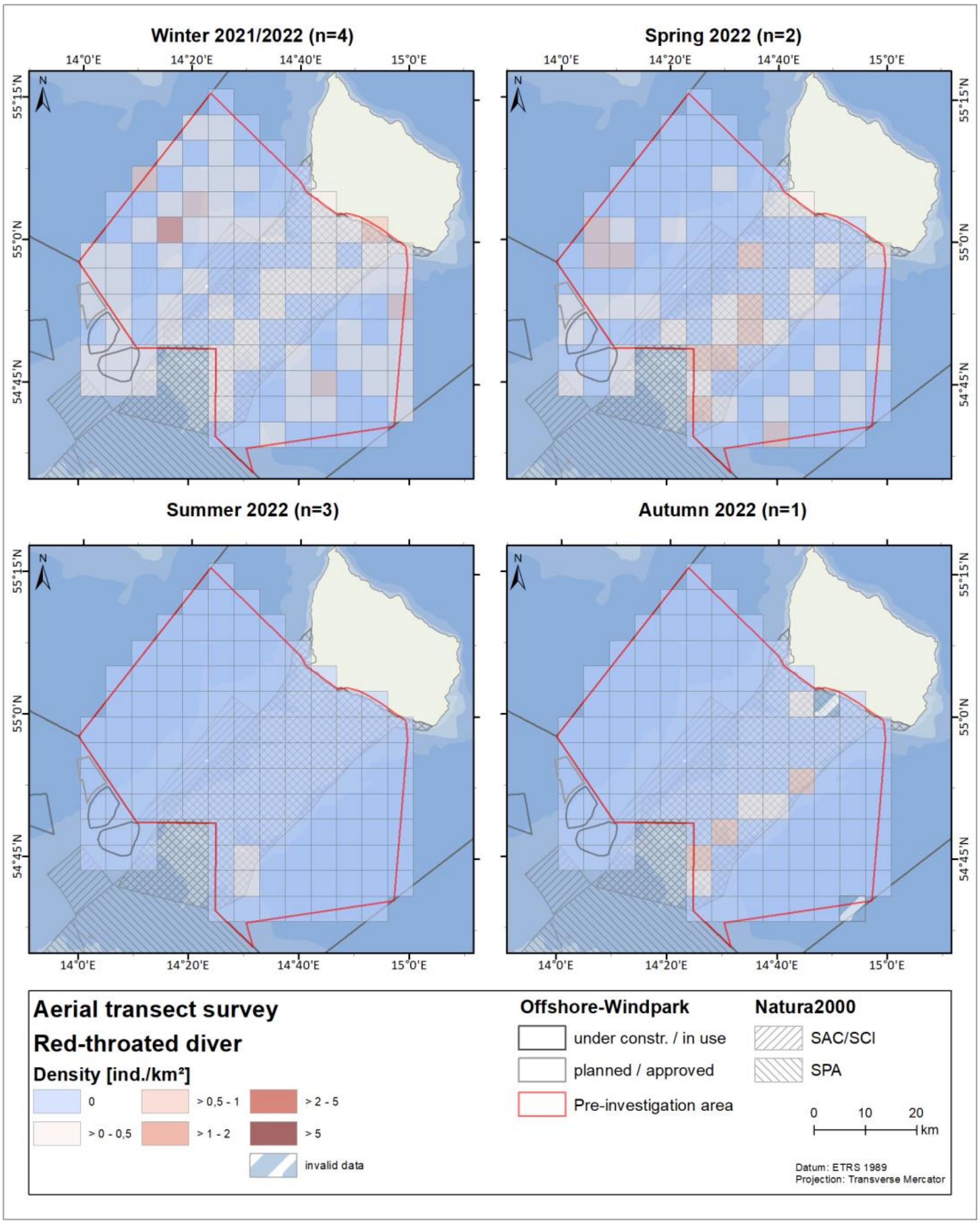

Figure 17. Distribution of red-throated divers in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys per season is given as n.

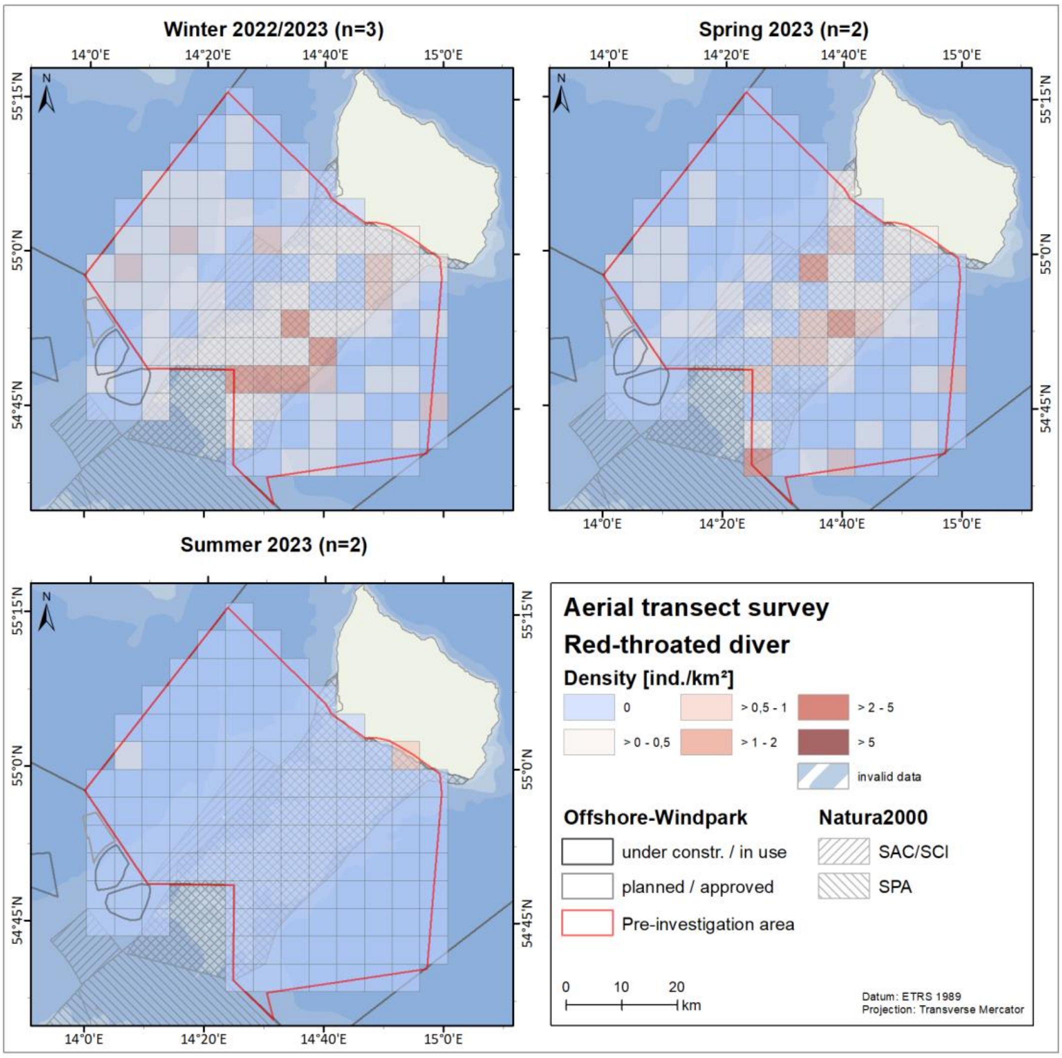

Figure 18. Distribution of red-throated divers in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and winter 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys per season is given as n.

During the nine digital aerial surveys conducted in the first study year, a total of 197 black-throated divers was recorded, whereas 131 individuals were recorded during the second survey year (see Table 7). The maximum monthly density of black-throated divers in the first year was 0.14 ind./km², recorded in December 2021. In the second year, highest densities were registered during March 2023 with 0.116 ind./km² Figure 19. Lower densities were detected during the summer months. Individuals were mainly residing in shallower waters within the protected areas (see Figure 20 and Figure 21).

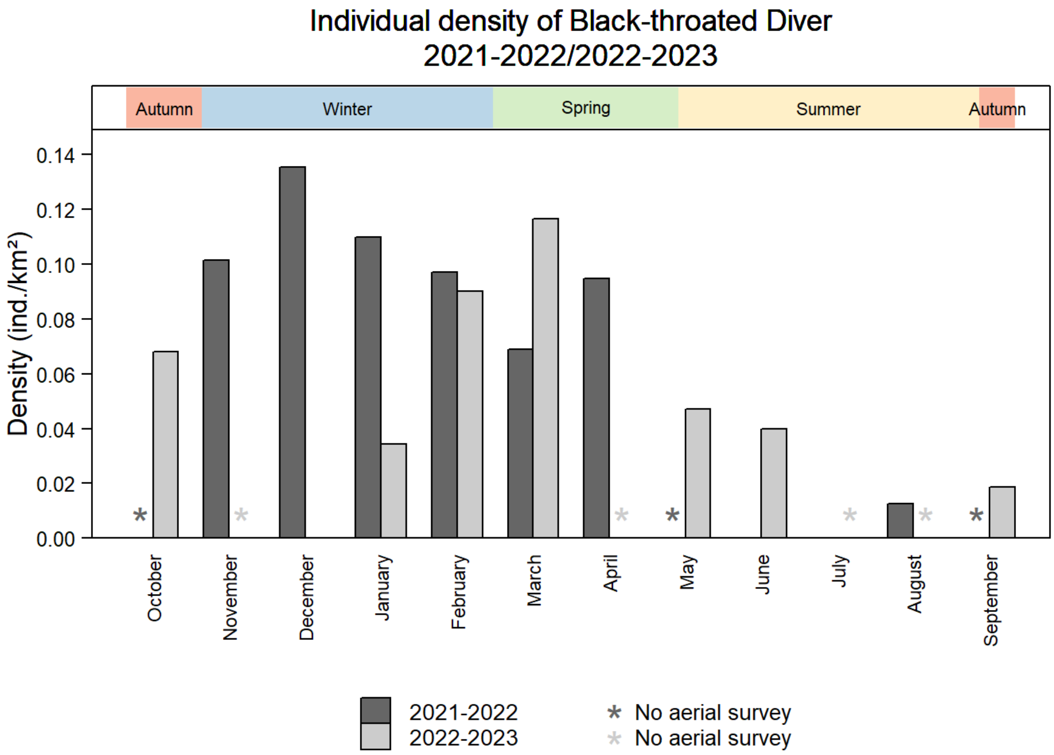

Figure 19. Monthly densities of black-throated divers given as individuals per km^2 calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey period (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

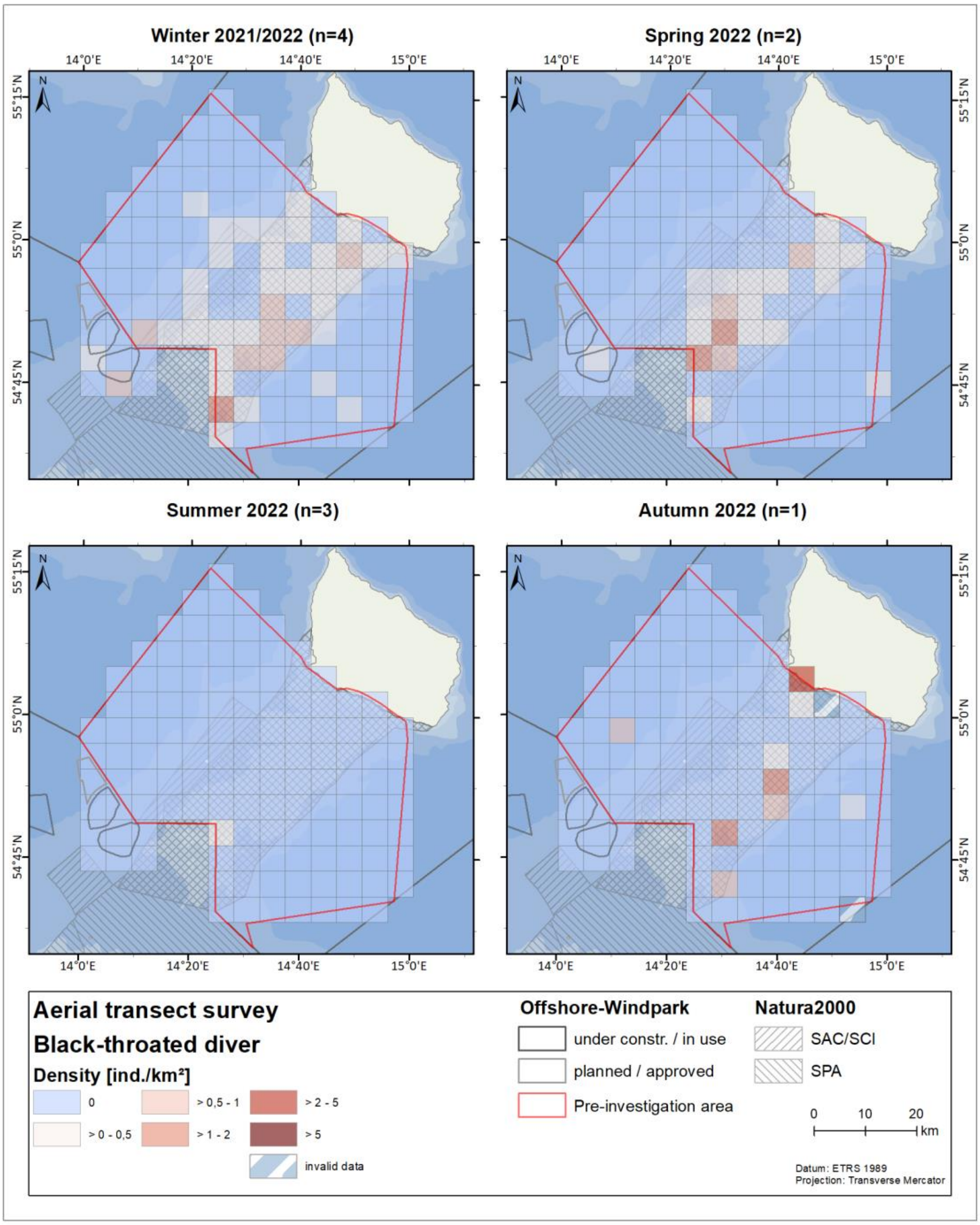

Figure 20. Distribution of black-throated divers in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

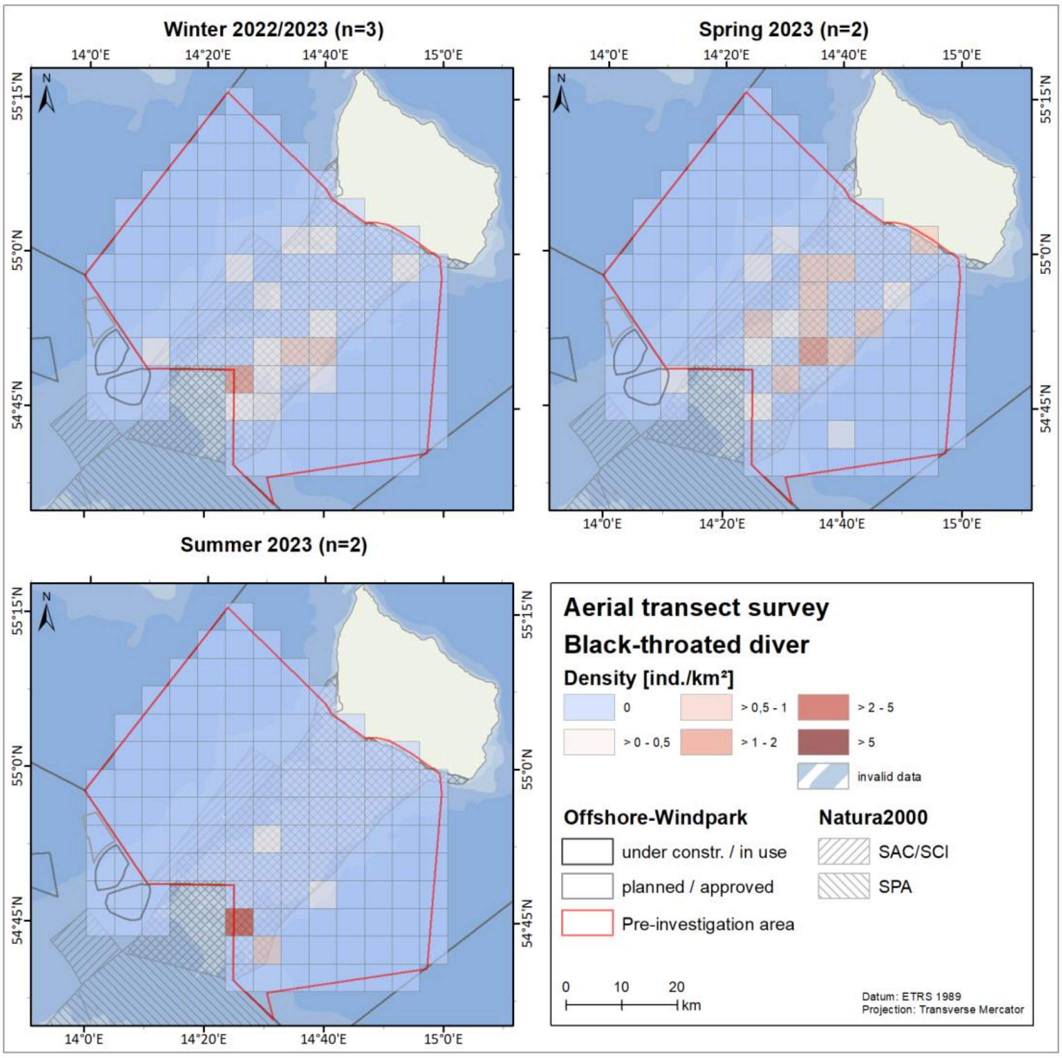

Figure 21. Distribution of black-throated divers in the pre-investigation area per species specific season counted during digital aerial surveys in the second study period between winter 2022/2023 and summer 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

GREBES

Grebes were only occasionally encountered during both survey years. In total, 59 individuals were registered, of which 58 % remained undetermined (34 individuals, Table 7). Sightings were distributed across the whole pre-investigation area and no clear pattern is recognised. The other individuals could be classified into three species: great-crested grebes, red-necked grebes and Slavonian grebes. Due to their low numbers, grebes are not further described.

GREAT CORMORANT

Despite being present year-round, great cormorants were observed only in low numbers. 26 individuals were counted during the first survey year, 80 individuals during the second (see Table 7). The maximum monthly density occurred in October 2022 with 0.065 ind./km² (Figure 22), being twice the maximum monthly density of the first year, which was 0.025 ind./km² (March 2022).

Great cormorants were mainly located in shallower areas and close to the coast of Bornholm Island (see Figure 23 and Figure 24).

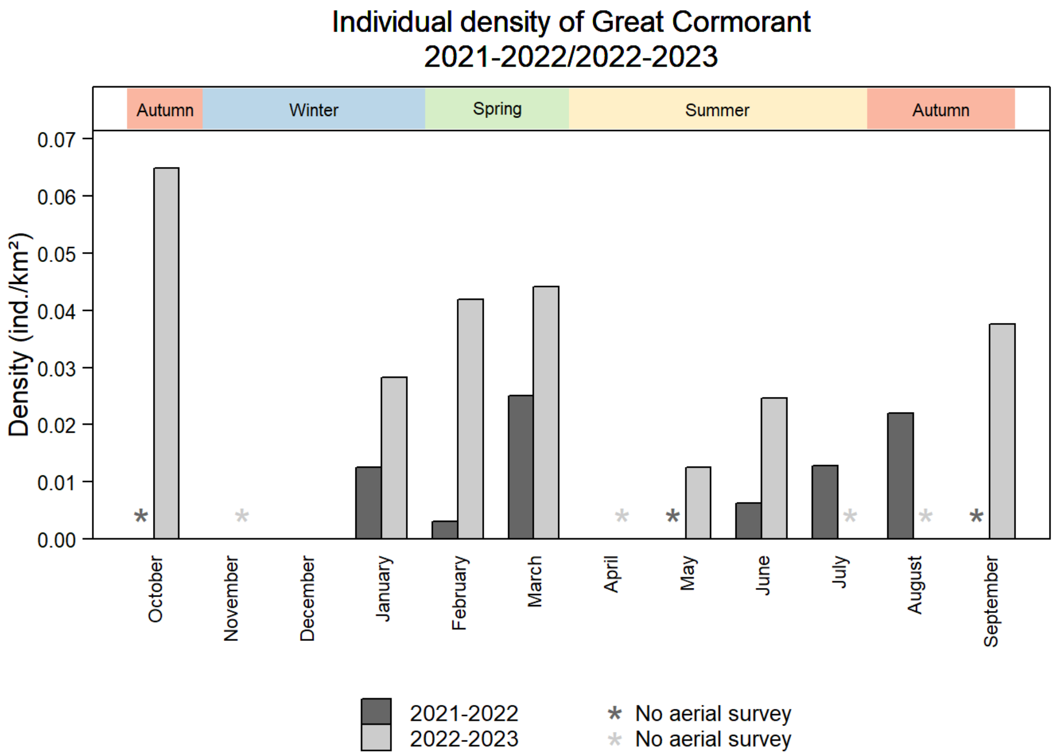

Figure 22. Monthly densities of great cormorants given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey period (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

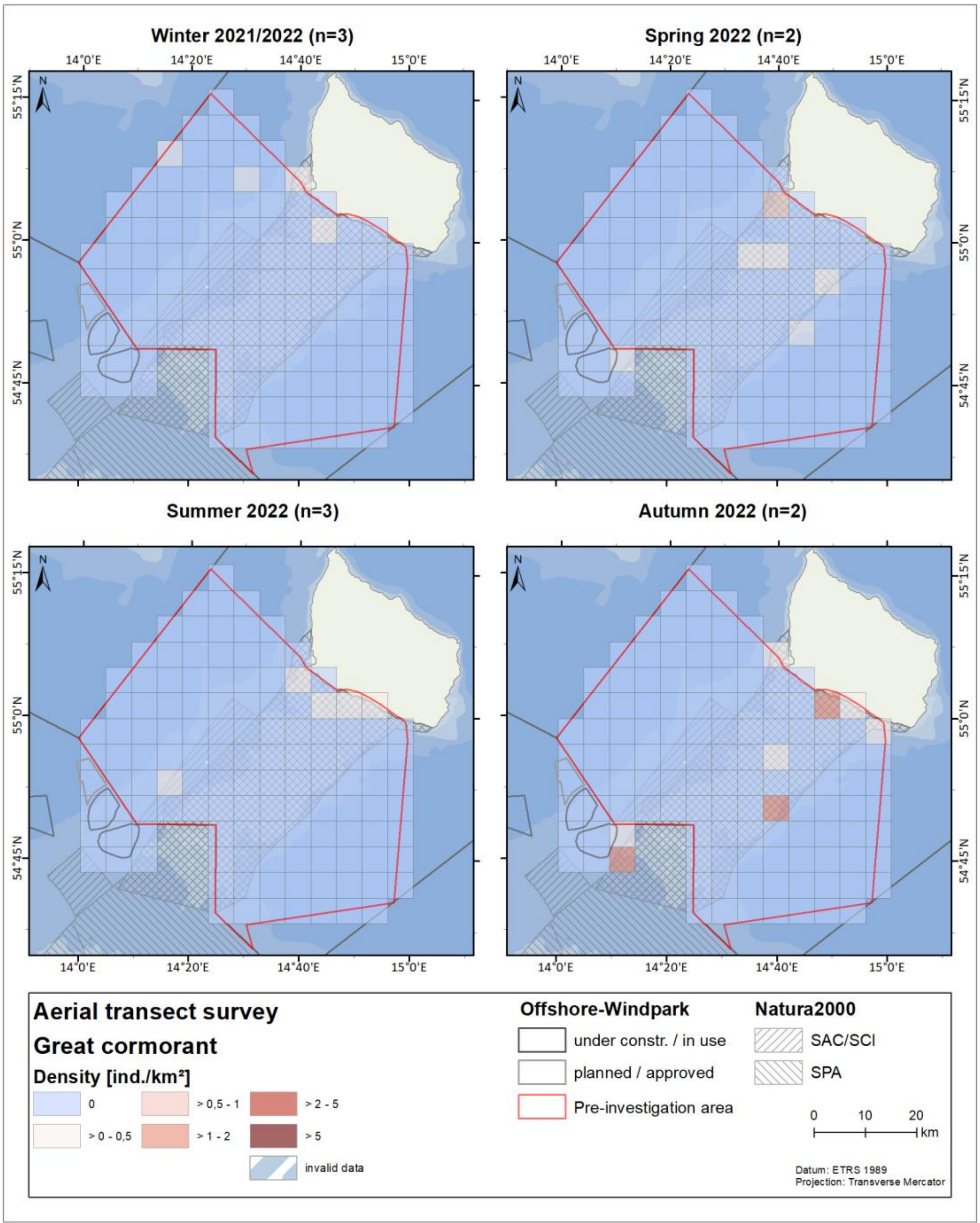

Figure 23. Distribution of great cormorants in the pre-investigation area per species specific season counted during digital aerial surveys in the first study period between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

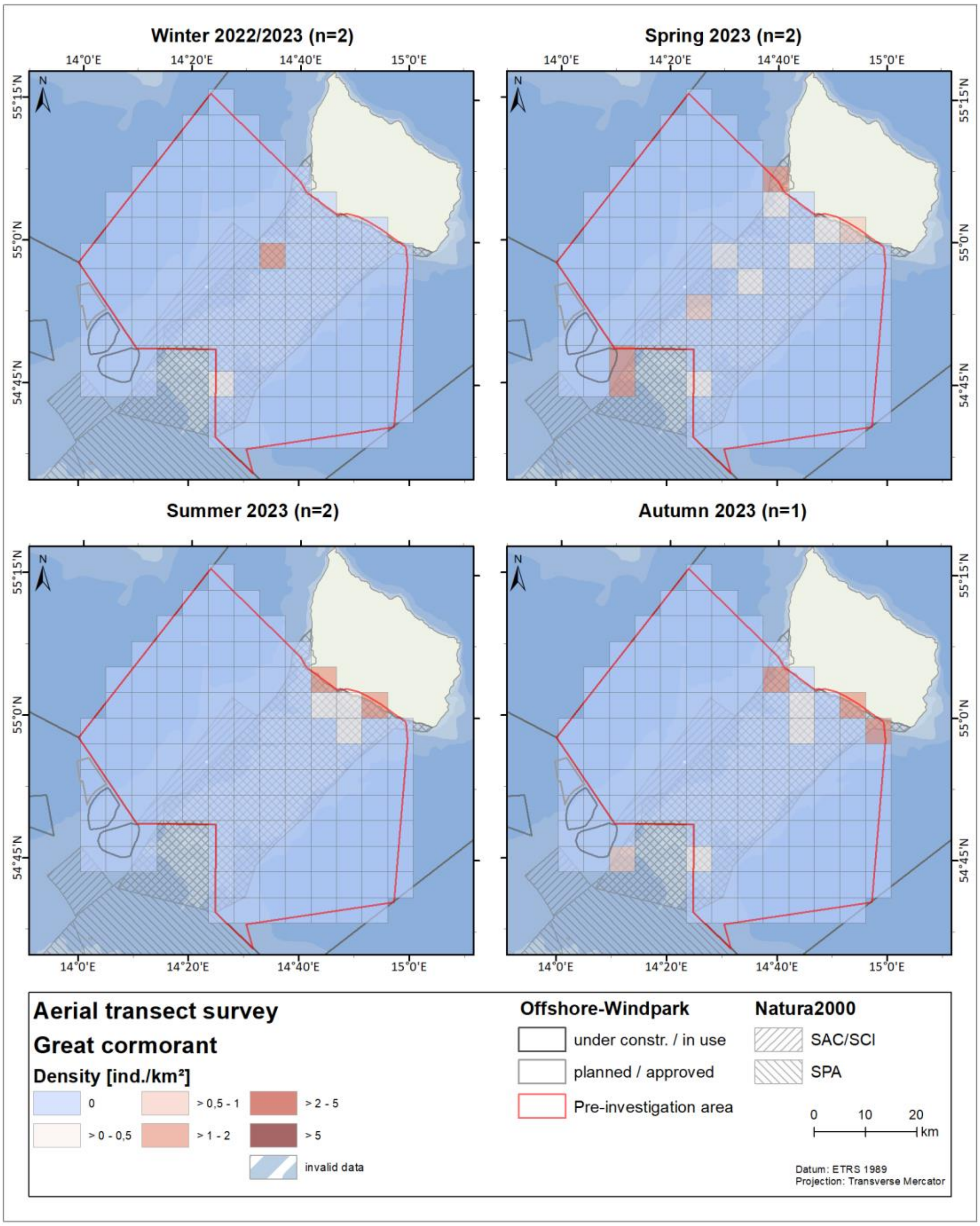

Figure 24. Distribution of great cormorants in the pre-investigation area per species specific season counted during digital aerial surveys in year two between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

SEA DUCKS

Sea ducks were the most common species group observed within the pre-investigation area and represented over 75 % of the total number of resting birds observed during the aerial survey (see Table 7). The most abundant sea duck species was the long-tailed duck whereas common eiders, common scoters and velvet scoters were observed only in lower numbers.

LONG-TAILED DUCK

Long-tailed ducks were the most common species among the sea ducks, but also among all resting birds observed in the pre-investigation area representing 79 % of all species. 11,736 individuals were counted in the first study year and 12,106 individuals in the second (see Table 7). In both years, highest densities were found in autumn and winter and no individuals were present during the summer months (Figure 25). The maximum monthly density of the first year was observed in autumn with 8.7 ind./km² in November 2021, whereas the maximum density of the second year was observed in December 2022 with 11.2 ind./km².

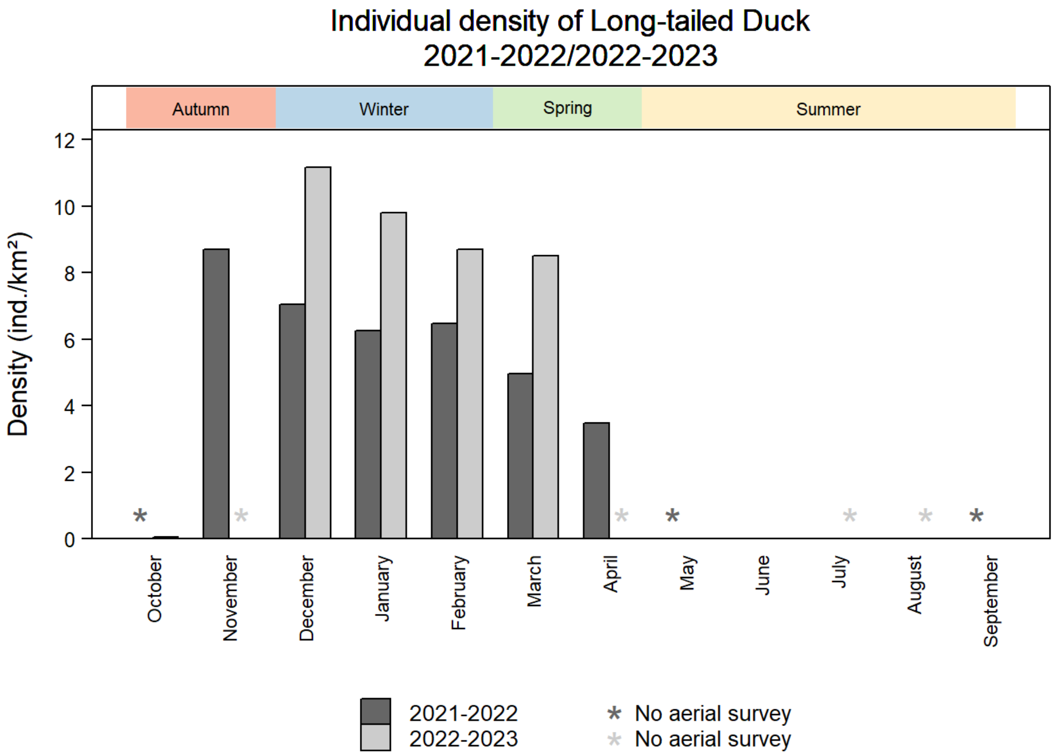

Figure 25. Monthly densities of long-tailed ducks given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey period (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

High densities of long-tailed ducks (>100 ind./km²) were observed in shallower waters including the protected areas and close to the Bornholm coast (see Figure 26 and Figure 27). During winter and spring, birds were generally spread across the entire pre-investigation area in lower densities with up to 5 ind./km².

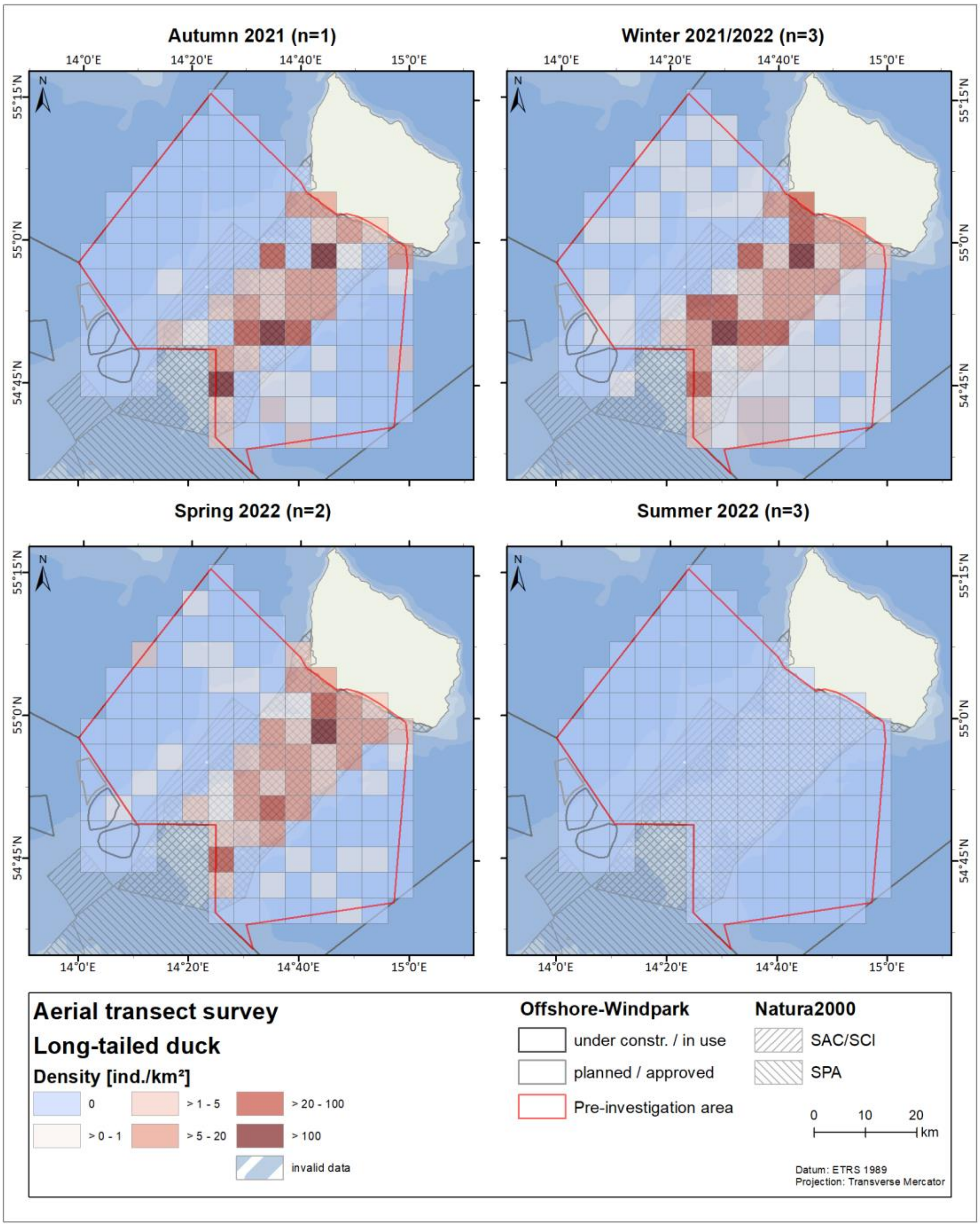

Figure 26. Distribution of long-tailed ducks in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between autumn 2021 and summer 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

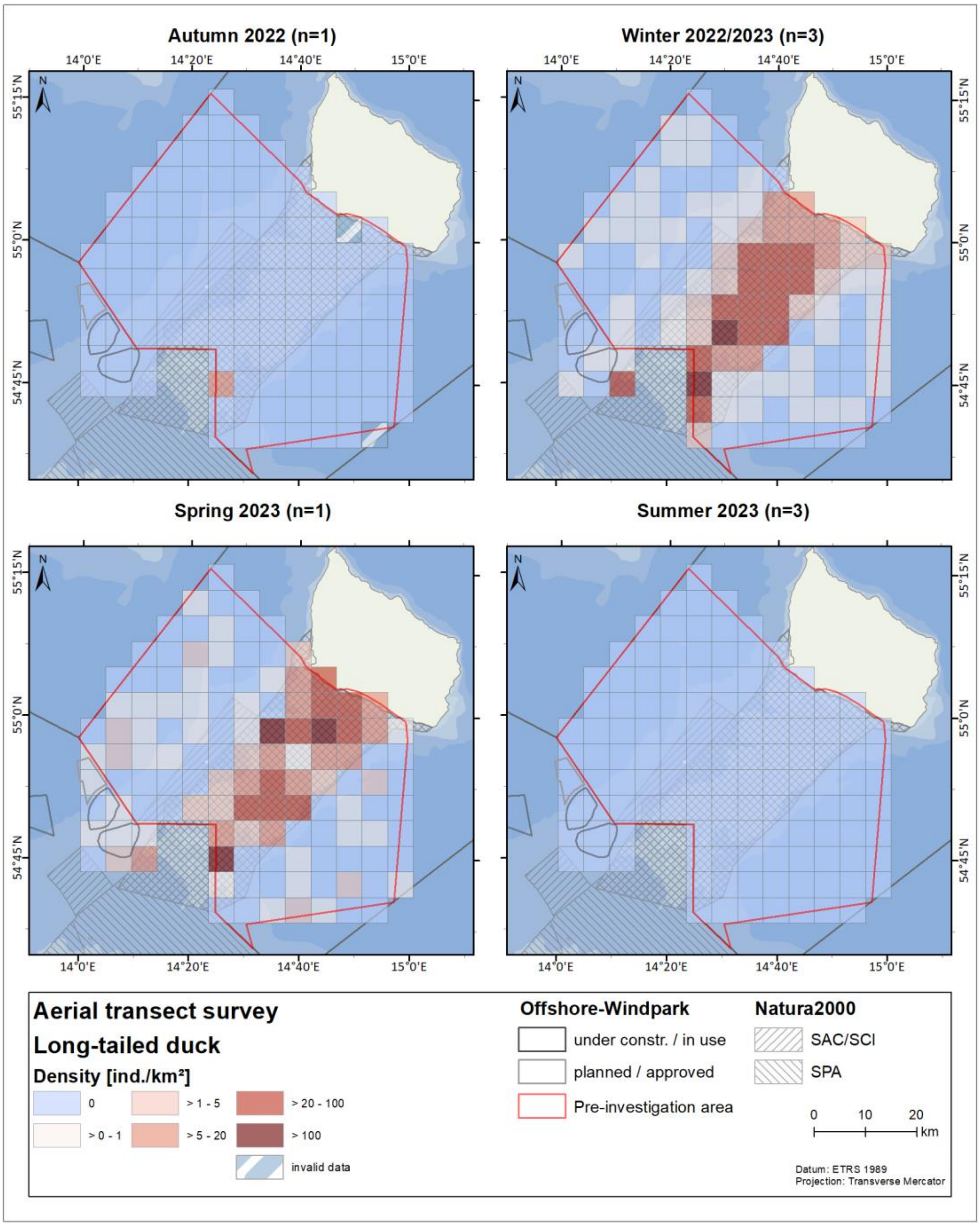

Figure 27. Distribution of long-tailed ducks in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between autumn 2022 and summer 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

Since the energy intake rate for long-tailed ducks is dependent on the water depth which they need to dive through to reach their main food resource bivalves, the occurrences recorded during aerial surveys were analysed investigating the connection between water depth and number of birds (Figure 28). Long-tailed ducks were mainly located in areas with shallow water depths of less than 20 m with highest concentration on the small areas with water depths of less than 10 m located in the SPA Rønne Banke (even though not much of such area could be covered). Only very few individuals were observed in areas with > 30 m water depths.

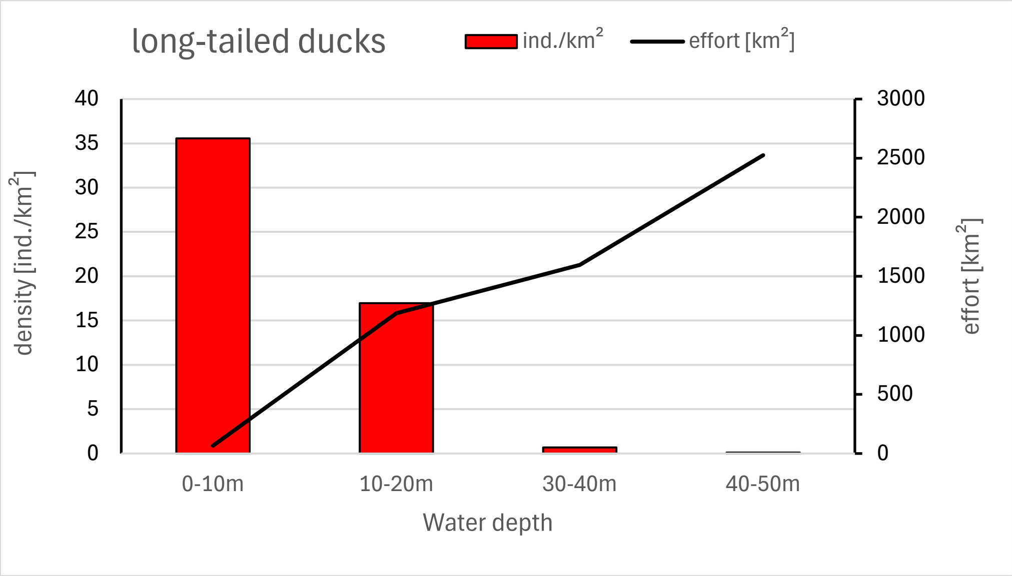

Figure 28. Long-tailed duck distribution within the pre-construction area by water depth based on digital aerial surveys from the present study. Densities are given as ind./km² and shown in relation to the effort in the different depth-classes.

COMMON EIDER

With 131 and 70 common eiders counted in the first and second year of study respectively (Table 7), they were the least common sea duck species observed in the area. Higher monthly densities were observed during April 2022 with 0.25 ind./km² and October 2022 with 0.17 ind./km² (see Figure 29). Besides 0.14 ind./km² in June 2022, densities during summer were generally low with less than 0.03 ind./km². Individuals were spatially limited and mainly spotted close to the coast of Bornholm and in shallower areas (see Figure 30 and Figure 31).

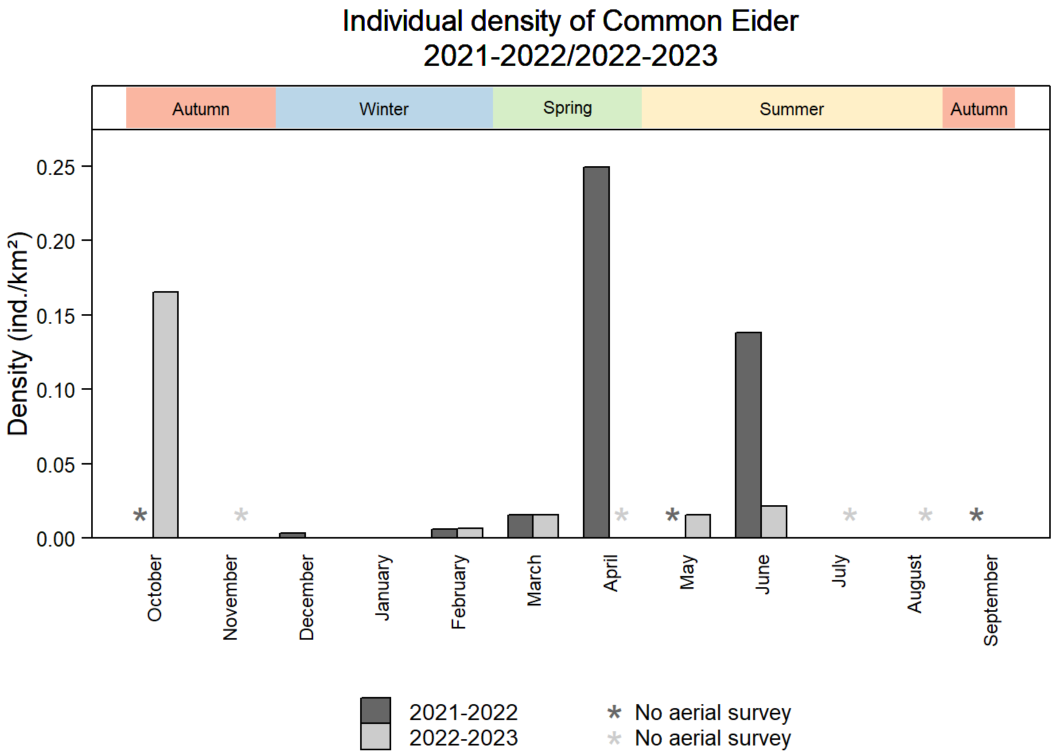

Figure 29. Monthly densities of common eiders given as individuals per km^2 calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

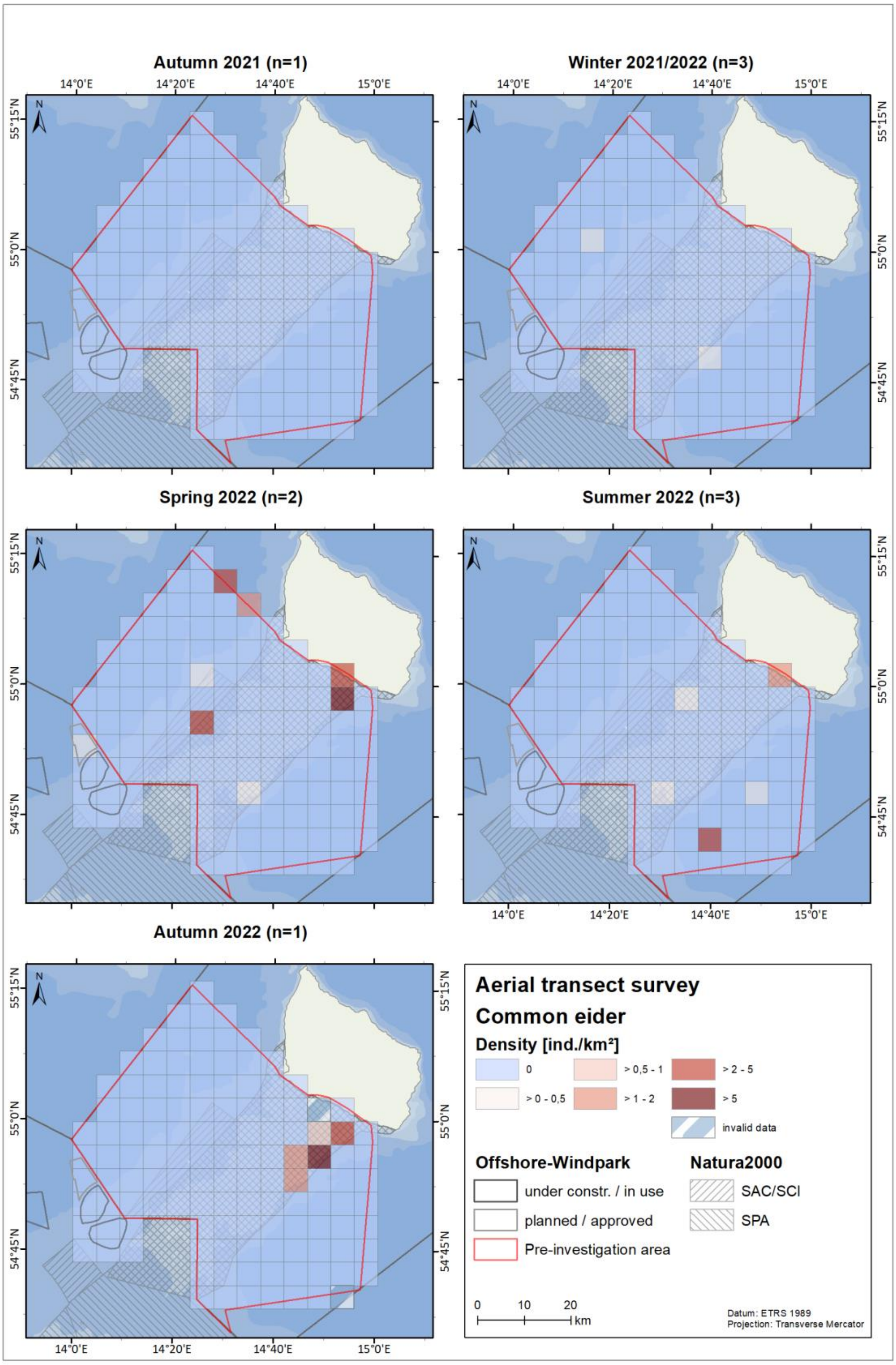

Figure 30. Distribution of common eiders in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between autumn 2021 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

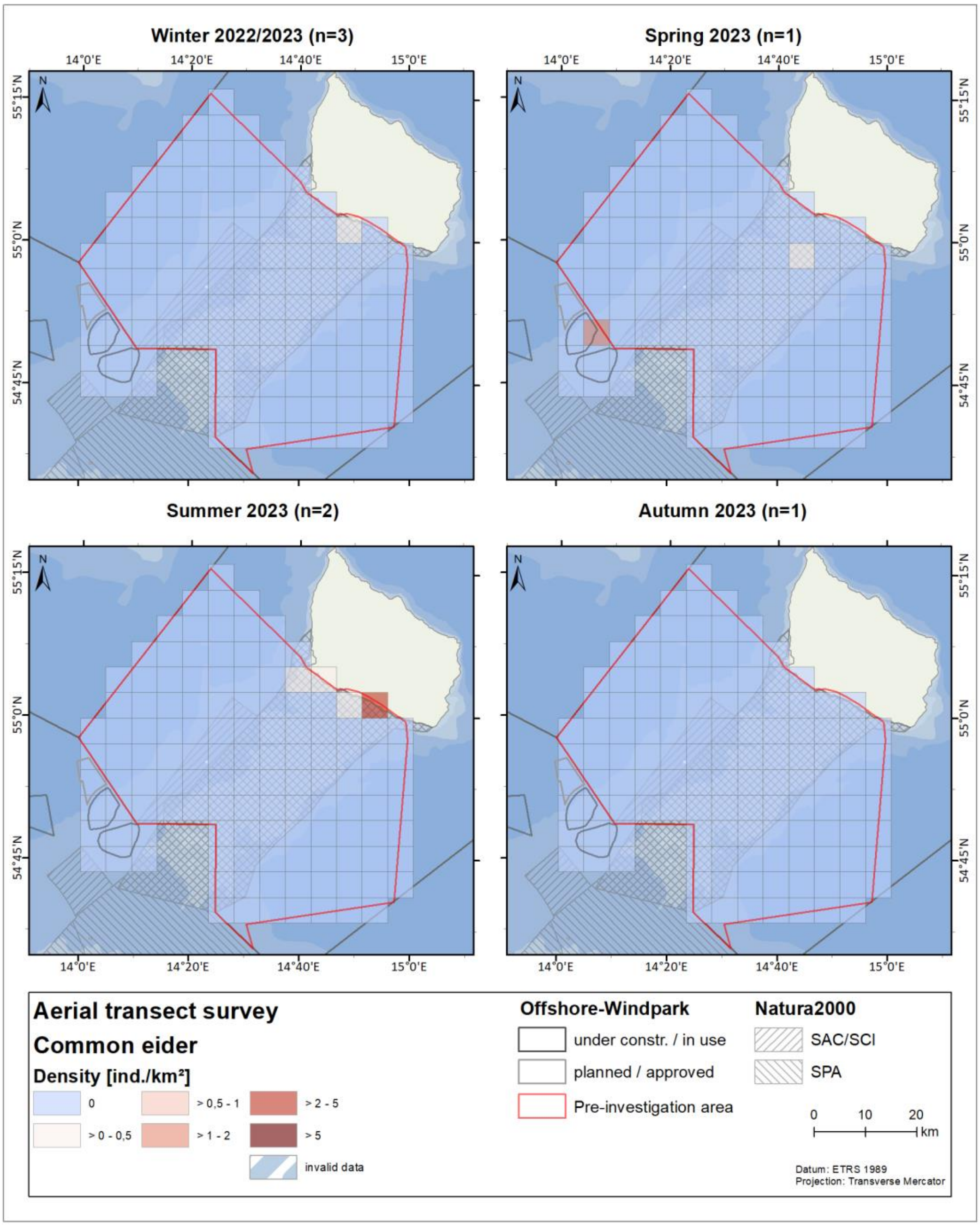

Figure 31. Distribution of common eiders in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The sample size is given as number of surveys (n).

COMMON AND VELVET SCOTER

170 and 205 common scoter individuals were observed during the first and second survey year (see Table 7). Their densities varied across survey years (Figure 32). The highest average monthly density with 0.29 ind./km² was observed in April 2022 during the first survey period, similar to that of the second year with 0.27 ind./km² observed in January 2023. Higher densities were also found during the summer in July 2022. Individuals appeared generally aggregated in shallow waters located in the protected areas with highest densities of up to 5 ind./km² (see Figure 33 and Figure 34).

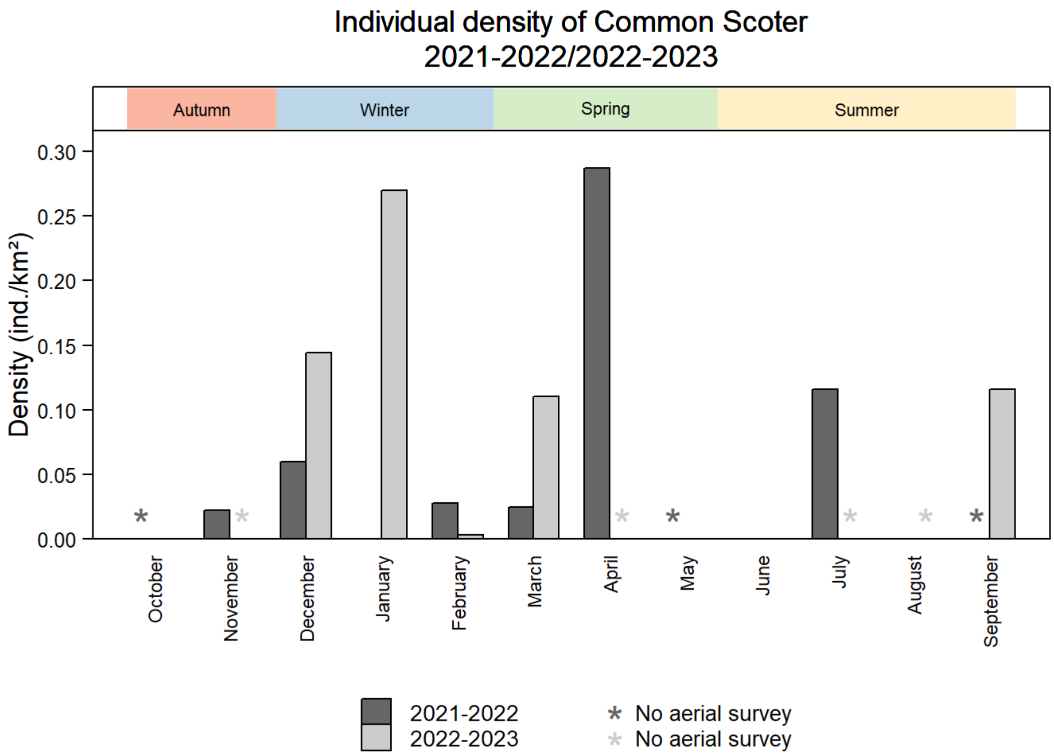

Figure 32. Monthly densities of common scoters given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

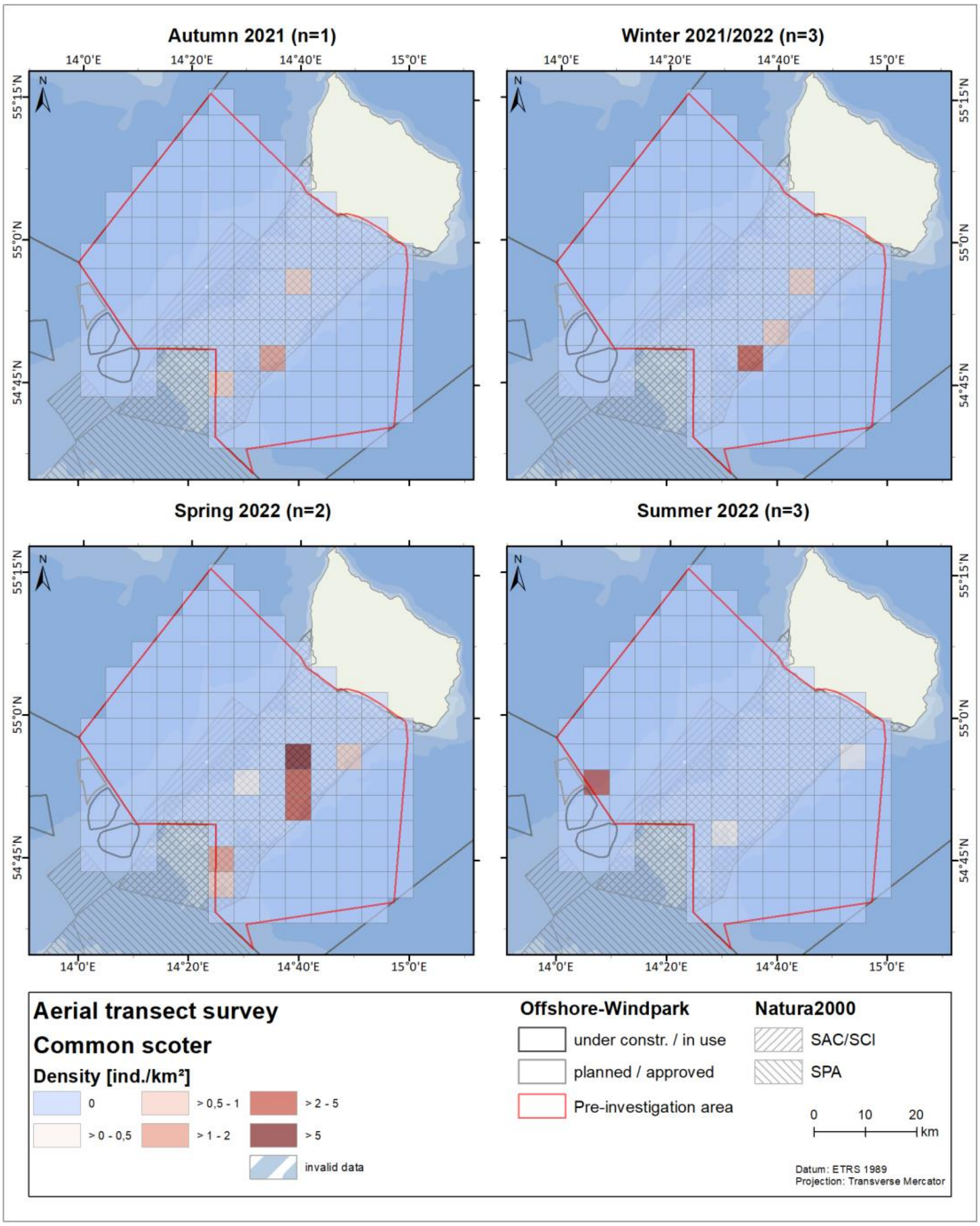

Figure 33. Distribution of common scoters in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between autumn 2021 and summer 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

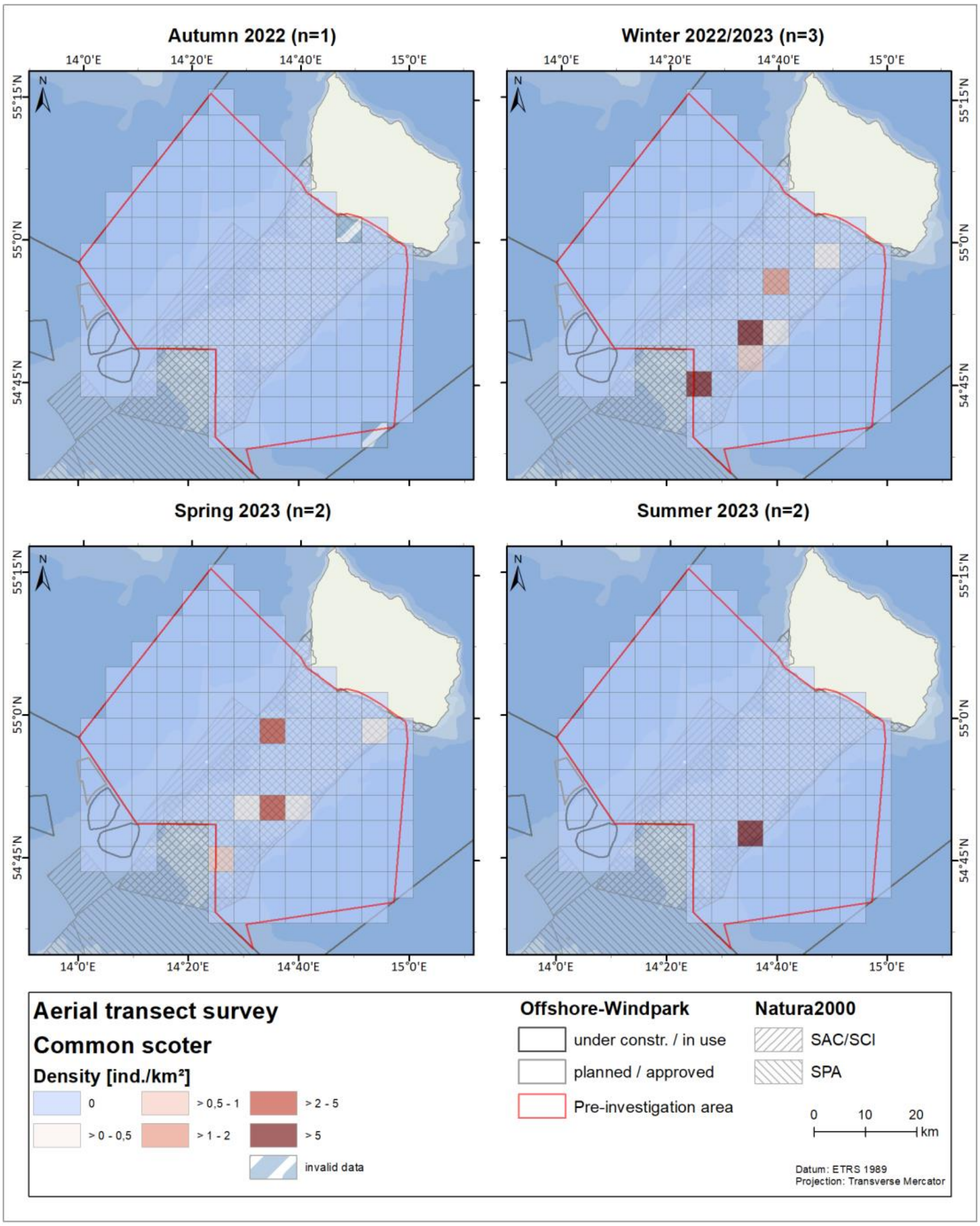

Figure 34. Distribution of common scoters in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and summer 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

Velvet scoters were more abundant, especially in the second study year. A total of 658 and 1,511 individuals were recorded in the first and second survey year respectively (see Table 7). Individuals were only observed from October until April. The maximum average monthly density during the first year was calculated as 0.76 ind./km² in March 2022, whereas the highest density in the second year was 2.37 ind./km² in February 2023 (see Figure 35). Most individuals appeared highly aggregated in shallow waters and within the protected areas, as well as close to Bornholm (see Figure 36 and Figure 37).

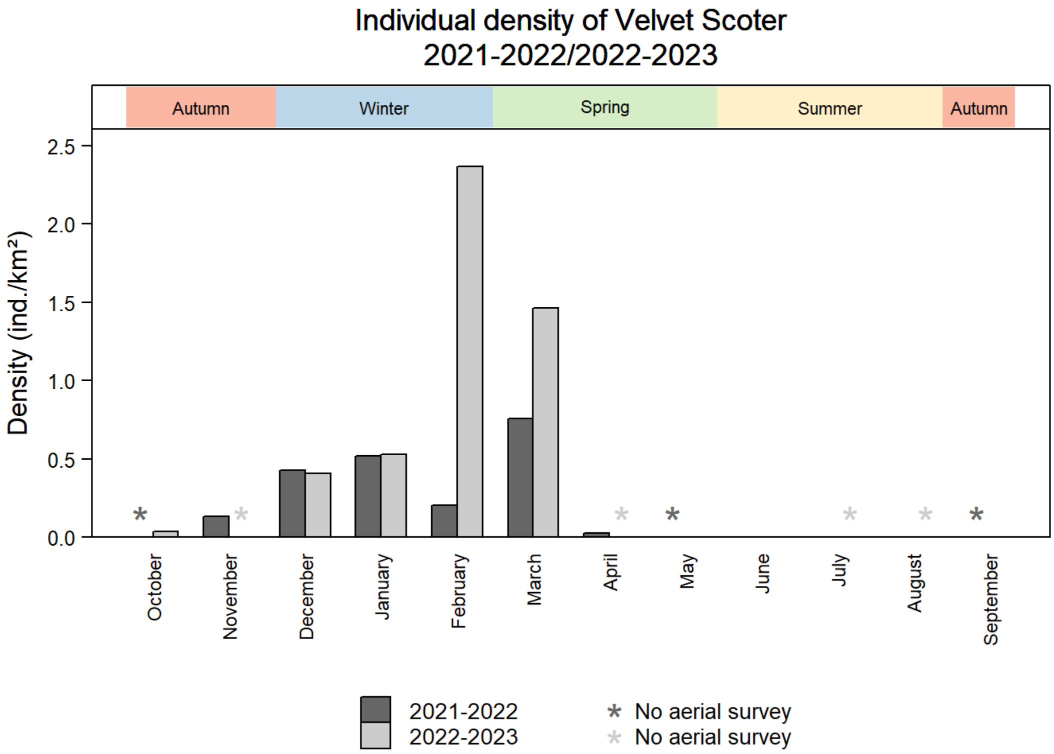

Figure 35. Monthly densities of velvet scoters given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

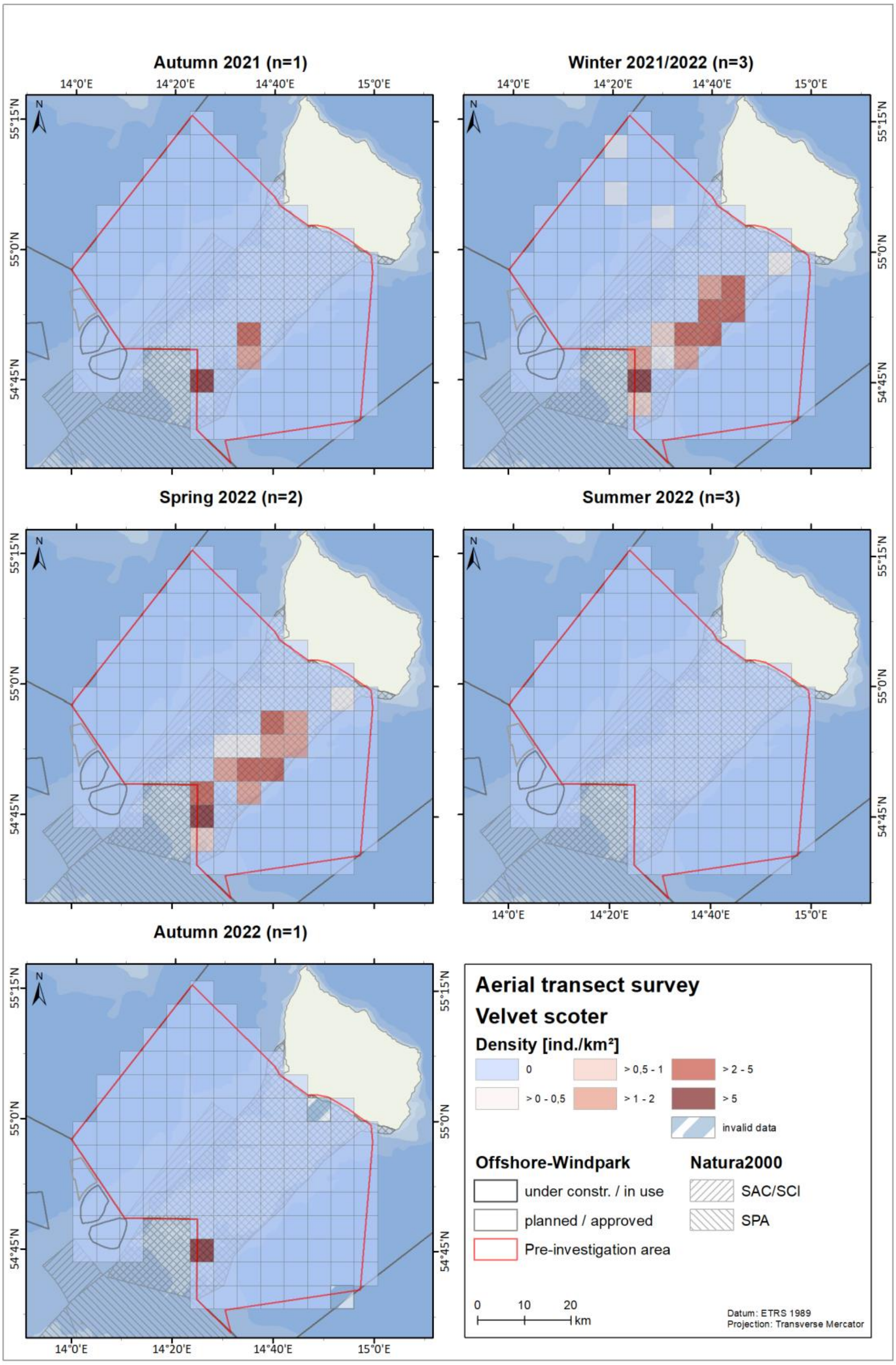

Figure 36. Distribution of velvet scoters in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between autumn 2021 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

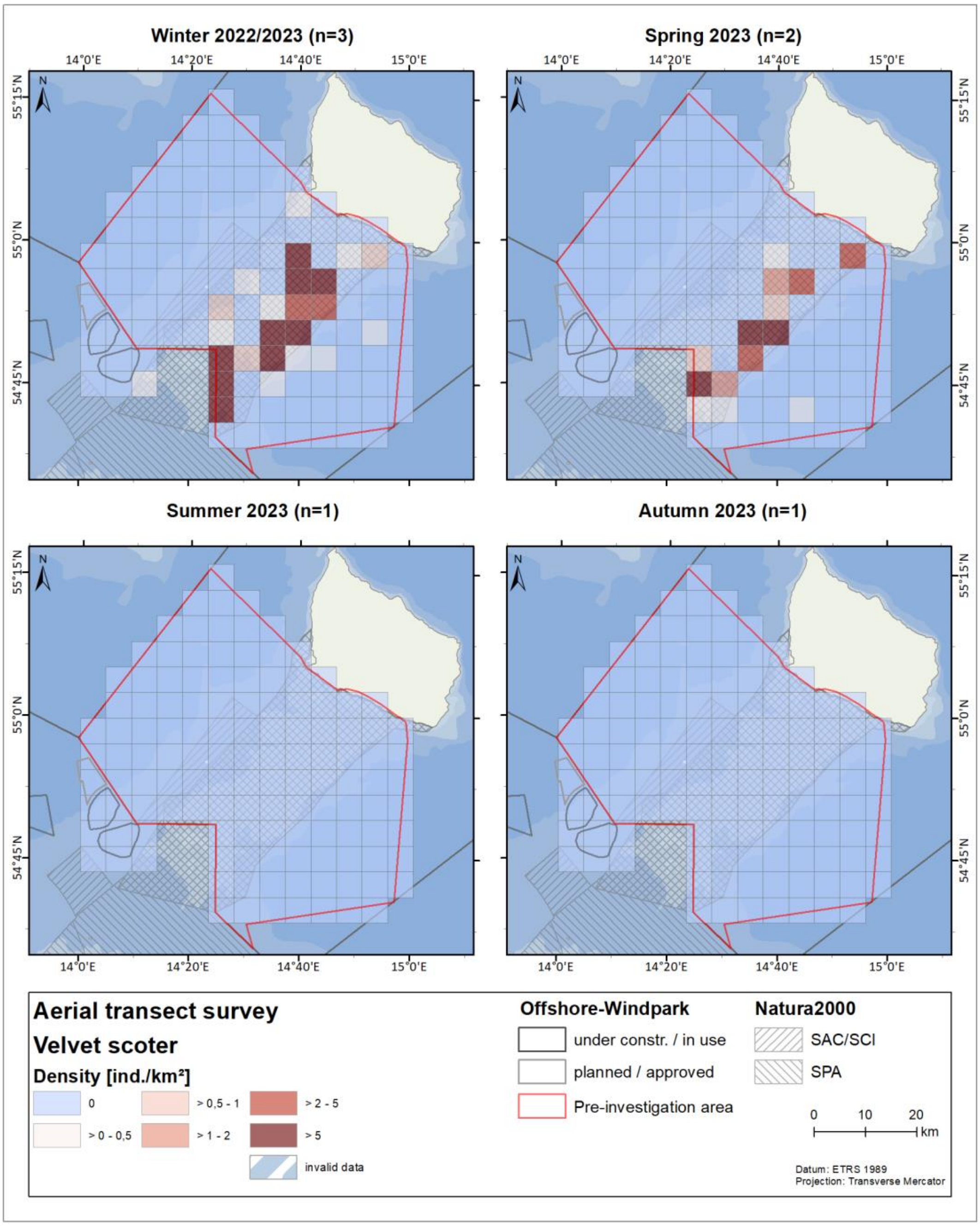

Figure 37. Distribution of velvet scoters in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

GULLS

Although some small gulls like the little gull and the black-headed gull were observed in the pre-investigation area, their numbers were quite low (see Table 7). Only a few lesser black-backed gull and black-legged kittiwake individuals were counted in the pre-investigation area during the digital aerial surveys in both years. Therefore, results will be described in further details only for common gulls, herring gulls and great black-backed gulls, as these were most common in the pre-investigation area.

COMMON GULL

Within the pre investigation area, 230 common gulls were registered during the first survey year and 120 individuals were counted during the second (see Table 7). Common gulls were observed across all seasons, but with higher densities during the winter. The maximum monthly density in the first year was 0.22 ind./km² found in December 2021, whereas the maximum density in the second year was 0.13 ind./km² observed during October 2022 (see Figure 38).

Individuals were distributed across the entire pre-investigation area but observed more frequently in offshore regions except for a single spot close to Bornholm (see Figure 39 and Figure 40).

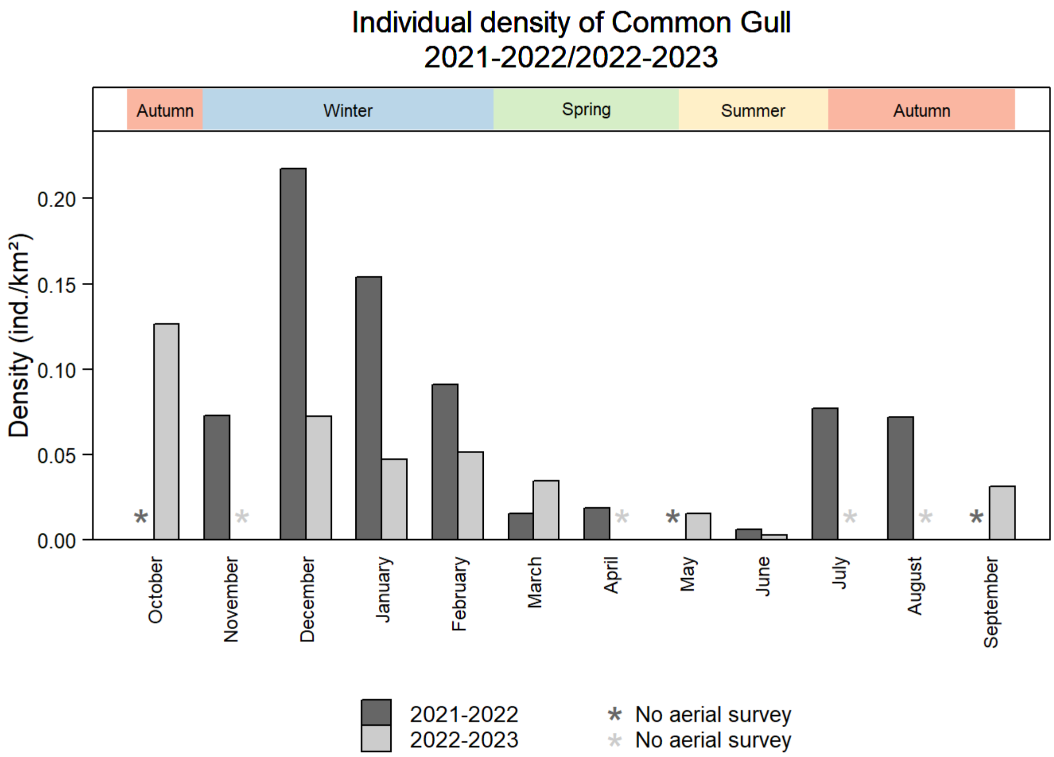

Figure 38. Monthly densities of common gulls within the pre-investigation area given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey period (October 2021 until September 2022). Light grey bars show results for the second survey year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

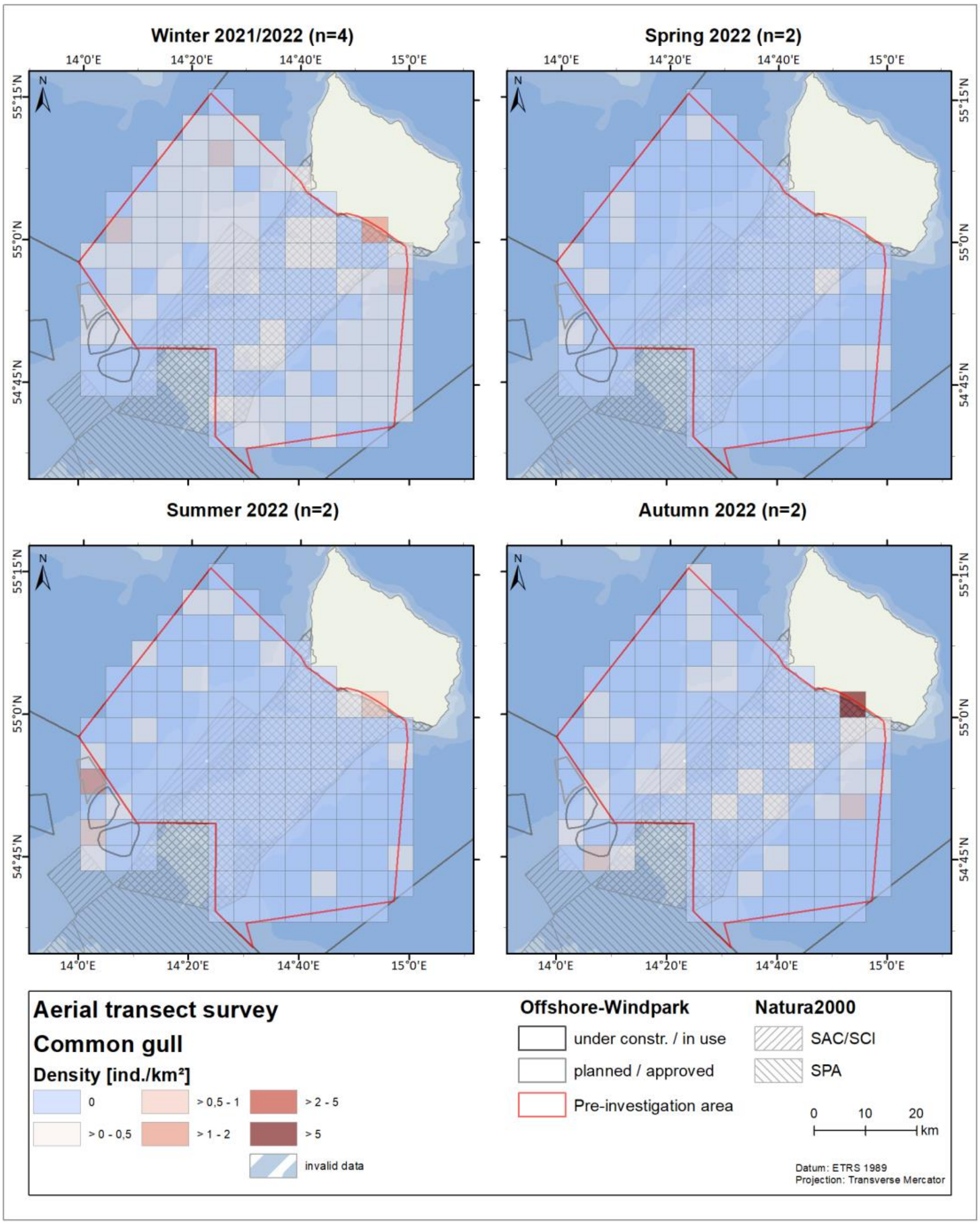

Figure 39. Distribution of common gulls in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

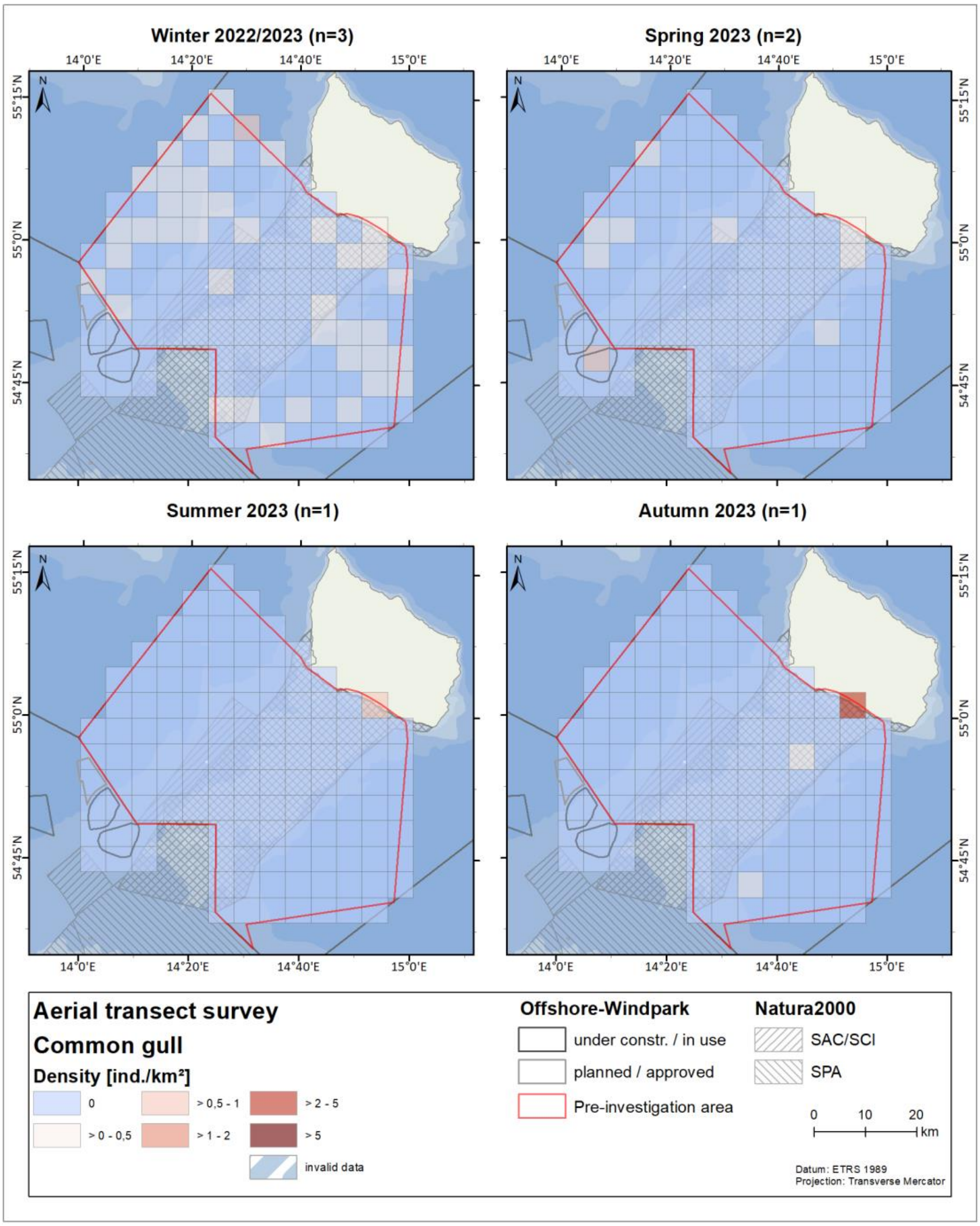

Figure 40. Distribution of common gulls in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

GREAT BLACK-BACKED GULL

Great black-backed gulls were less common with a total of 124 individuals recorded during the study period (see Table 7). Their abundance in the first survey year represented around 0.5 % of the total resting birds. The highest calculated average monthly density was ~0.1 ind./km² for November 2021, whereas a maximum of 0.05 ind./km² were observed in January 2023 (Figure 41).

Individuals were located across the entire pre-investigation area, preferably in the offshore areas (see Figure 42 and Figure 43).

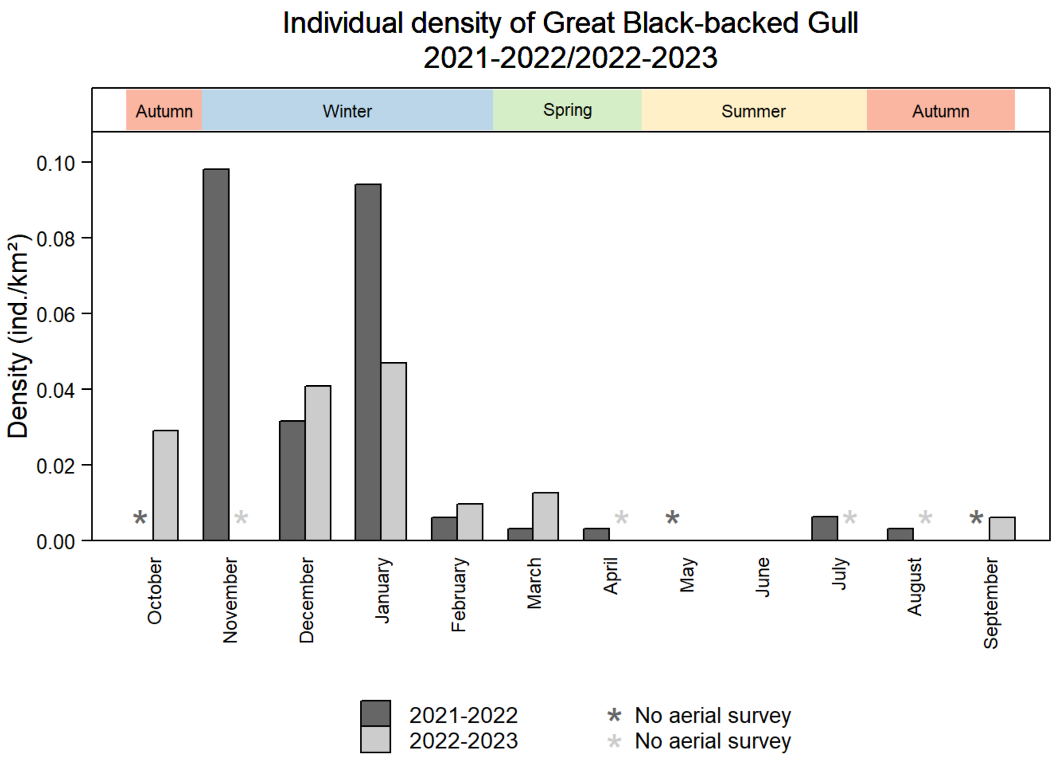

Figure 41. Monthly densities of great black-backed gulls within the pre-investigation area given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey period (October 2021 until September 2022). Light grey bars show results for the second survey year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

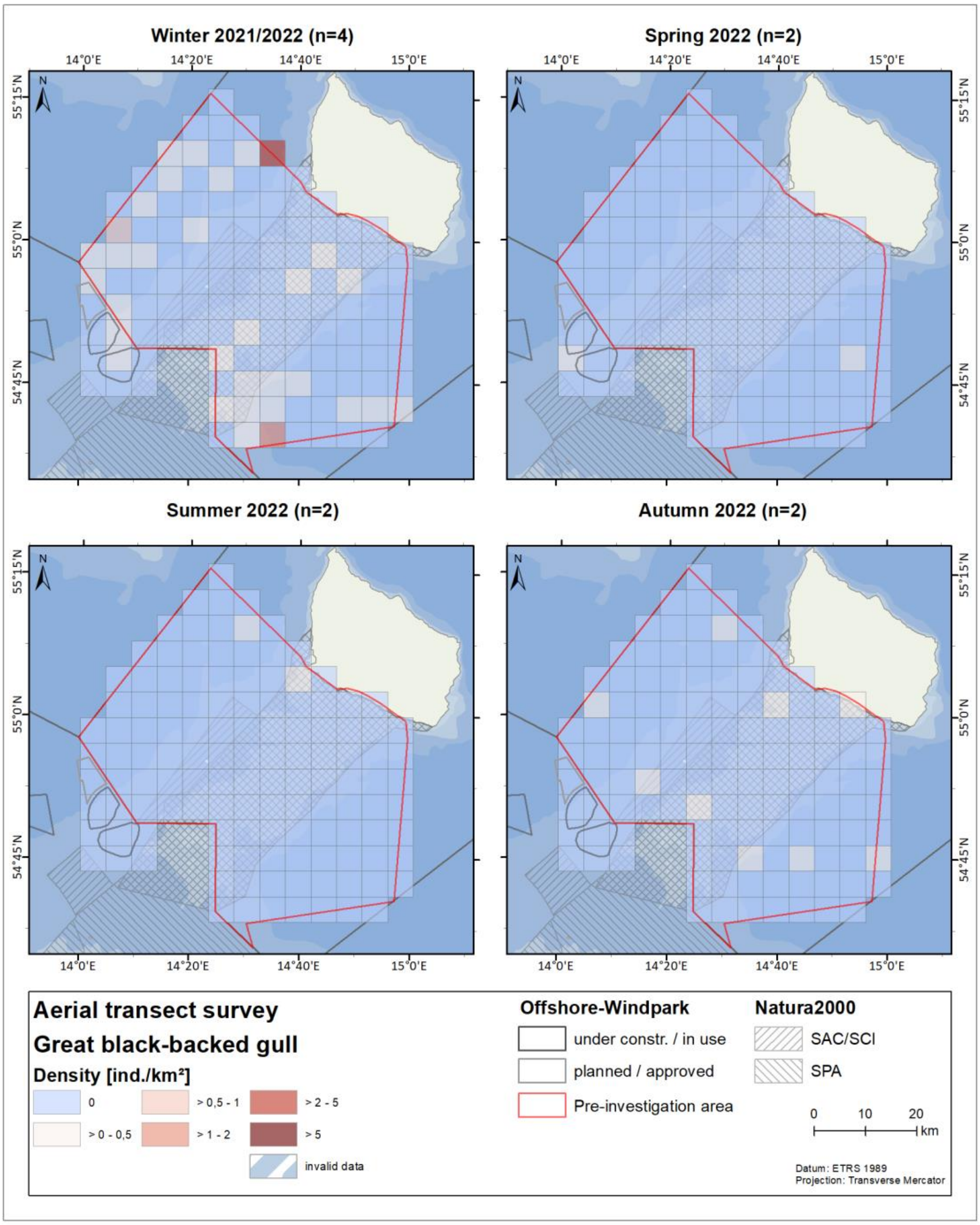

Figure 42. Distribution of great black-backed gulls in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

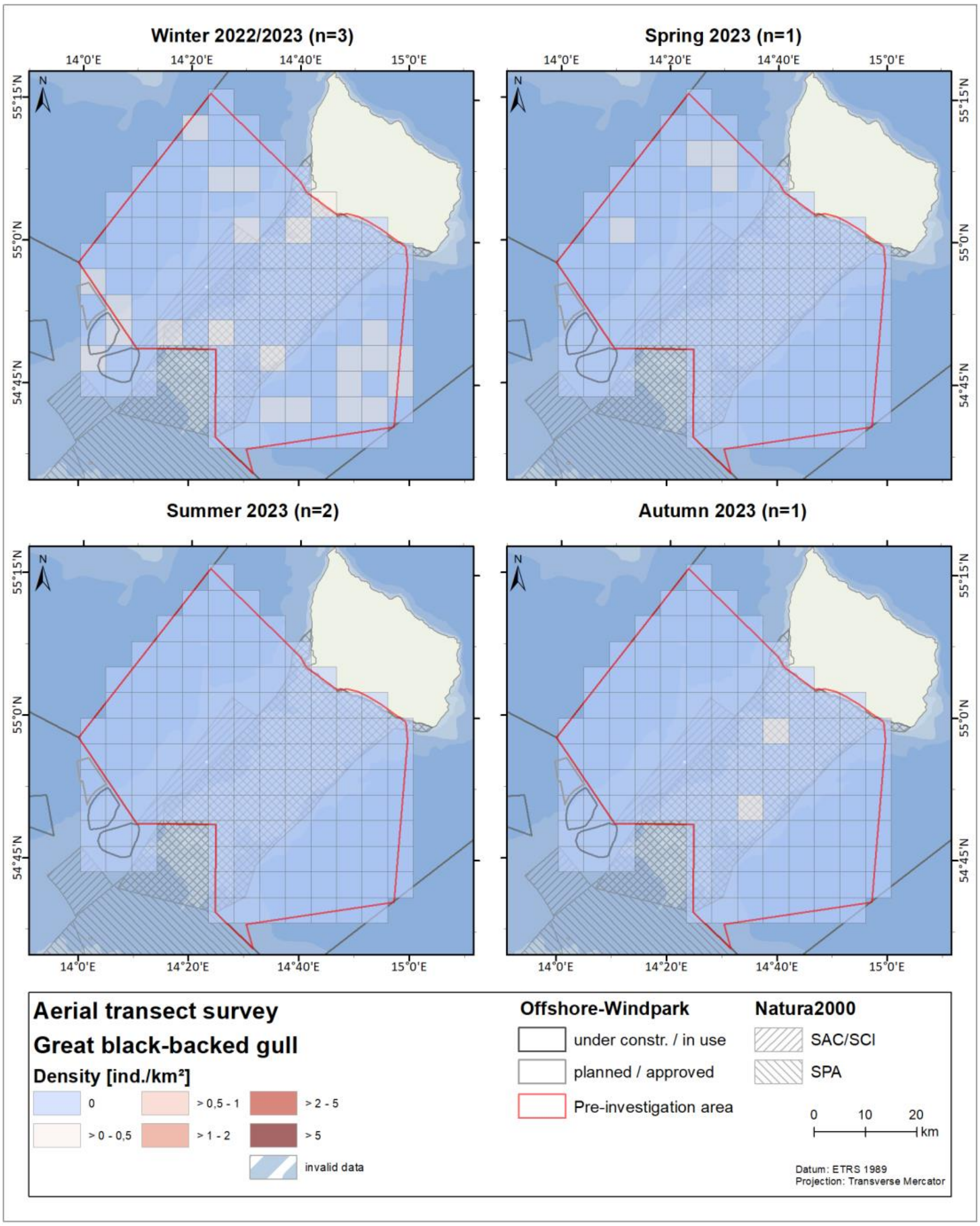

Figure 43. Distribution of great black-backed gulls in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

HERRING GULL

Among the observed gull species, herring gulls were the most abundant species within the pre-investigation area. They were more abundant in the first study year with 633 individuals observed individuals, compared to 346 in the second year (see Table 7). The largest densities were observed during the winter periods, but they were generally present in the pre-investigation area throughout the year. Maximum average monthly densities were observed both in November 2021 and January 2022 with around 0.49 ind./km² (see Figure 44), whereas the maximum monthly density in the second year was found in December 2022 with 0.25 ind./km².

Herring gulls were distributed across the entire pre-investigation area with higher densities occurring more often in offshore regions or close to the island Bornholm (see Figure 45 and Figure 46). Gulls, especially herring gulls are known for following fishing vessels and exceptional high numbers of these birds are always connected to anthropogenic activities like fishing. This is also reflected in the distribution patterns in both years.

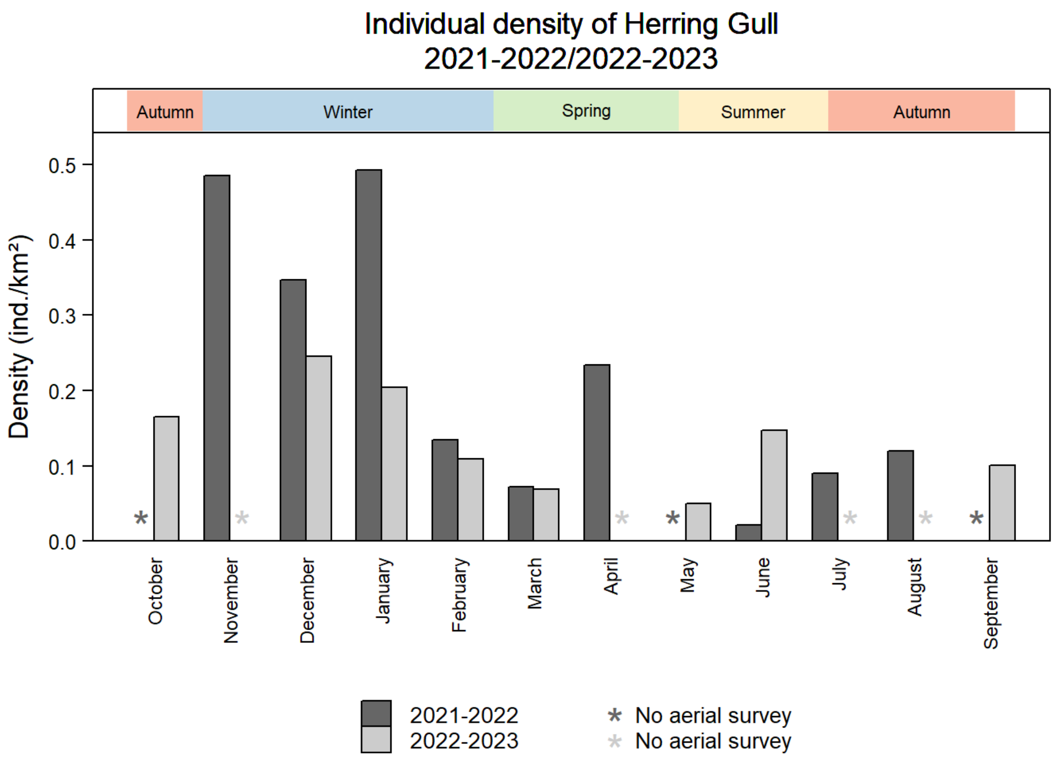

Figure 44. Monthly densities of herring gulls within the pre-investigation area given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

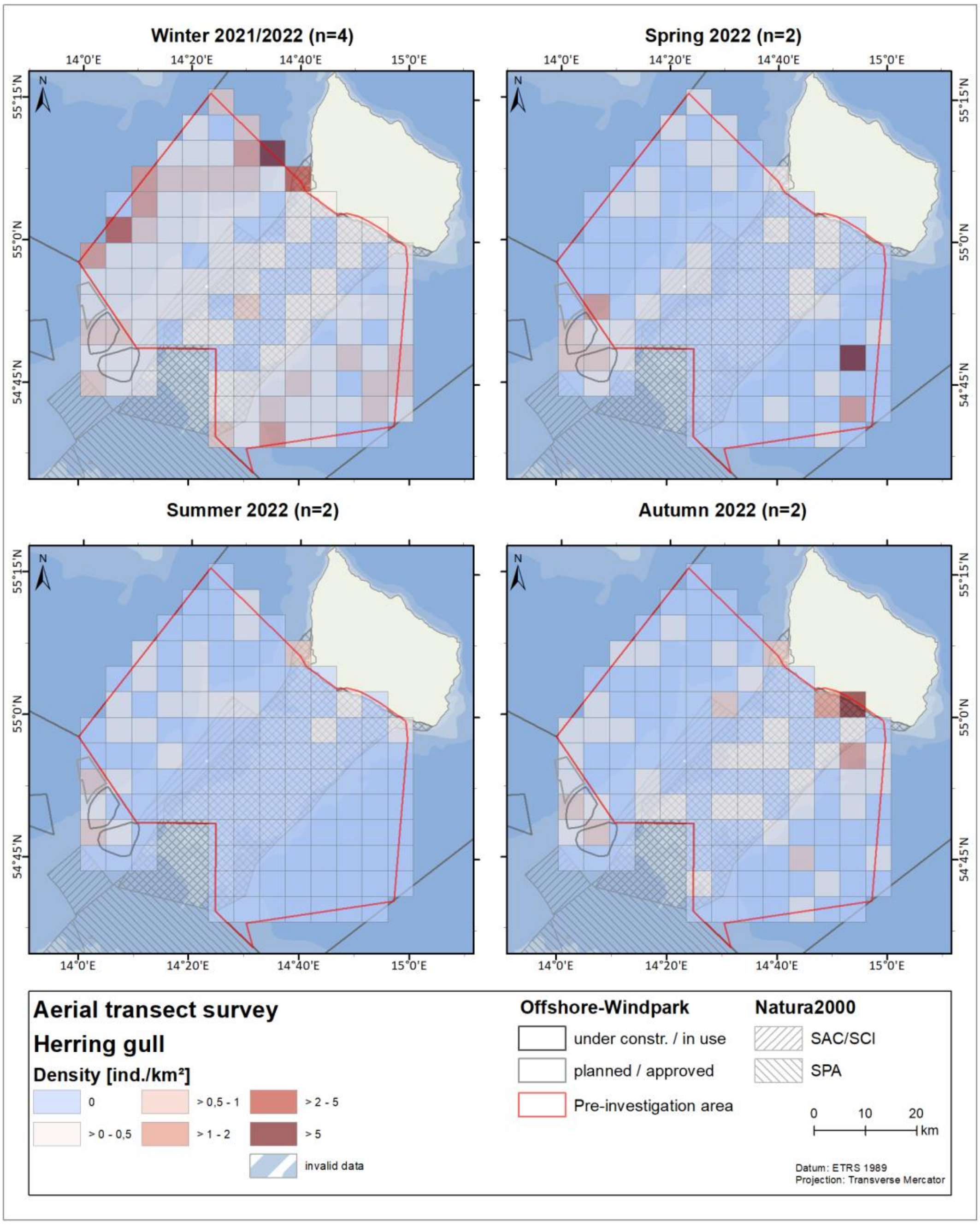

Figure 45. Distribution of herring gulls in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

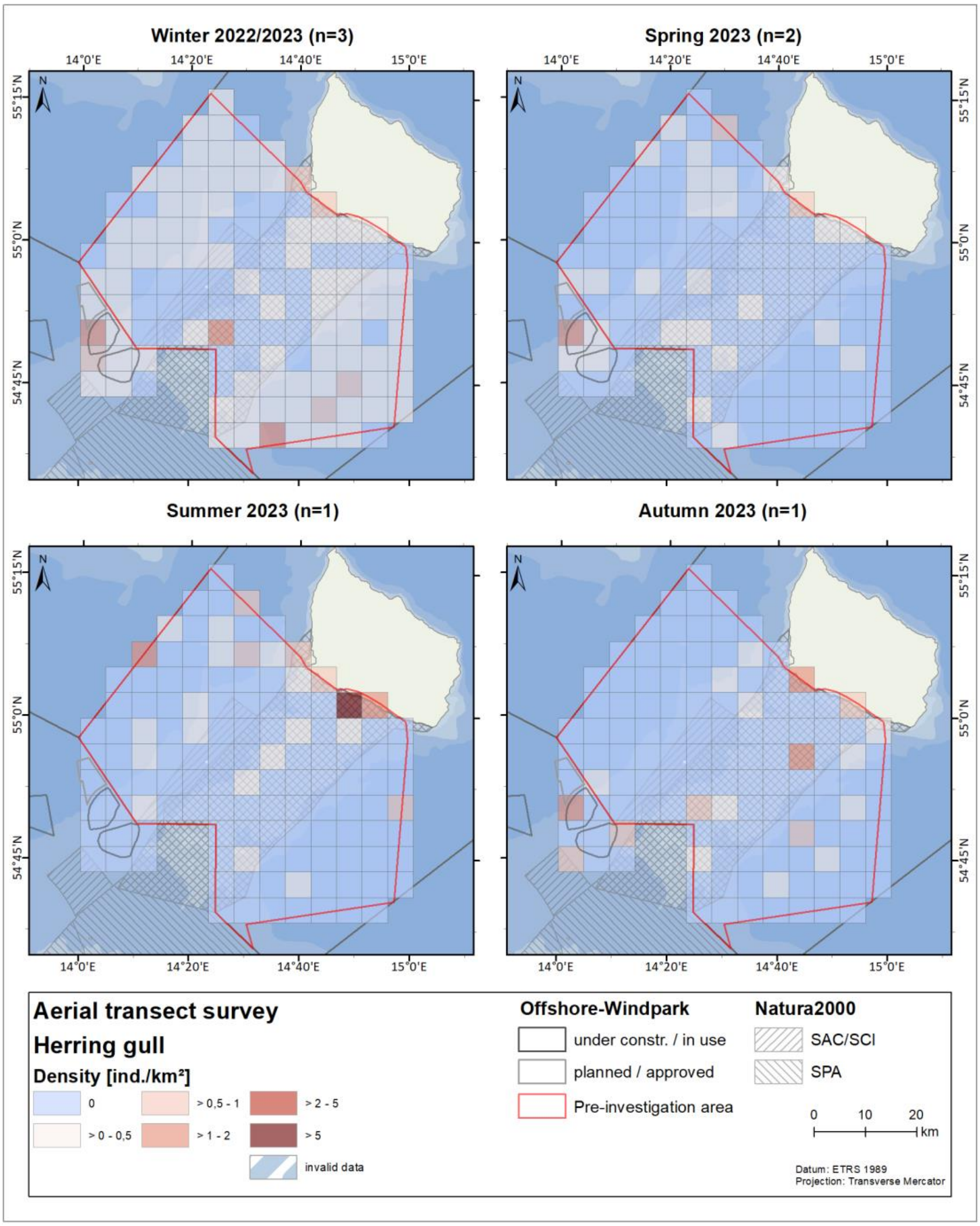

Figure 46. Distribution of herring gulls in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

AUKS

Auks were the second most abundant species group observed in the pre-investigation area representing 5.45 % of all observed species (see Table 7).

COMMON GUILLEMOT

Common guillemots were the most common auk species in the pre-investigation area. A total of 954 and 831 individuals were present in the first and second year of the present study, representing 5.9 % and 5.0 % of all resting birds respectively (see Table 7). Common guillemots were present during the whole year, but more abundant in winter (Figure 47). During the first year, the highest average monthly density was calculated for November 2021 with 0.8 ind./km², whereas the largest density during the second study year with 0.65 ind./km² was observed in January 2023.

Common guillemots were spread across the entire pre-investigation area with higher densities observed in regions further offshore, particularly in the area northwest and southeast of the bird SPA 'Adler Grund og Rønne Banke' with high local densities of more than 2 ind./km² (seeFigure 48 and Figure 49).

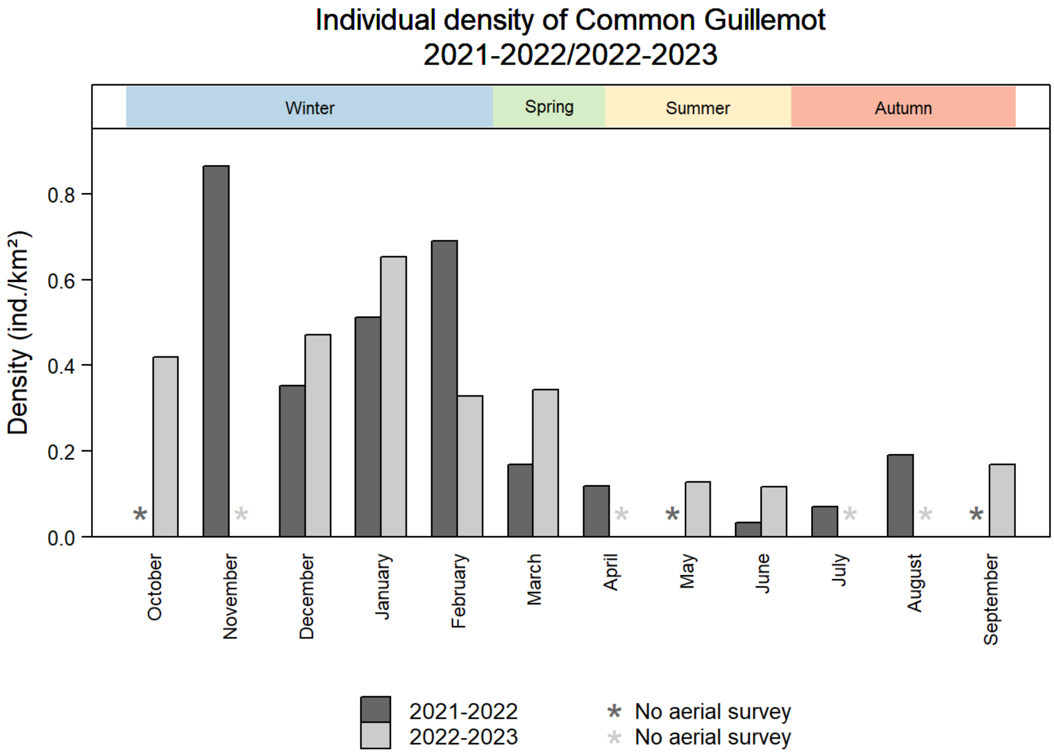

Figure 47. Monthly densities of common guillemots within the pre-investigation area given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

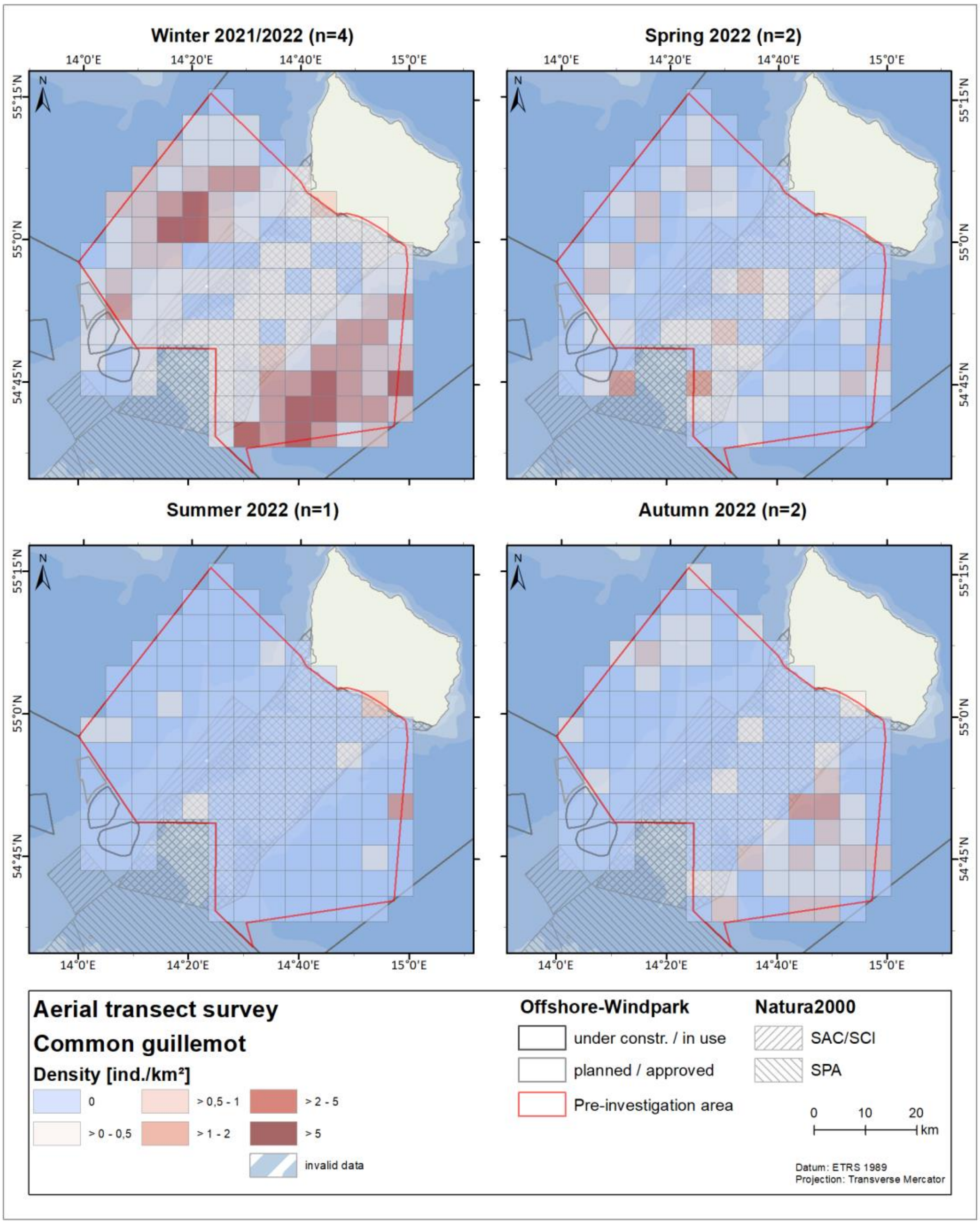

Figure 48. Distribution of common guillemots in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

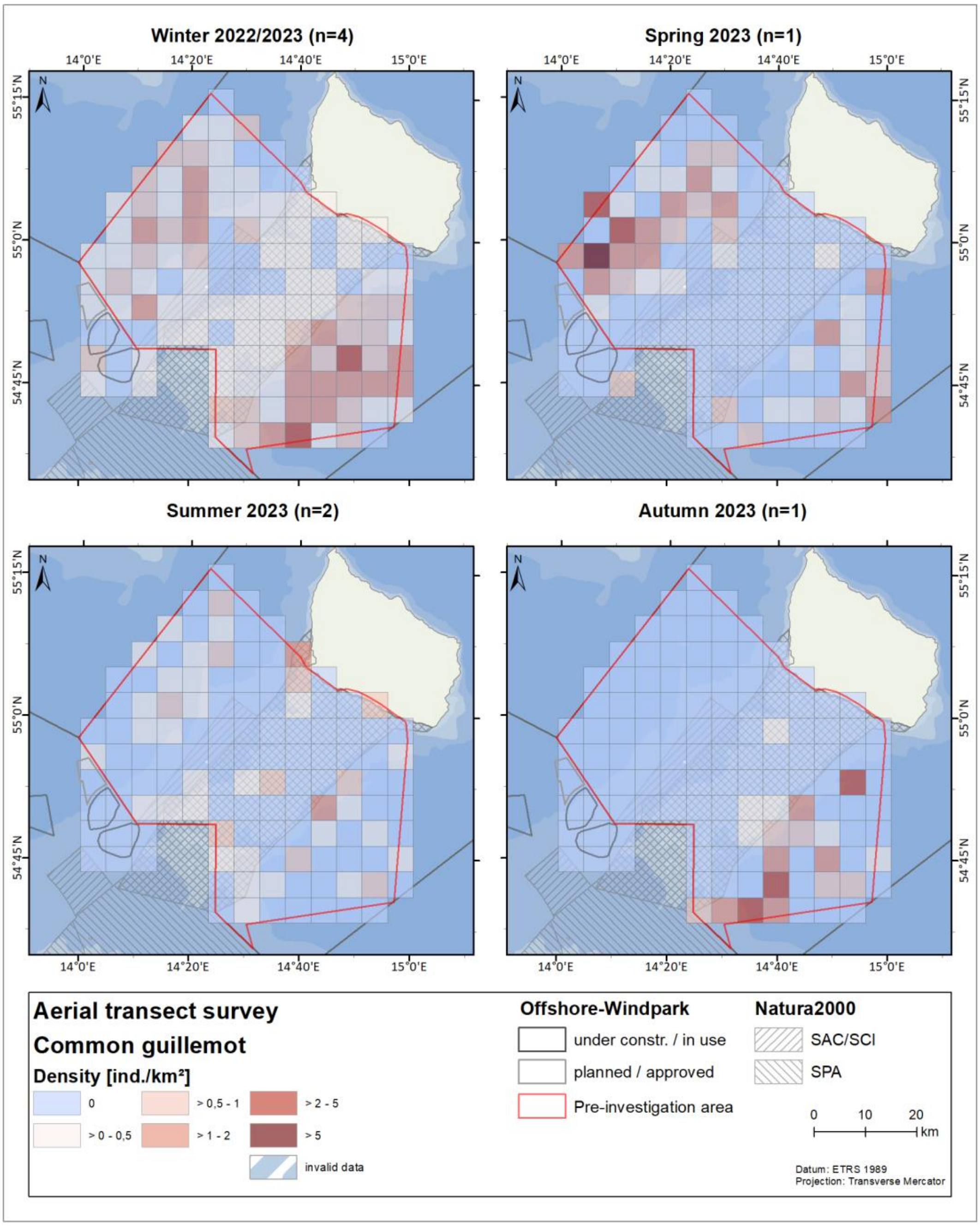

Figure 49. Distribution of common guillemots in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

RAZORBILL

Razorbills were not observed in the area between June and August. Their densities were highest in winter, and they were more abundant in the first year compared to the second year (324 vs. 186 individuals, see Table 7). The highest average monthly density of the first year was observed in November 2021 with 0.51 ind./km² whereas the highest monthly density in the second year was observed in December 2022 with 0.38 ind./km², (see (Figure 50).

Razorbills were distributed across the entire pre-investigation area. Higher densities in confined areas were mainly located in shallow waters in or at the western tip of the protected area (see Figure 51 and Figure 52).

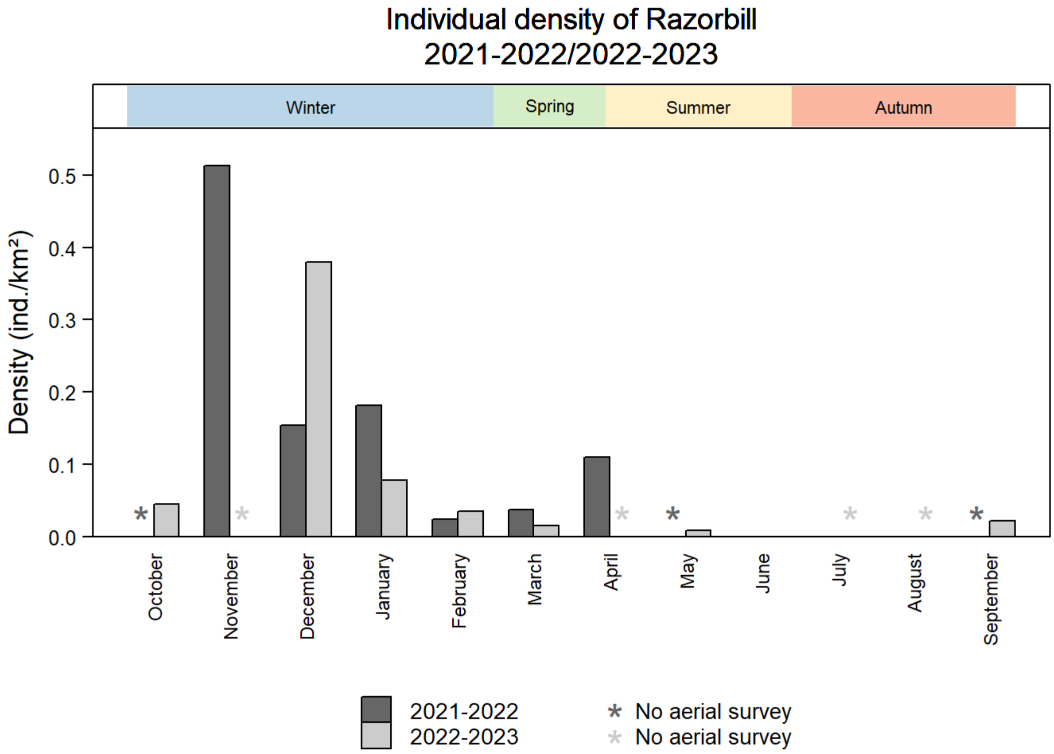

Figure 50. Monthly densities of razorbills within the pre-investigation area given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

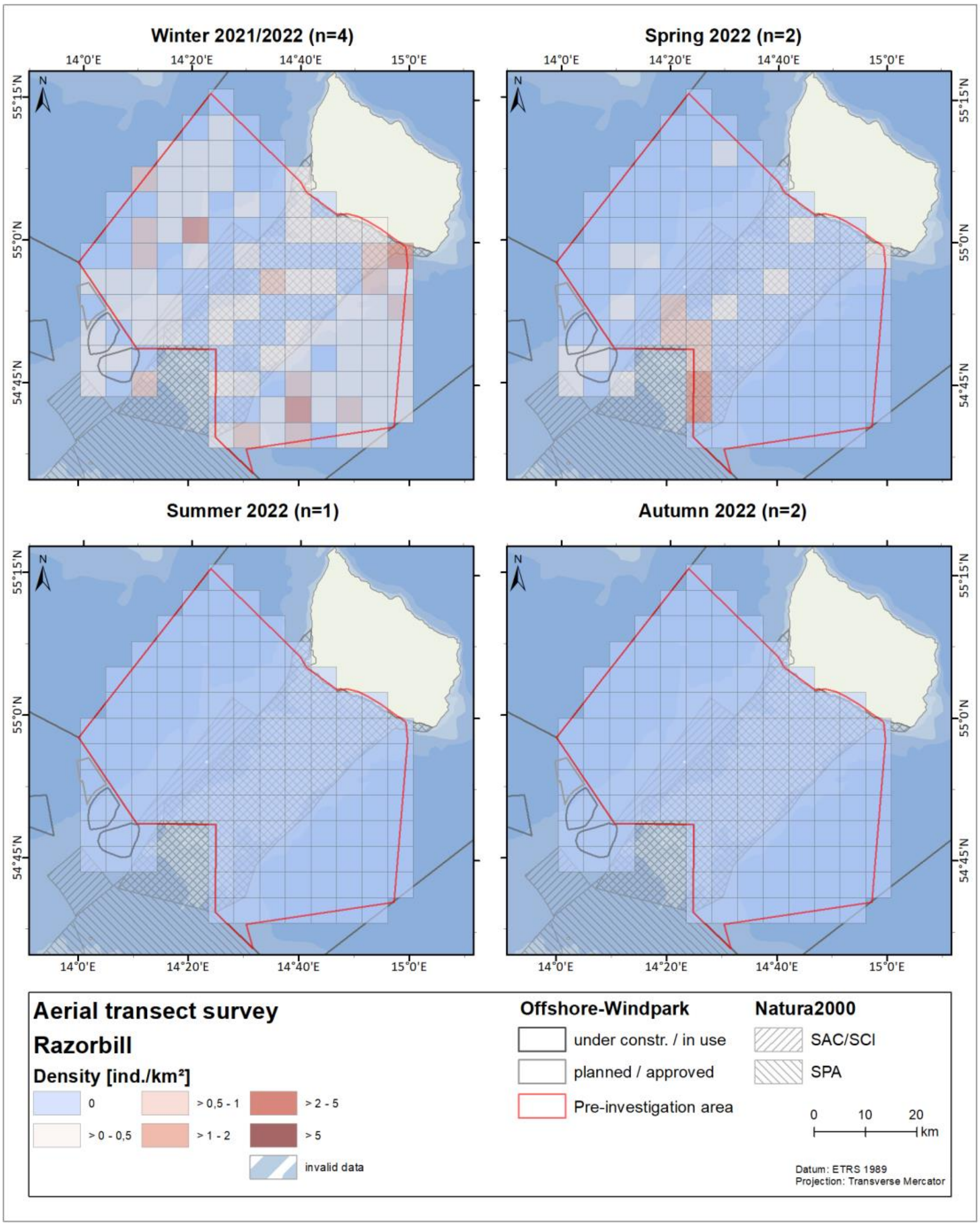

Figure 51. Distribution of razorbills in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between winter 2021/2022 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

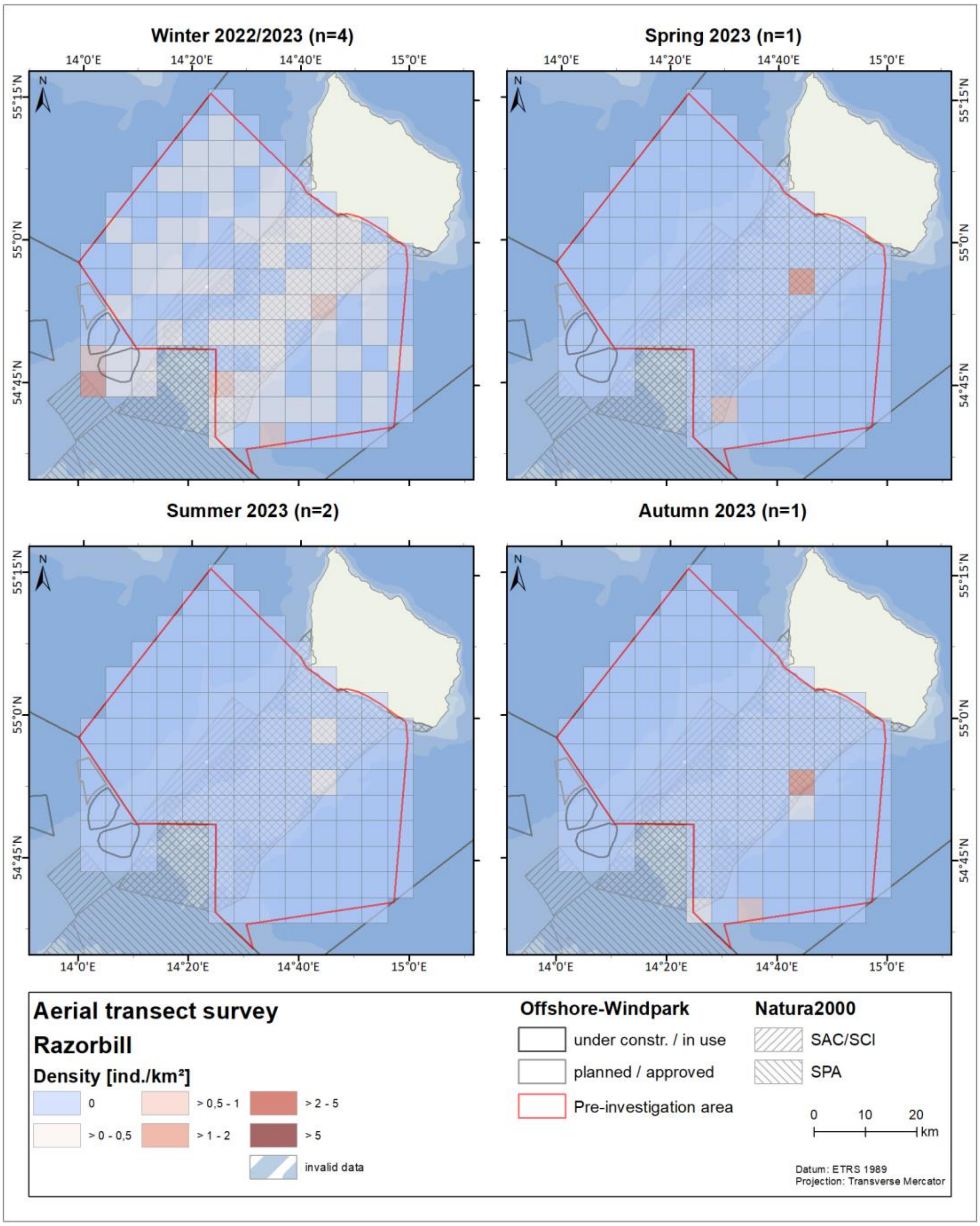

Figure 52. Distribution of razorbills in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

BLACK GUILLEMOT

Black guillemots were present in low numbers during both years (54 and 59 individuals), no individuals were recorded during summer (see Table 7). Their numbers generally increased during the wintering season, peaking in late winter/early spring. During the first study year, the maximum average monthly density was observed in March 2022 with 0.08 ind./km², whereas a maximum of 0.09 ind./km² was calculated in February 2023 in the second study year (see Figure 53).

Individuals were mainly located in the protected area in shallow waters, only few were observed in low densities in other regions during winter and autumn (see Figure 54 and Figure 55).

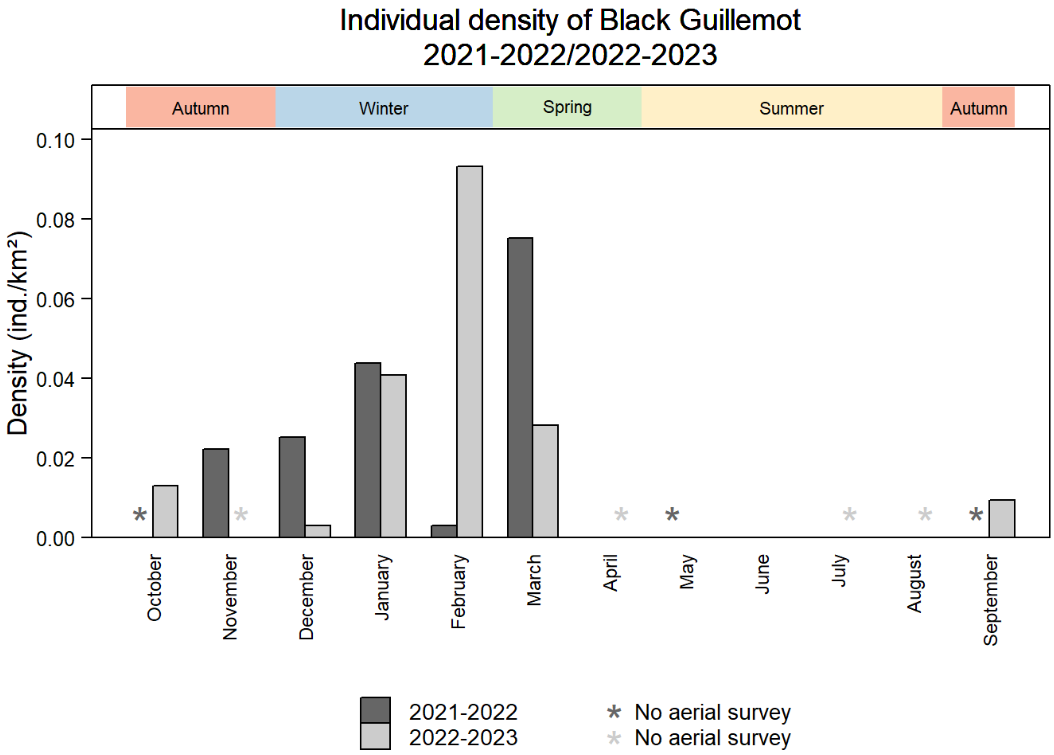

Figure 53. Monthly densities of black guillemots within the pre-investigation area given as individuals per km² calculated based on digital aerial surveys conducted between November 2021 and September 2023. Dark grey bars show results for the first survey year (October 2021 until September 2022). Light grey bars show results for the second survey period year (October 2022 until end of September 2023). Species specific seasons are given above according to Garthe et al. 2007.

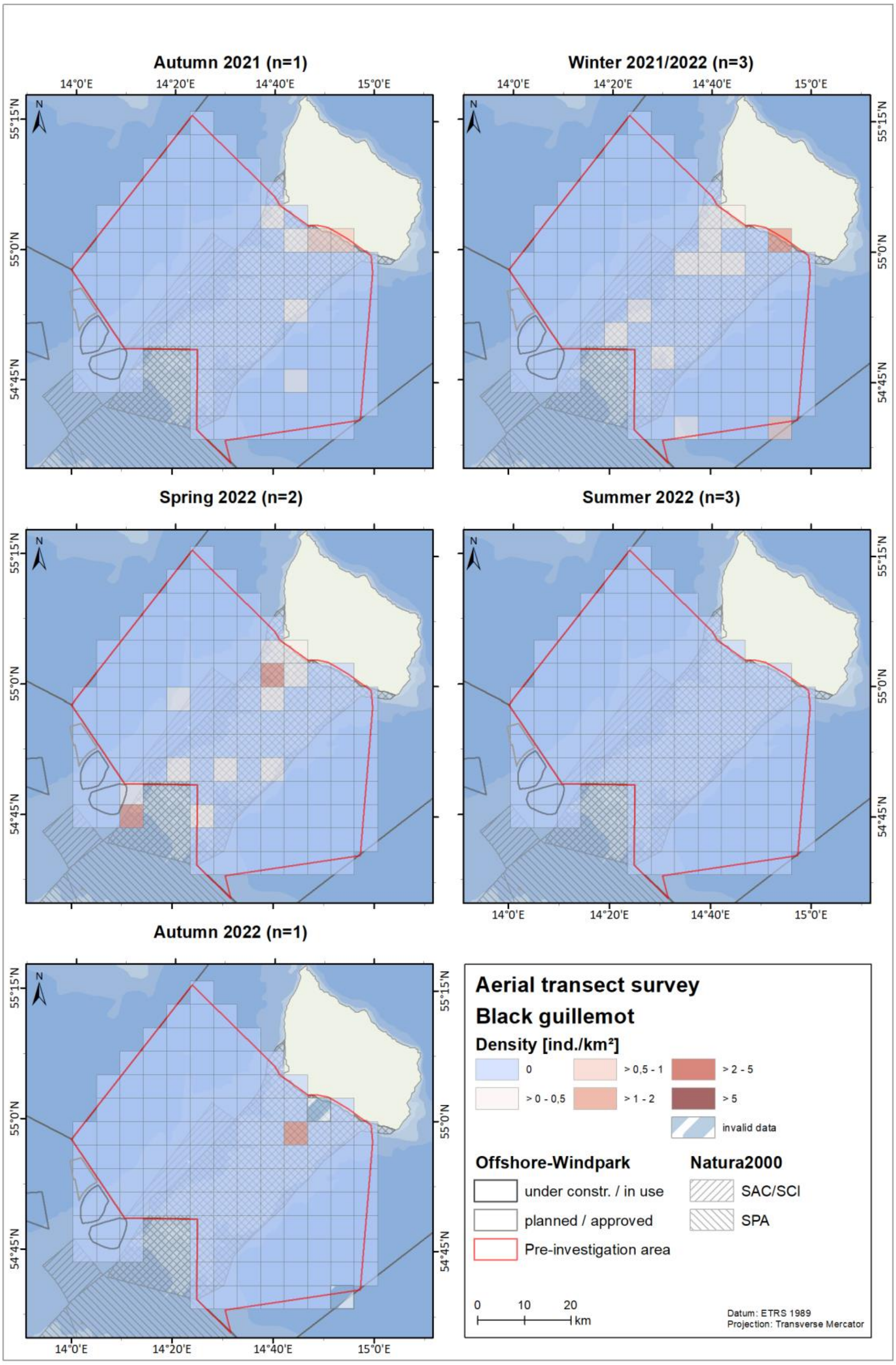

Figure 54. Distribution of black guillemots in the pre-investigation area per species specific season counted during digital aerial surveys in the first study year between autumn 2021 and autumn 2022 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

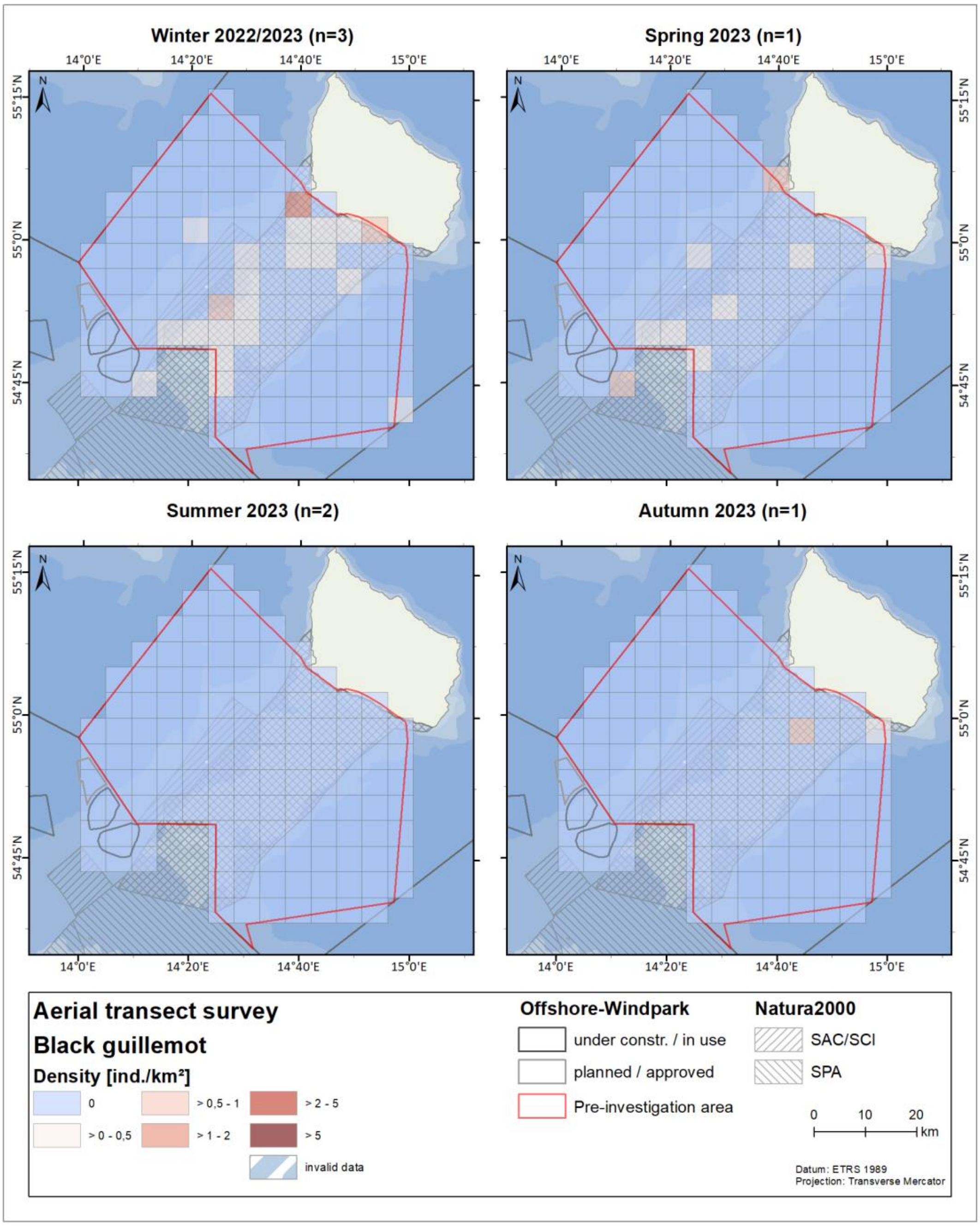

Figure 55. Distribution of black guillemots in the pre-investigation area per species specific season counted during digital aerial surveys in the second study year between winter 2022/2023 and autumn 2023 (species specific seasonal classification according to Garthe et al. 2007). The number of surveys is given as n.

POTENTIAL EFFECTS OF EXISTING OWFS ON THE BIRD DISTRIBUTION

Two operating OWF are located at the edge of the German -Danish border in the Baltic Sea and therefore in the direct neighbourhood of the pre-investigation area for Energy Island Bornholm. The construction of the OWF "Wikinger" started in March 2016 and all turbines were in operation by the end of 2017. The construction of the OWF "Arkona" located directly south of "Wikinger" started in August 2017 and is in operation since the end of 2018.

For several different seabird species, it is known that their distribution can be strongly influenced by the presence of offshore wind farms (e.g. Mendel et al. 2019, Peschko et al. 2024, Dierschke et al. 2016, Petersen et al. 2016, Vilela et al. 2020). One of the most sensitive species regarding the avoidance of OWF areas are red-throated divers. Various publications from the North Sea show an almost complete avoidance of OWF areas and significant avoidance radii of up to 10-15 km away from the OWF (Mendel et al. 2019, Heinänen et al. 2020, Vilela et al. 2021). Studies investigation the distribution of common guillemots in the North Sea showed that their numbers inside OWFs are significantly reduced compared to the baseline data gathered pre construction (Garthe et al. 2023, Peschko et al. 2024). Recent analysis by Peschko et al. (2024) report avoidance distances of even up to 19 km derived from cumulative impacts of several OWFs in the German North Sea.

Studies from Petersen et al. (2011) and Fox & Petersen (2019) have shown that the presence of OWFs can also lead to significant reductions in numbers of sea ducks in and around wind farms, even if the conclusion for these species is not entirely clear and sightings of larger numbers of sea ducks within OWF can occur regularly (Dierschke et al. 2016).

To check the possible impact of operating OWFs on the distribution of seabirds within the pre-investigation area, the transect design was adapted before the start of the survey and transect lines were expanded to cross the wind farm areas of “Arkona” and “Wikinger” during each regular survey (Figure 3). To receive a better picture of a possible effects the (effort-corrected) densities of birds within the OWF area and in 1 km wide buffer zones around the OWF up to a distance of 10 km were plotted. Additionally, the effort (area covered given in km²) is presented to see how reliable the density distribution is. Since the BSH published survey data from the monitoring programme for the OWF area O-1.3, data from 19 digital aerial surveys carried out between April 2016 and December 2017 could be included. This enabled the analysis of data before the start of construction at least for the OWF ‘Arkona’ and at least data before commissioning (albeit during the construction phase) for the OWF ‘Wikinger’. Thus, this period could be evaluated as a baseline phase relatively unaffected by operating OWFs. This baseline data was then compared (visually) with the data gathered for the present study.

Divers

Divers, which include red-throated and black-throated divers, were observed during the present study within the “Wikinger” OWF during two digital aerial surveys. A couple of individuals were observed in close proximity to both OWFs during three other surveys as well. These observations are remarkable as it is known for the North Sea that divers very rarely enter the inner area of an OWF (Vilela et al. 2021).

Overall, the mean densities in the present study within and up to 10 km from the OWF were about twice as high compared to the period 2016/2017. Even though the distribution of divers from the present study in relation to the distance to the OWF shows increasing densities from inside the OWF until 2-3 km distance (Figure 56), it cannot be concluded that this indicates an avoidance effect since reduced numbers of divers were sighted until the distance band 3-4 km during the baseline. Thus, it seems that the OFW area is no attractive place for divers anyway. Overall, the low densities do not allow a conclusive assessment, but a strong displacement effect as described for the North Sea cannot be recognised. An impact of the existing OWF on the large-scale distribution of divers in the pre-investigation area can at least be ruled out.

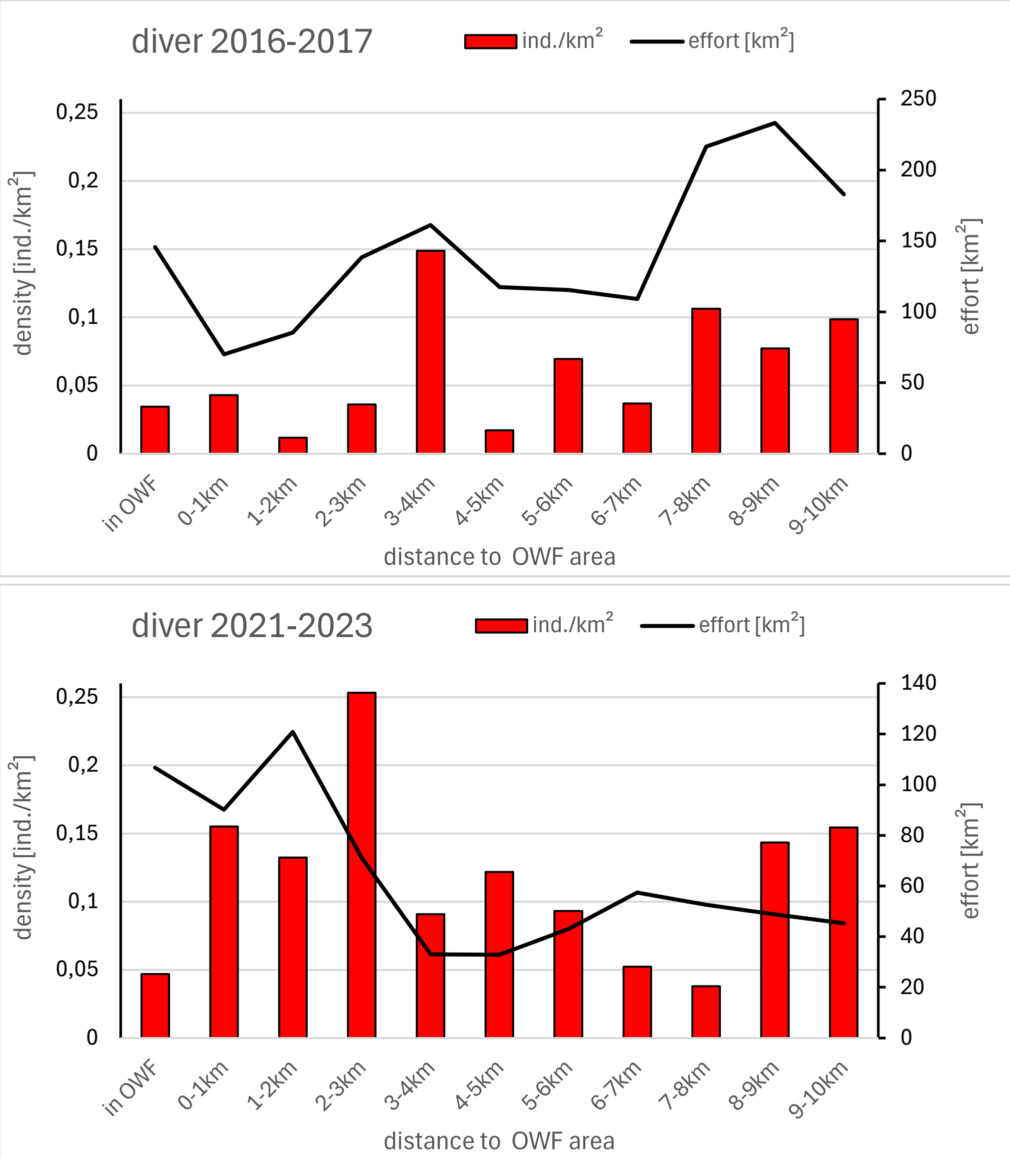

Figure 56. Diver distribution by buffer zones around the German OWFs "Arkona" and "Wikinger" during baseline/construction (2016/2017; data source: BSH 2020) and operation (2021-2023). Densities as ind./km² are given in relation to the effort given in km² within each buffer zone.

Long-tailed duck

During the 17 digital aerial surveys carried out during the present study, sightings of long-tailed ducks in or around the OWFs were only made during five surveys. A single long-tailed duck individual was observed within the "Arkona" OWF twice and a few long-tailed duck individuals were observed near both operating OWFs during three other flights (see Appendix).

The results of the comparison of densities of long-tailed ducks in different 1 km wide distance bands from 2016/2017 with the present study show that within 10 km around the two OWF the density of long-tailed ducks was very low. While the densities of long-tailed ducks sometimes reached >100 ind./km²) in the centre of the Rönnebank SPA, there were on average less than 2 ind./km² in the area up to 10 km around the OWF. Before the OWF "Arkona" was built, relatively low densities occurred in close vicinity to the OFW areas. During 2016/2017, 3.2 ind./km² were found inside the OWF area. Highest densities of 6.8 ind./km² occurred at 7-8 km distance to the OWF. During the present study long-tailed ducks were observed in densities >1 ind./km² at the distance class of 2-3 km and only a few birds were seen closer than 2 km to the OWF. Additionally, few birds were found further than 4 km away (Figure 57). Whether the reduced number of long-tailed ducks inside the OWF is caused by the operation of the two OWFs cannot be determined on the basis of the presented data. This pattern could also be based on natural distribution since long tailed ducks were absent at greater distances to the OWF and relatively scare in the area. Within the Kriegers Flak Offshore Wind Farm no clear and consistent sign of habitat displacement was detected (see chapter 2.4 Existing Data) and long-tailed ducks were also observed inside the existing OWF. Based on the observed distribution pattern (Figure 11), long-tailed ducks observed in the pre-investigation area seem to prefer the central parts located within the SPA Rønne Banke. The data from the present study cannot show any strong impact of the German OWF on the distribution of these birds within the pre-investigation site for Energy Island Bornholm. Whether this is due to a lower displacement distance (compared to the literature) or to the already low occurrence in the area of the OWFs cannot be assessed at this point.

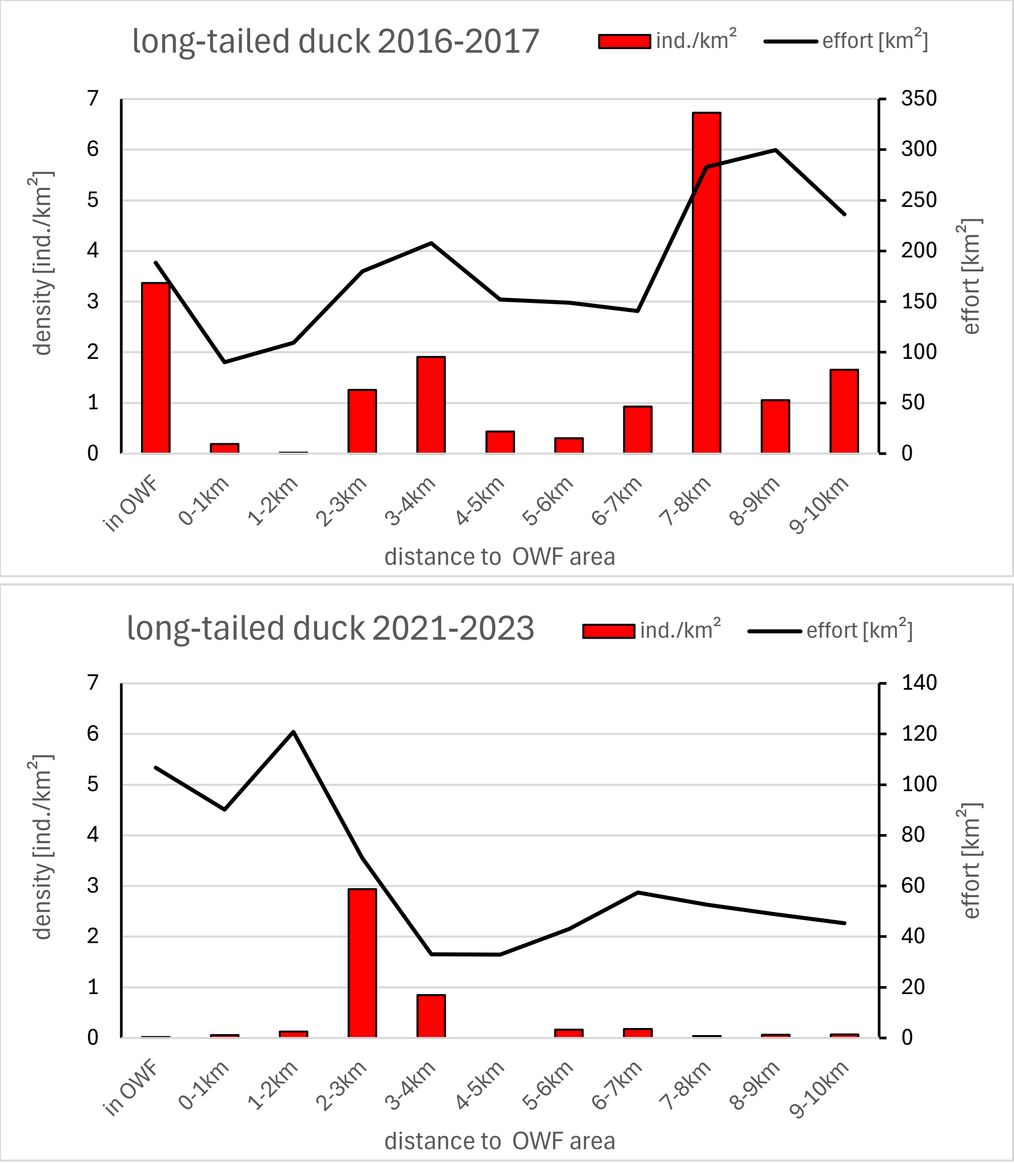

Figure 57. Long-tailed duck distribution by buffer zones around the German OWFs "Arkona" and "Wikinger" during baseline/construction (2016/2017; data source: BSH 2020) and operation (2021-2023). Densities as ind./km^2 are given in relation to the effort given in km^2 within each buffer zone.

Auks

The distribution maps of auks (which include common and black guillemots, as well as razorbills) show that despite a proven avoidance effect of OWF these birds are not completely displaced from the OWF area and were regularly observed both in “Arkona” and “Wikinger” during several digital aerial surveys. This observation confirms studies specifically investigating avoidance effects of auks towards OWFs (Peschko et al. 2024, Leopold et al. 2011, 2012).

The density distribution in different distance bands shows a clear gradient of increasing densities with distance to the OWF areas for both time periods (Figure 58). This pattern was more pronounced in 2016/2017 and the gradient extended up to a distance of 6 km to the OWF. In the current study, a maximum was already reached at a distance of 3 km. As the construction work for the OWF "Wikinger" was already underway in 2016/2017, it cannot be completely ruled out that this already triggered displacement effects. However, it is more likely that there is a natural gradient here, as the turbines for the OWF "Wikinger" were only installed in the second half of 2017 and were therefore only present in very few surveys. Nevertheless, the results show that an influence of the two existing OWFs on the distribution of guillemots in the pre-investigation area can be ruled out.

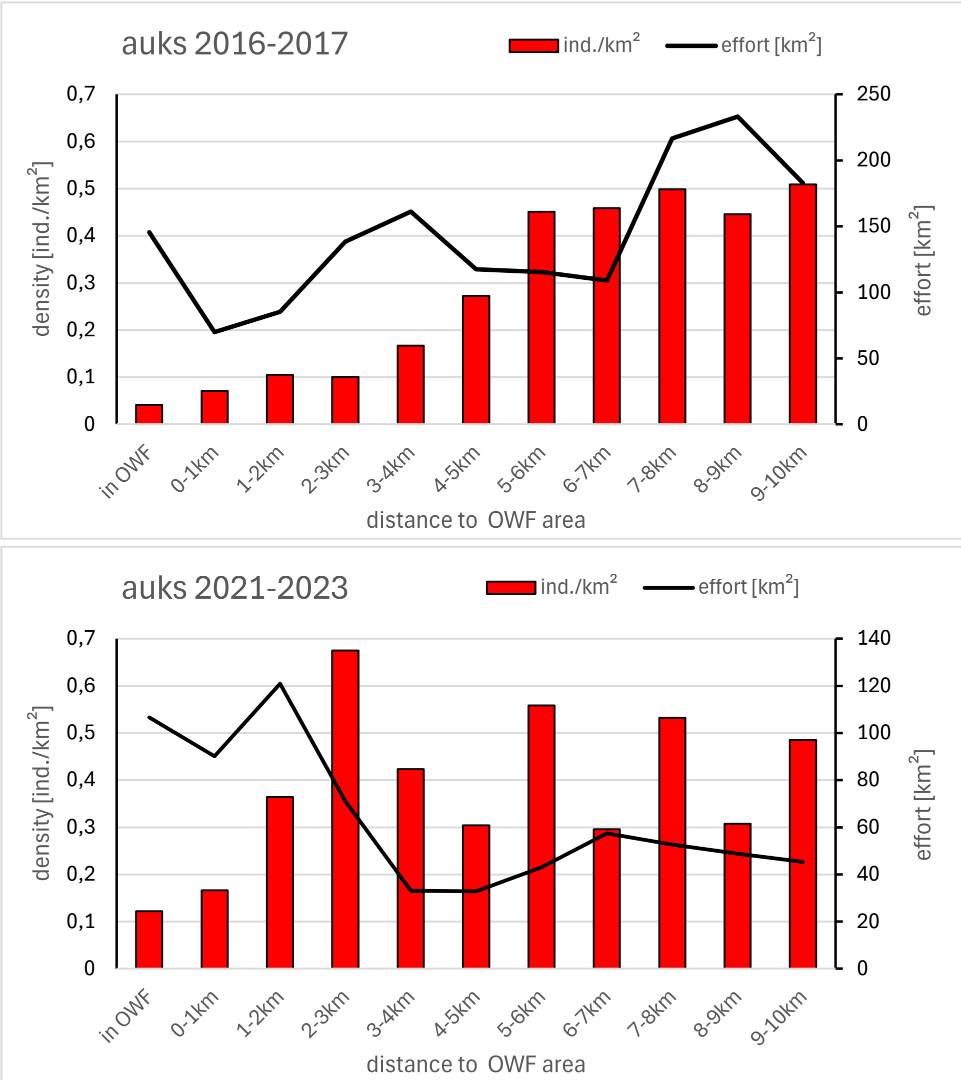

Figure 58. Auk distribution by buffer zone around the German OWFs "Arkona" and "Wikinger" during baseline/construction (2016/2017; data source: BSH 2020) and operation (2021-2023). Densities as ind./km² are given in relation to the effort given in km² within each buffer zone.

LONG-TAILED DUCK OBSERVATION SURVEYS

A total of 871 long-tailed ducks were observed during the vessel surveys. The highest number of individuals were observed in December 2021 (n=576), but considerable numbers were also recorded in January 2022 (n=295), see Table 10. The majority, 94 % of all observations of long-tailed ducks, were recorded in the morning during the first three hours after sunrise.

Table 10. Overview of specific observation dates, the total number of birds and the numbers recorded during the morning and afternoon, respectively.

Anchoring point	Date	Morning	Afternoon	Total
	December 2021	**539**	**37**	**576**
1 - West	07-12-2021	90	0	**90**
2 - West	09-12-2021	26	2	**28**
3 - West	10-12-2021	8	1	**9**
1 - East	13-12-2021	115	23	**138**
2 - East	12-12-2021	273	2	**275**
3 - East	11-12-2021	27	9	**36**
	January 2022	**280**	**15**	**295**
1 - West	25-01-2022	3	0	**3**
2 - West	09-01-2022	22	4	**26**
3 - West	06-01-2022	14	0	**14**
1 - East	24-01-2022	15	1	**16**
2 - East	08-01-2022	71	0	**71**
3 - East	07-01-2022	155	10	**165**
	Total (whole survey)	**819**	**52**	**871**

Overall, a higher proportion of birds were observed from the eastern anchoring points at the border of the project area Bornholm II during both surveys Figure 59).

In December 2021, the highest numbers of long-tailed ducks (275 individuals) were recorded from anchoring point ‘2 east’. In January 2022, the highest numbers (164 individuals) were observed from anchoring point ‘3 east’.

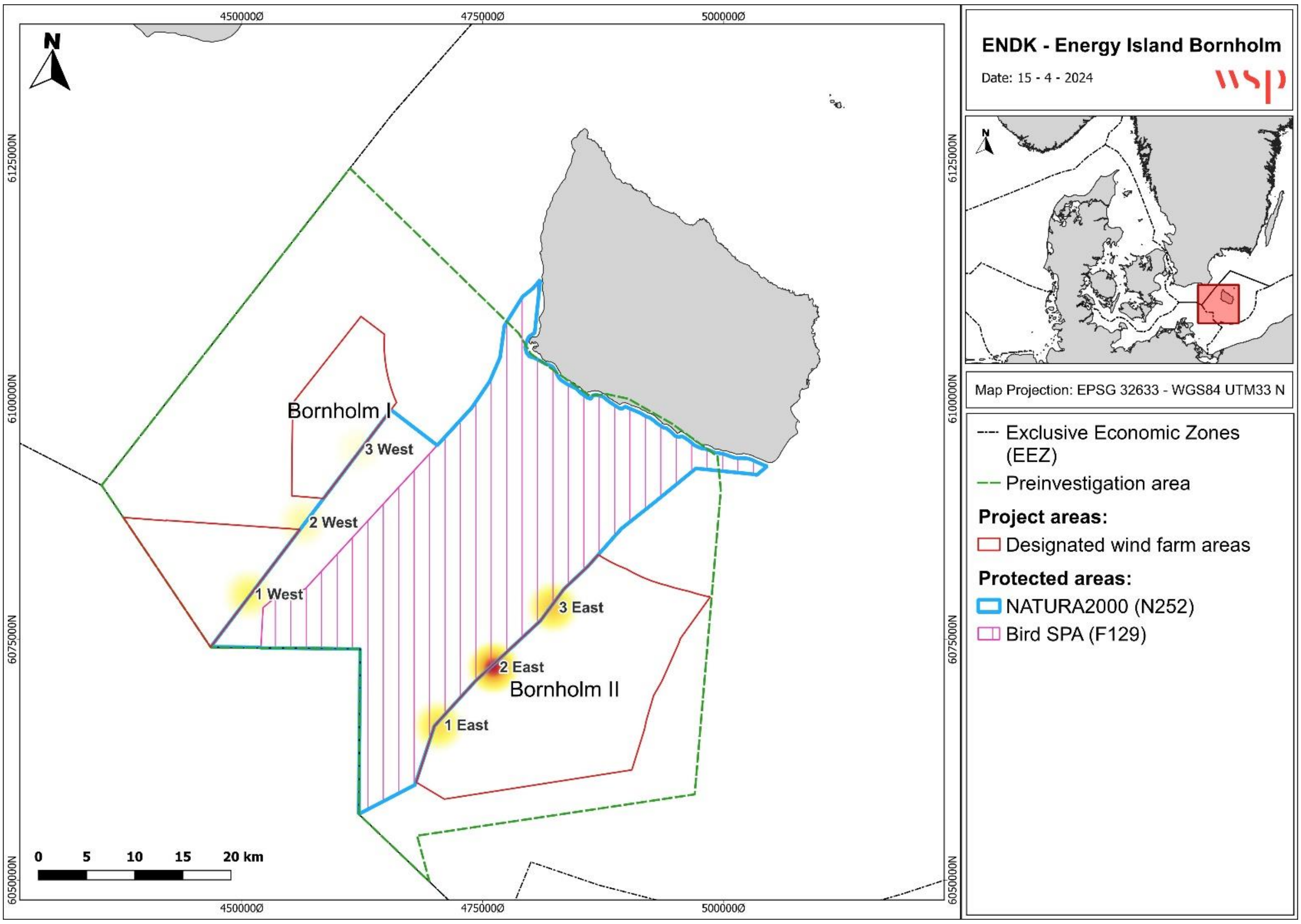

Figure 59. Overview of the intensity of observed bird movements at each of the six anchoring points illustrated by heatmap circles. A total of 871 individuals were counted during the surveys in December 2021 and January 2022.

The recorded flight directions of long-tailed ducks varied between the anchoring points as well as over the time of day. Some movement of long-tailed ducks into the bird SPA (F129) did occur, especially in the morning and most commonly from the eastern anchoring points, but overall, the observed movement patterns appeared slightly random.

In the morning, the direction of flight from the eastern anchoring points was mainly in directions between south and west (67 %), whereas directions were more diverse in the afternoon. A diverse pattern of flight directions was also evident from the western anchoring points but with some tendency of movements directly towards or directly away from the designated SPA area, especially in the morning.

TEMPORAL PATTERN

Movements of long-tailed ducks were recorded throughout the day as shown in Figure 60. However, most observations were recorded during the first hour after sunrise especially between 0745 – 0815 (UTC).

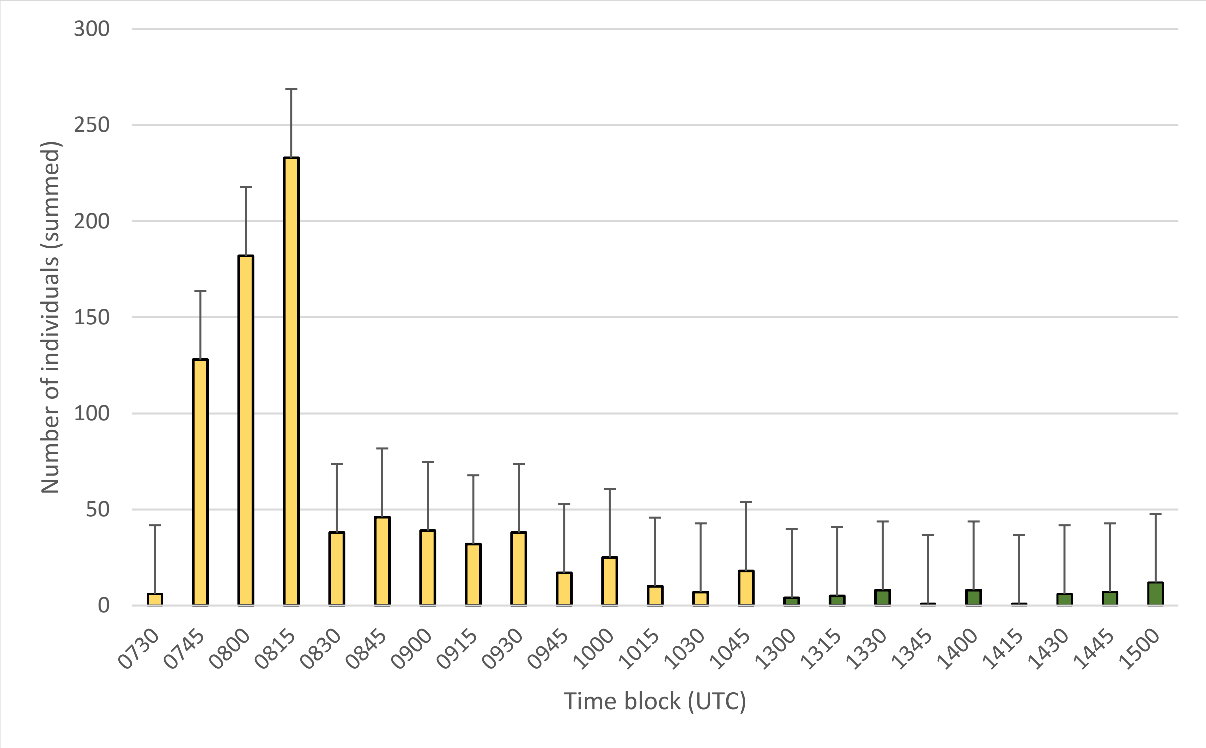

Figure 60. Observed movements of long-tailed ducks summed up for all anchoring points, during the vessel surveys in December 2021 and January 2022. The movements are displayed by the mean number of individuals on the y-axis (standard deviation =35.76) and the y-axis as a function of time in 15 minutes time blocks on the x-axis. Morning observations are displayed with yellow bars, whereas afternoon observations are displayed with green bars.

FLIGHT ALTITUDE

The recordings show that the majority of the observed long-tailed ducks flew in altitudes between 0 – 5 m above the sea surface, followed by the second largest proportion, that flew in an altitude of approximately 10 m. Some of the observed birds did however show higher altitudes, even up to 100 meters at the most. The recorded flight altitude distribution of long-tailed ducks is shown in Figure 61.

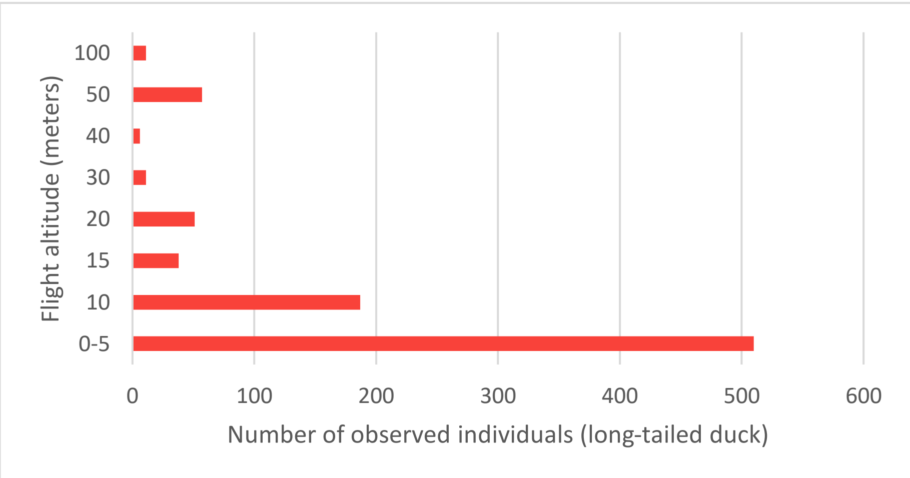

Figure 61. Recorded flight altitude distribution of long-tailed ducks based on visual assessments during vessel surveys in December 2021 and January 2022.

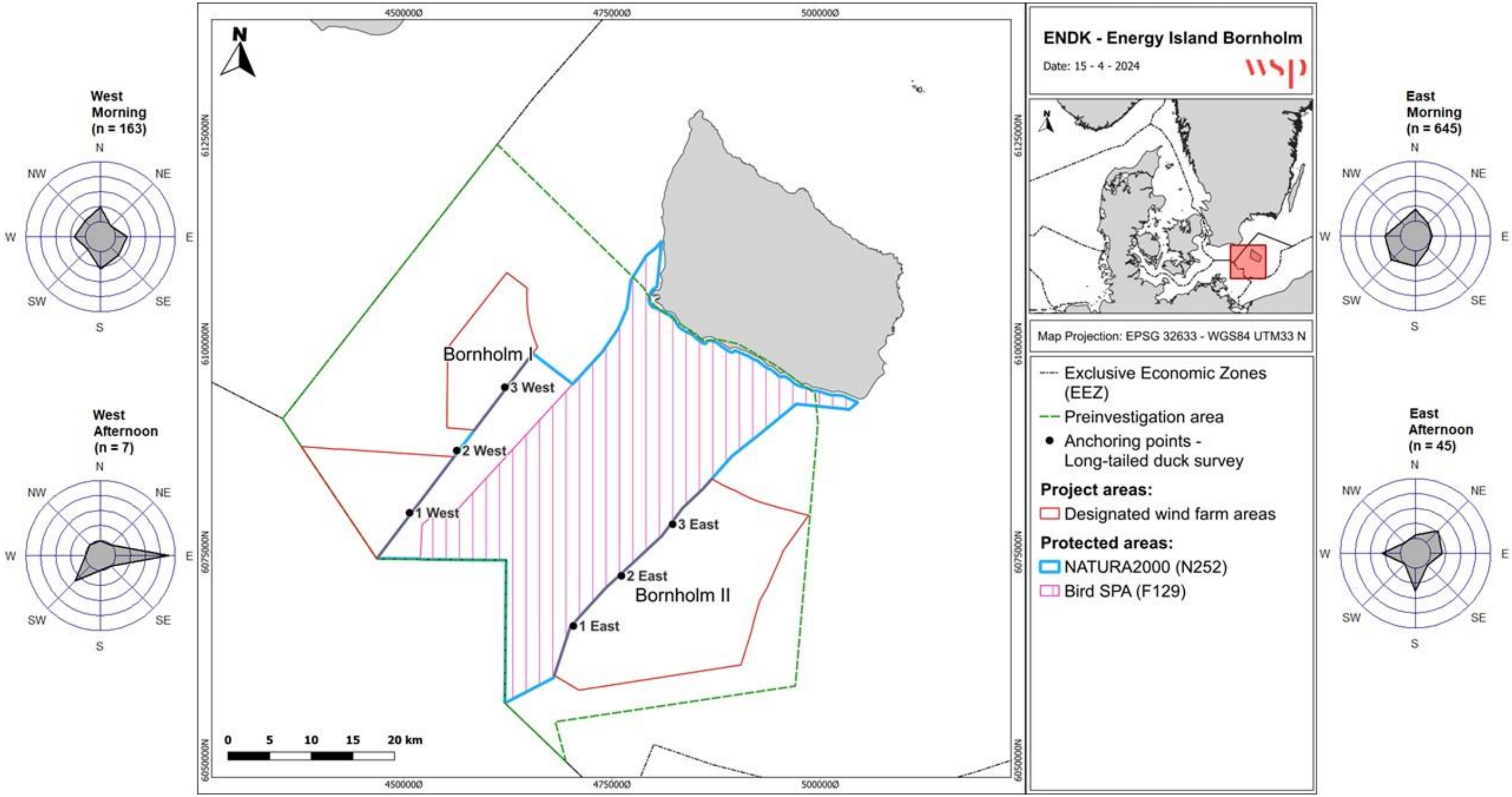

Figure 62. Flight directions of long-tailed ducks during the vessel surveys in December 2021 and January 2022. The relative proportion of flight directions (north, northeast, east, southeast, south, southwest, west, and northwest) at the western and eastern anchoring points, respectively, and during the morning and afternoon periods, is shown in separate radar plots.

5 CONCLUSIONS

In the two years of study between October 2021 and September 2023, during which 17 digital aerial surveys were conducted, 32,749 resting birds were detected. These birds belonged to 23 different species.

In both years, sea ducks comprised by far the most dominant group of the 23 resting bird species with long-tailed ducks representing 72.8 % of the total number of all individuals in each year. “Rønne Banke” situated southwest of Bornholm has been known for decades as an important staging ground for resting long-tailed ducks (Petersen et al. 2016). Therefore, it was designated as Natura 2000 site (SPA). Regular aerial surveys conducted by the Danish Center for Environment and Energy (DCE) have estimated a total of 18,000-30,000 wintering individuals on Rønne Banke (Petersen et al. 2016). Long-tailed ducks being the most common among all observed resting bird species confirmed these findings thus showing the importance of this area. In both years, their densities were higher in autumn and winter, decreasing in spring, and birds were entirely absent during summer.

High densities of long-tailed ducks (>100 ind./km²) were observed in shallow areas, including the special protection area in the centre of the pre-investigation area and close to the shore of Bornholm. During winter and spring, birds were generally spread across the entire pre-investigation area in lower densities with up to 5 ind./km². They were most often located above coarse substrate and muddy sand. These sediment types correspond closely with the presence of their preferred prey items. Long-tailed ducks are sea ducks that mainly feed on bivalves, crustaceans, bristle worms and snails (Madsen 1954).

A study conducted by Petersen et al. (2019) confirmed these results, showing that this species is a rather opportunistic feeder. (WSP 2023a) investigated the benthic communities in the pre-investigation area. They showed that the area had high abundances of blue mussels (*Mytilus edulis*) and some other bivalve species such as the Baltic tellin (*Limecola balthica*) and the Icelandic cyprine (*Artica islandica*). Especially blue mussels are usually occurring on hard substrates, sometimes forming large mussel banks. Also, smaller, mobile mussel “clumps” were found in the pre-investigation area. The study showed that the Natura 2000 area designated for long-tailed ducks had the highest abundance of food sources such as blue mussels, and less so in the planned wind farm area (Figure 13). Other sea duck species, such as the common and the velvet scoter also prefer bivalves as prey just as long-tailed ducks. The results of the digital aerial surveys confirmed data from the literature stating that velvet scoters are likely to occur in greater numbers compared to common scoters in the pre-investigation area. Both species were mainly observed in shallow areas within the SPA above sandy sediment (see Figure 33 to Figure 37 for reference).

To investigate potential impacts on the distribution of long-tailed ducks caused by OWFs, the aerial transect design was adapted to cover the operating wind farms “Arkona” and ”Wikinger”, which are located south-west of the pre-investigation area within the German EEZ. During five surveys, a few individuals were either observed within or near both OWFs. The large majority of birds were located within or around the SPA. These findings confirm the results of the environmental impact studies conducted prior, during and after construction of both wind parks (see e.g. BioConsult SH 2016, 2018; IfAÖ & BioConsult SH 2019).

These reports showed that the majority of long-tailed ducks was located within the SPAs” Westlich Rønnebank”, “Adlergrund” and the newly established “Rønne Banke”, as well as around both wind farms. Another report investigating the distribution of resting birds at the preliminary site O-1.3, which is located north of “Wikinger”, confirmed these observations as well (BioConsult SH et al. 2020a). While these findings cannot completely rule out an impact of operating offshore wind farms on the distribution of long-tailed ducks, the before mentioned results as well as the results of this report suggest, that the factor most likely to influence the distribution is the presence of available prey items. Nevertheless, other studies such as Petersen et al. (2011) and Fox & Petersen (2019) have shown that the presence of OWFs can lead to significant reductions in numbers in and around wind farms.

Gulls were the third most common species group observed during the surveys. Among these, herring gulls were the most common. During most surveys, they were spread widely across the entire pre-investigation area (see Figure 45 and Figure 46 for reference). They occurred throughout the year, but with higher densities during the winter with a maximum of 0.49 ind./km² in November 2021 and January 2022. Additionally, common gulls were also observed widely distributed across the pre-investigation area with highest densities of 0.22 ind./km² in December 2021 (see Figure 38 for reference). While no larger breeding colonies of common gulls exist close to the pre-investigation area, an important breeding colony of herring gulls is located on Ertholmene (Lyngs 1992, Bregnballe & Lyngs 2014). Therefore, it is not surprising that they were observed widespread and in higher numbers across the pre-investigation area.

That gulls in general are more often found in areas further offshore might not only be explained by their preferred prey items, which they mainly pick up from the water surface (e.g. Mendel et al. 2008). Many gull species are also known to follow fishing vessels to feed on discard (e.g. Camphuysen et al. 1995; Mendel et al. 2008; Garthe et al. 2016). While only limited fishing activity is happening within the SPA, higher levels of bottom and midwater trawling activities have been reported in the surrounding areas(Ramboll 2023)). Based on this information, it seems likely that the distribution of some gull species can at least partially be explained by the distribution of fishing vessels.

Red- and black-throated divers were expected in the pre-investigation area mainly during winter. Largest densities had been previously recorded for the Rønne Banke area (1-2 ind./km²) (Durinck et al. 1994, Skov et al. 2011). During the study years, the highest density of red-throated divers was 0.30 ind./km², whereas the highest densities for black-throated divers were 0.14 ind./km². Both peaks were observed in December. Higher densities of red-throated divers occurred in the shallower areas on “Rønne Banke”. Both species are listed under several categories of protection measures, as their numbers especially for the wintering populations have been decreasing.

Additionally, divers are very susceptible to anthropogenic impacts. Burger et al. (2019) showed strong avoidance behaviour of divers to approaching vessels with size and speed of vessel as important factors governing the impact distance. Fliessbach et al. (2019) state that red-throated divers displayed the longest escape distances to vessels and highest proportion of escaped individuals in their study, assigning this species a high disturbance index. Other studies from North Sea areas have shown that divers avoid offshore wind farms on a large scale revealing strong displacement up to a distance of more than 10 km (e.g. Mendel et al. 2019; Heinänen et al. 2020; Vilela et al. 2021; Garthe et al. 2023).

While the aerial survey data presented in this report does not provide a comprehensive basis to analyse potential effects of existing OWFs on the distribution of divers, the results nevertheless show no evidence for a strong avoidance behaviour as published from North Sea areas.

Surprisingly, a few individuals were even observed within or very close to the two operating wind farms. These observations suggest that the escape distances of divers from offshore wind farms may be area- and context-specific, and that the birds in the western Baltic Sea behave differently towards these structures. However, to find an answer to this question, projects specifically focused on this issue would have to be carried out in future.

Based on the finding that they are preferably located in shallower areas, it is to be assumed that their distribution is likely mainly driven by the availability of profitable prey resources. Red-throated divers residing in the Baltic Sea are known to feed primarily on pikeperch and herring (Guse et al. 2009). WSP (2023b) investigated the fish populations in the pre-investigation area. According to their findings, the Atlantic herring (*Clupea harengus*) and other potential prey species were present across most of the pre-investigation area. This is in line with the wide distribution of divers over the whole pre-investigation area with a slightly higher concentration inside the SPA Rønne Banke.

Auks (common guillemots, razorbills, and less frequently black guillemots) were the second most common species group. Two species were very common (common guillemot and razorbills), but black guillemots are also worth mentioning, as Rønne Banke is an important resting area for this species, whose numbers have been declining in the recent years. Important breeding colonies of the two fish-eating auks, common guillemot and razorbills, are located close the pre-investigation area on two small islands west of Gotland and on the archipelago Ertholmene. Razorbills also breed along the coast of Bornholm at Hammershus (Moshøj & Vikstrøm 2020) thus, mid-densities of these species are to be expected in the area, especially at offshore locations. The maximum density of common guillemots was 0.8 ind./km² in November 2021, whereas the maximum density of razorbills also occurred in the same month with 0.51 ind./km². Both species were widely spread over the whole pre-investigation area with some higher densities outside the SPA in the northwest and southeast of the pre-investigation area.

Black guillemots occurred at much lower densities (max of 0.09 ind./km² in February 2023) and concentrated at the shallower Rønne Banke area. Analysing auk distribution in the pre-investigation area in relation to sediment type did not reveal a clear preference for a certain substrate. The same is true for their distribution in relation to certain water depths, as individuals were observed in shallow as well as in deep waters. While most observed individuals were spread across the entire pre-investigation area, a few individuals were observed within the operating wind farms "Arkona" and "Wikinger" during several aerial surveys. For common guillemots in the North Sea, it has been shown that the presence of offshore wind farms can have strong negative effects on their distribution with individuals displaying noticeable avoidance behaviour (e.g. Peschko et al. 2020, 2024). Nevertheless, single individuals still enter those areas, and it is yet to be determined, which effect this might have on a population level. From the distribution pattern observed here, no evidence for a strong impact of the existing wind farms can be detected. Based on the fish species most commonly present in the pre-investigation area (WSP 2023b) , it can be assumed that the factor mainly influencing auk distribution is the availability of profitable prey resources. Both common guillemots and razorbills preferably feed on herring, sand eels, sprat and cod among others (e.g., Leopold et al. 1992; Benvenuti et al. 2001; Lyngs 2001; Engvall et al. 2023).

While great cormorants were observed in the pre-investigation areas, their numbers were low with a total of only 106 individuals counted in both survey years. Most of them were observed in shallow areas within the SPA. Around 27,000 breeding pairs were found in Denmark in 2012 (Herrmann et al. 2014), but great cormorants generally are mostly associated with coastal habitats and rarely found further offshore. Therefore, it is not surprising that only a few individuals were recorded during the surveys. Nevertheless, cormorants have been reported to be attracted by offshore structures, such as offshore wind farms, as they use these as potential resting sites or even foraging grounds (Dierschke et al. 2016).

Similar to cormorants, grebes were found in low densities as well with their observed numbers being even lower (see. Table 7 for reference). While 3,500-4,000 pairs of great-crested grebes breed in Denmark (Meltofte 1996), they prefer shallow coastal areas or lakes. Thus, they were not expected to occur in noticeable densities in the pre-investigation area. These findings are supported by a study conducted by BioConsult SH et al. (2020a), which investigated the area west of the pre-investigation area. They also reported small numbers of grebes being present in the area.

Based on total numbers, estimated densities and the spatial distribution of the long-tailed duck observations found in this study, there seems to be no clear and consistent sign of habitat displacement caused by the Kriegers Flak Offshore Wind Farm. The pronounced preference for the western pre-investigation area suggests specific habitat characteristics that are particularly favourable to long-tailed ducks during the winter months, such as shallow waters ideal for foraging.

Even though the Western area (A1), west of the offshore wind farm, had the highest numbers of long-tailed ducks overall, it is worth noting that the greatest count on any of the four surveys was recorded inside the wind farm array (A2). In conclusion, the post-construction monitoring of distribution patterns of long-tailed ducks provide valuable insights into the dynamics of resting birds during the operation phase of the Kriegers Flak wind farm. The findings show an expected increase in density over the three winter months, highlighting the significance of the area west of the wind farm as preferred habitat due to favourable foraging conditions WSP (2023b).

During the long-tailed duck observation surveys in December 2021 and January 2022, a total of 871 long-tailed ducks were observed and their flight directions were recorded from the three western and three eastern anchoring points.

The majority, 94 % of all long-tailed duck observations, were recorded during the early morning within the first three hours after sunrise, even though movements occurred throughout the day. The recordings showed that long-tailed ducks tend to fly at very low altitudes, typically between 0 – 5 m above the sea surface, but higher flight altitudes were also observed, although they were relatively few.

Overall, a higher proportion of birds were observed from the eastern anchoring points at the border of the planned wind farm area Bornholm II during both surveys. In general, the majority of the observed long-tailed ducks showed a diverse movement pattern, but with some tendency of morning flights towards the designated SPA, F129, especially from the eastern anchoring points.

Given that most of the long-tailed ducks were recorded from the eastern anchoring points in the morning, and that their direction of flight was in all other directions than east, could mean that long-tailed ducks utilize planned wind farm area Bornholm II during the night and fly back into the SPA, F129 around sunrise.

Although there is some indication that some long-tailed ducks may utilize the operating wind farm areas for foraging during the night, the observed numbers are small compared to the total size of the wintering population of long-tailed ducks in the area, as revealed by the HighDef digital surveys. The occurrence within the planned wind farm areas for nocturnal foraging by long-tailed ducks wintering within the designated SPA F129 is likely rather limited.

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7 APPENDIX PART A RESTING BIRDS

DISTRIBUTION OF SEABIRDS IN THE PRE-INVESTIGATION AREA, INCLUDING EXISTING GERMAN OWFS

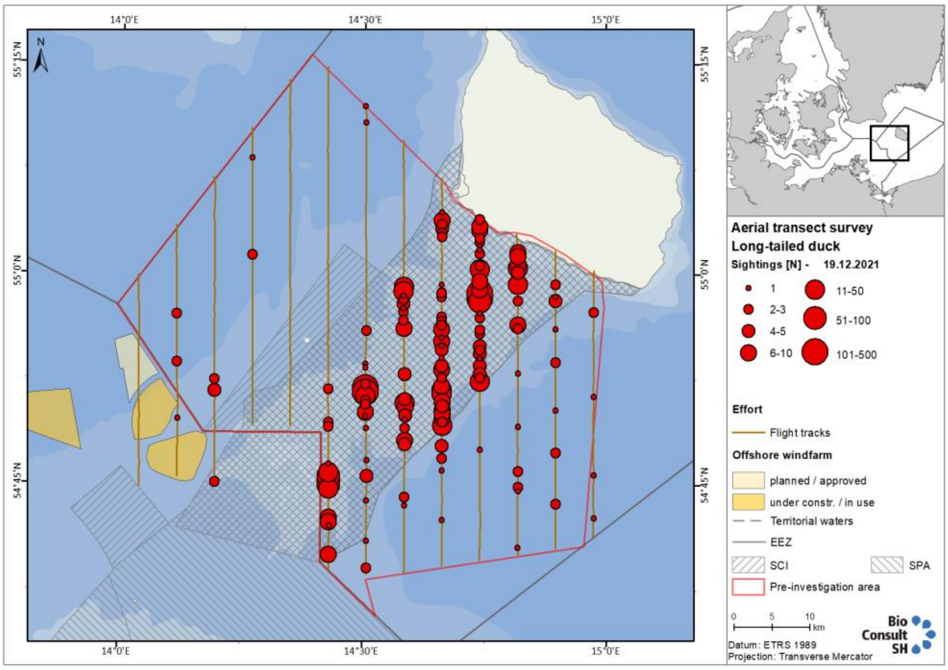


Figure 63. Long-tailed duck distribution in the pre-investigation area counted during the digital aerial survey on 19.12.2021. Counts are given as absolute numbers.

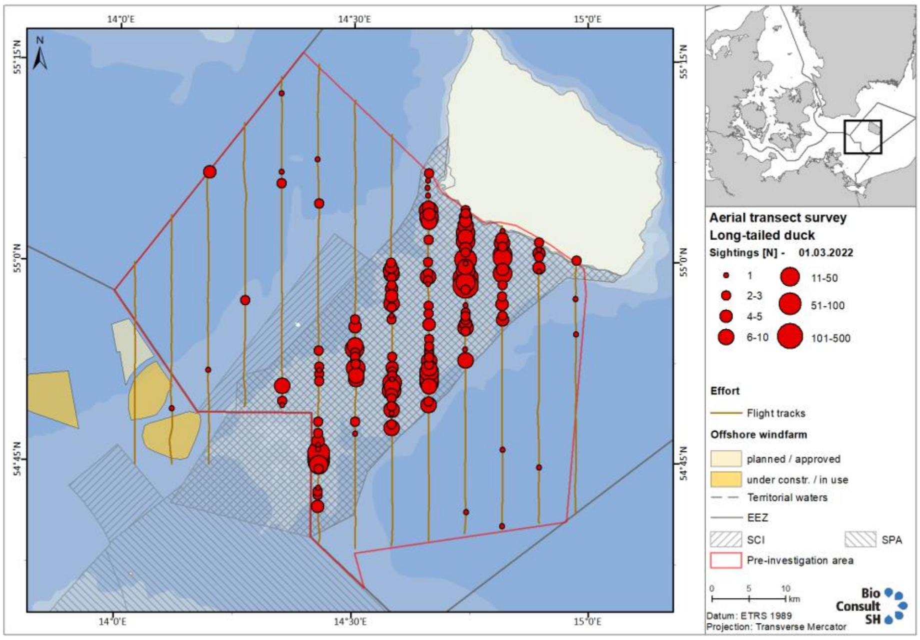


Figure 64. Long-tailed duck distribution in the pre-investigation area counted during the digital aerial survey on 01.03.2022. Counts are given as absolute numbers.

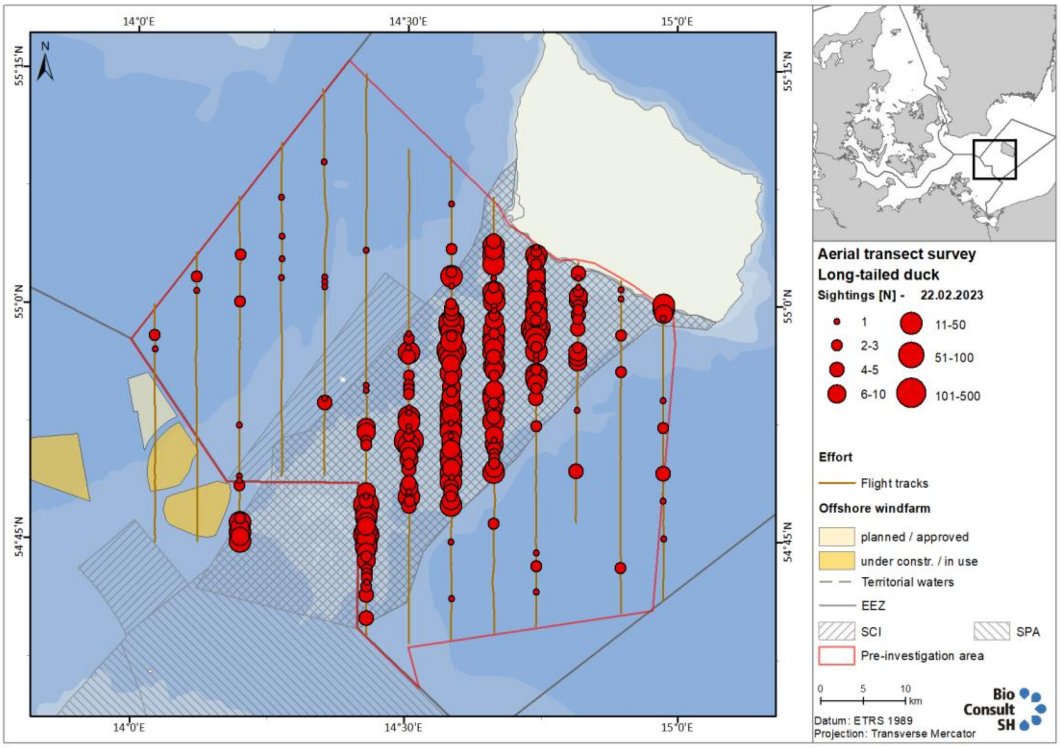


Figure 65. Long-tailed duck distribution in the pre-investigation area counted during the digital aerial survey on 22.02.2023. Counts are given as absolute numbers.

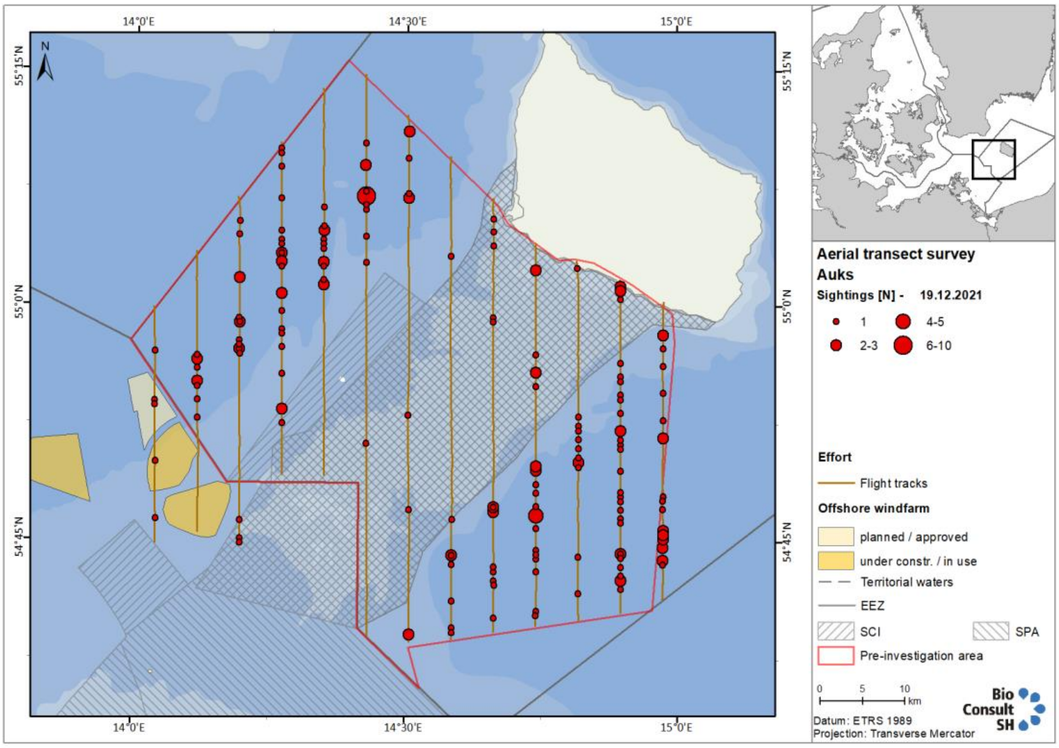


Figure 66. Auk distribution in the pre-investigation area counted during the digital aerial survey on 19.12.2021. Counts are given as absolute numbers.

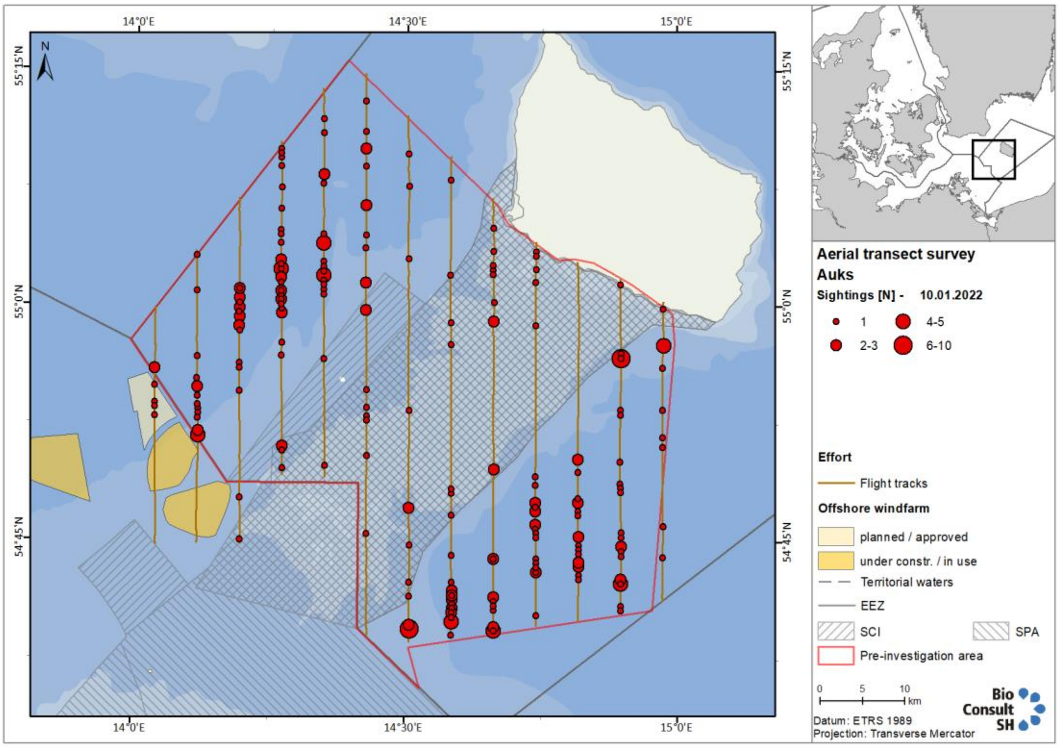


Figure 67. Auk distribution in the pre-investigation area counted during the digital aerial survey on 19.01.2022. Counts are given as absolute numbers.

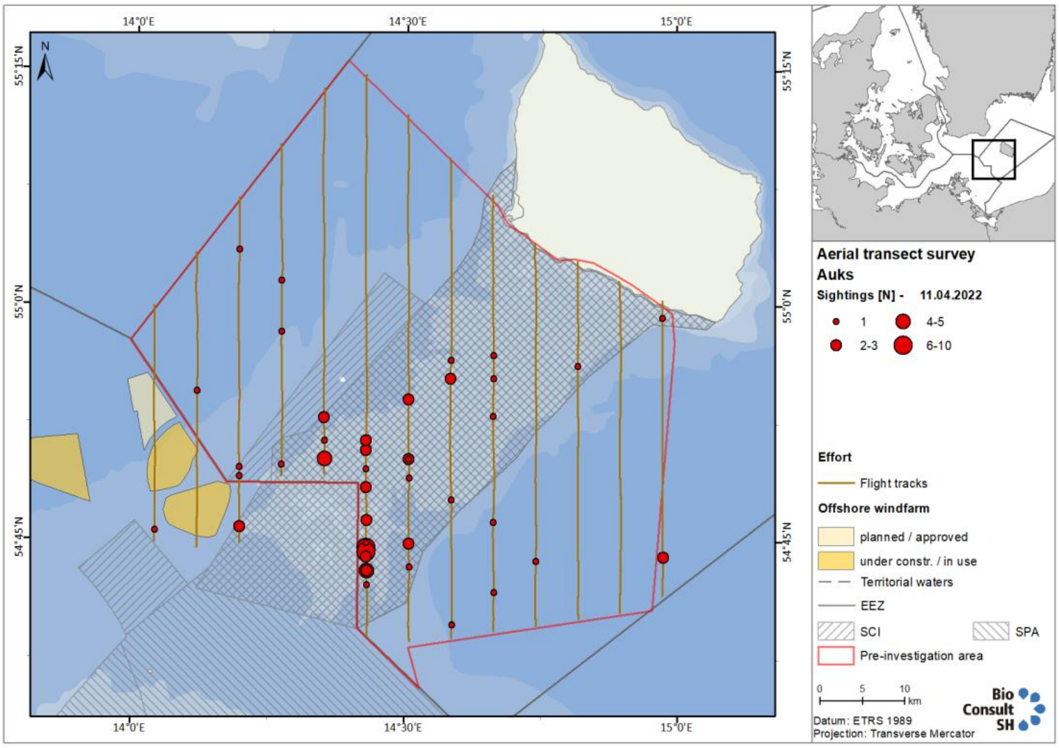


Figure 68. Auk distribution in the pre-investigation area counted during the digital aerial survey on 11.04.2022. Counts are given as absolute numbers.

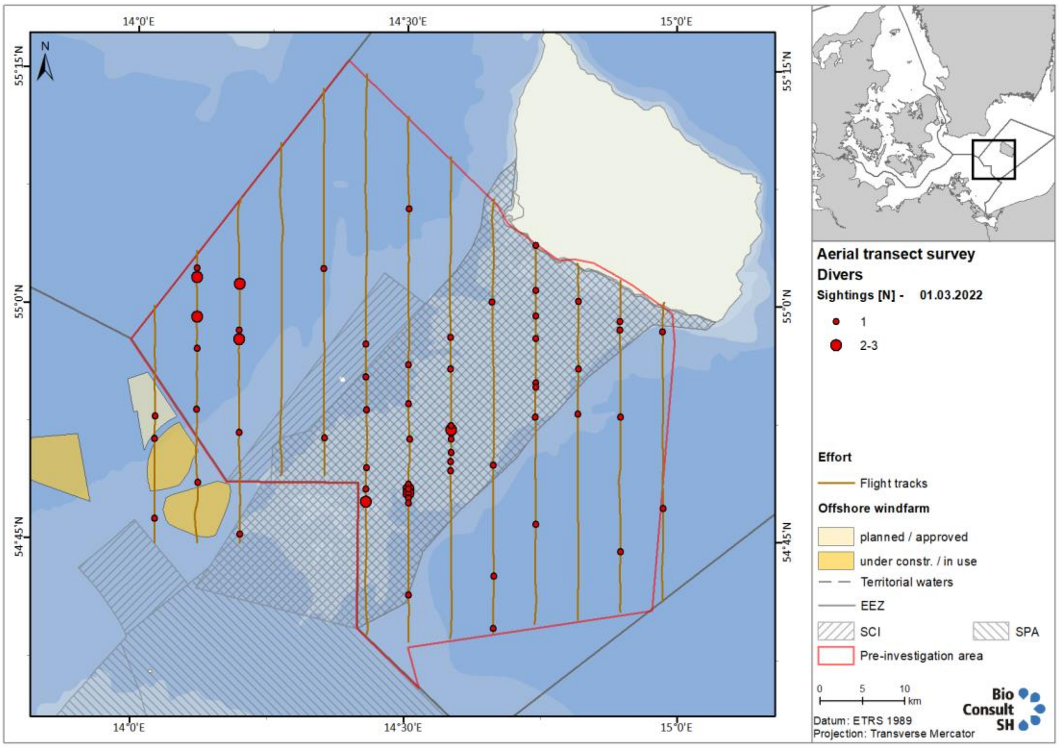


Figure 69. Diver distribution in the pre-investigation area counted during the digital aerial survey on 01.03.2023. Counts are given as absolute numbers.

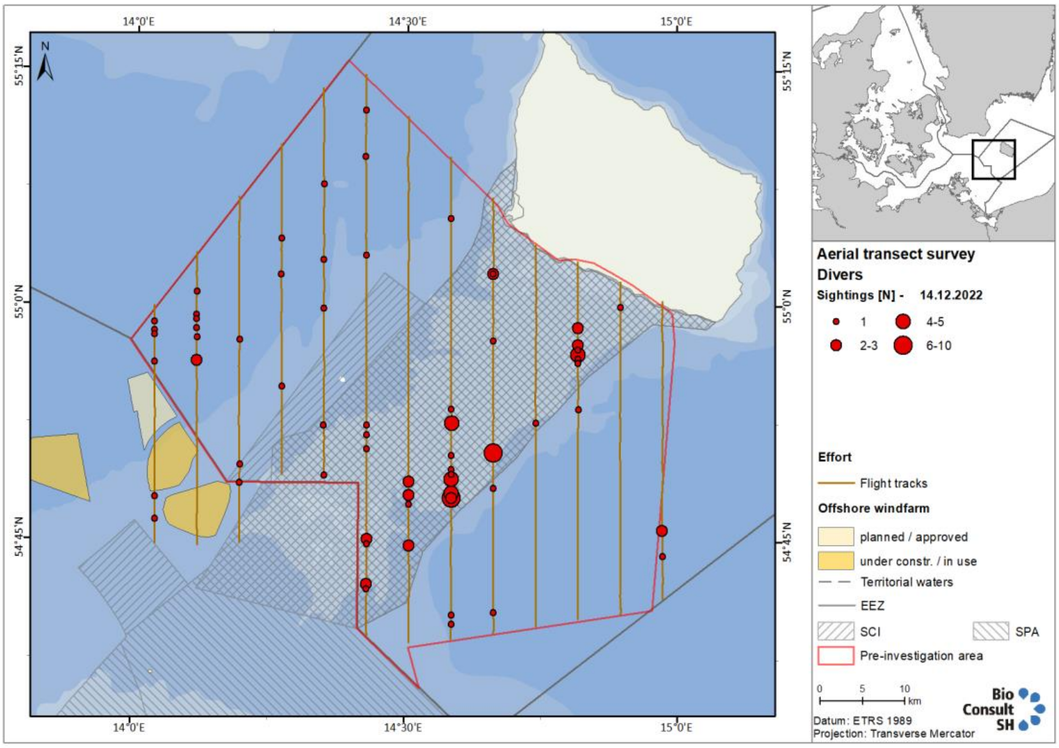


Figure 70. Diver distribution in the pre-investigation area counted during the digital aerial survey on 14.12.2022. Counts are given as absolute numbers.

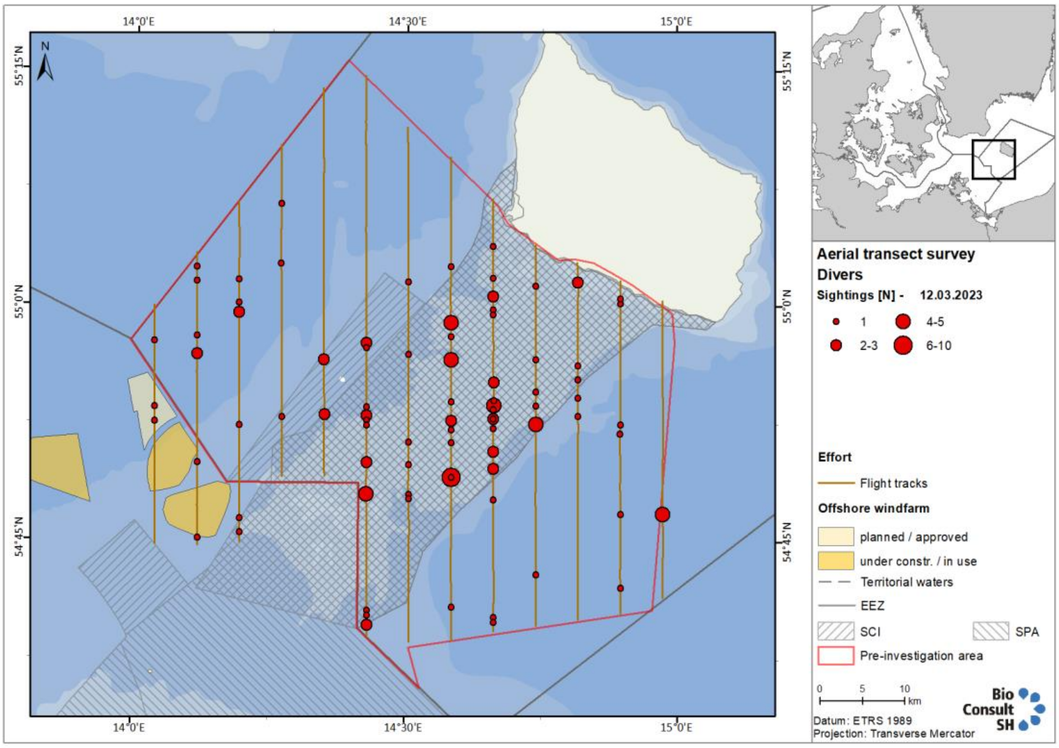


Figure 71. Diver distribution in the pre-investigation area counted during the digital aerial survey on 12.03.2023. Counts are given as absolute numbers.

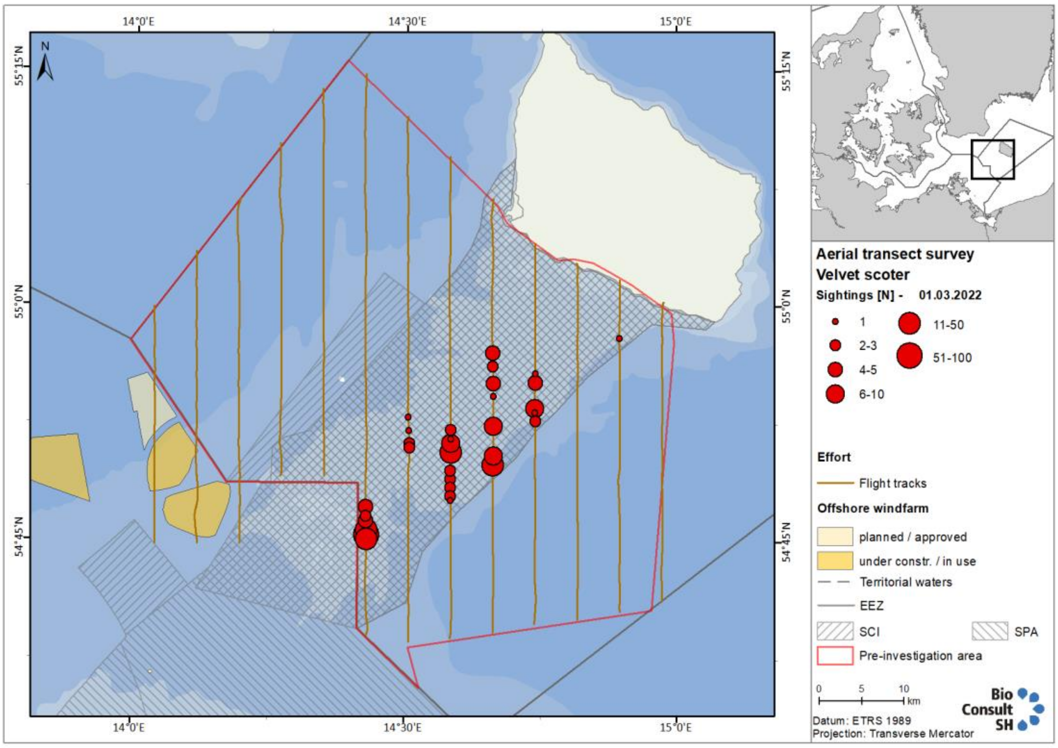


Figure 72. Velvet scoter distribution in the pre-investigation area counted during the digital aerial survey on 01.03.2022. Counts are given as absolute numbers.

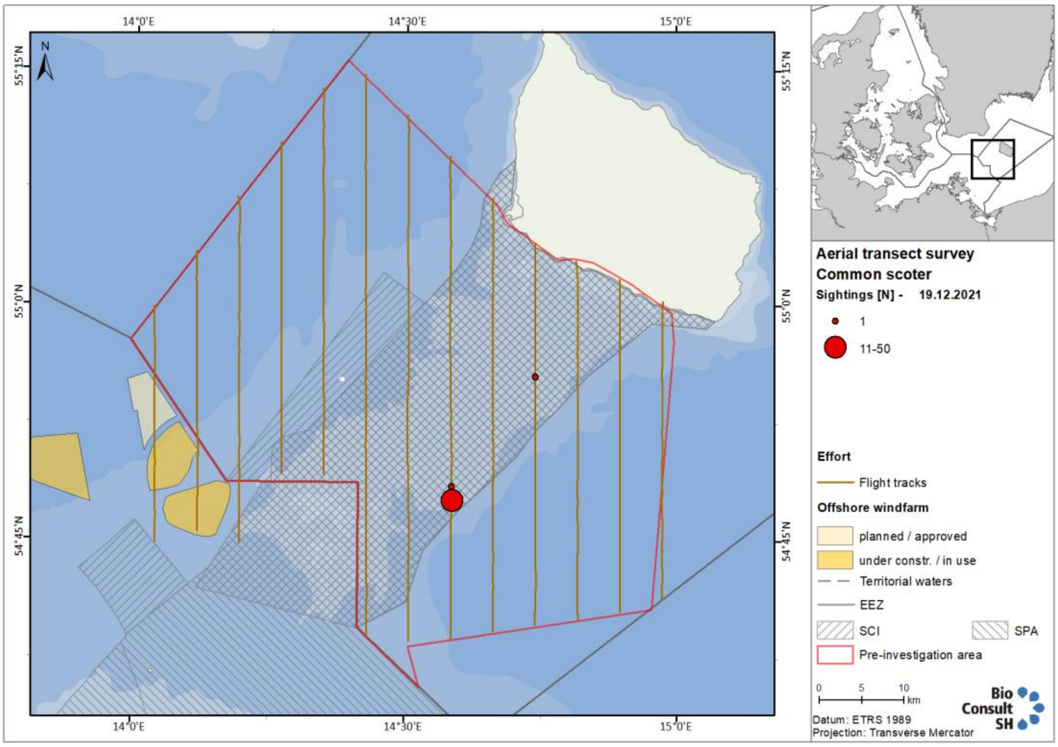


Figure 73. Common scoter distribution in the pre-investigation area counted during the digital aerial survey on 19.12.2021. Counts are given as absolute numbers.

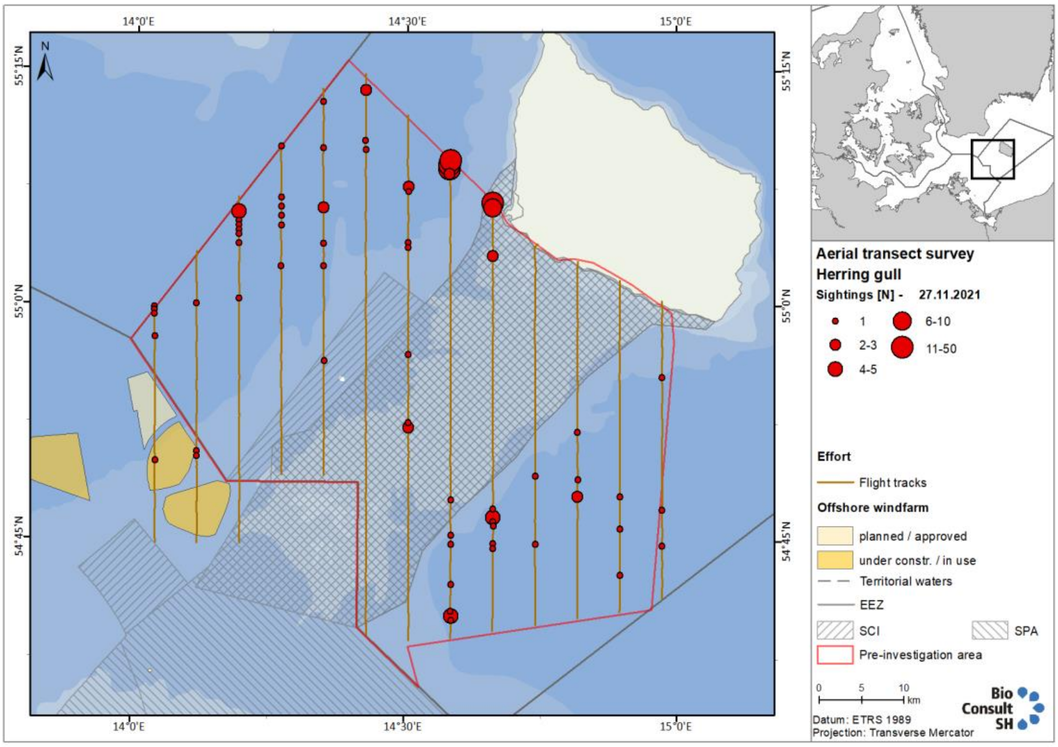


Figure 74. Herring gull distribution in the pre-investigation area counted during the digital aerial survey on 27.11.2021. Counts are given as absolute numbers.

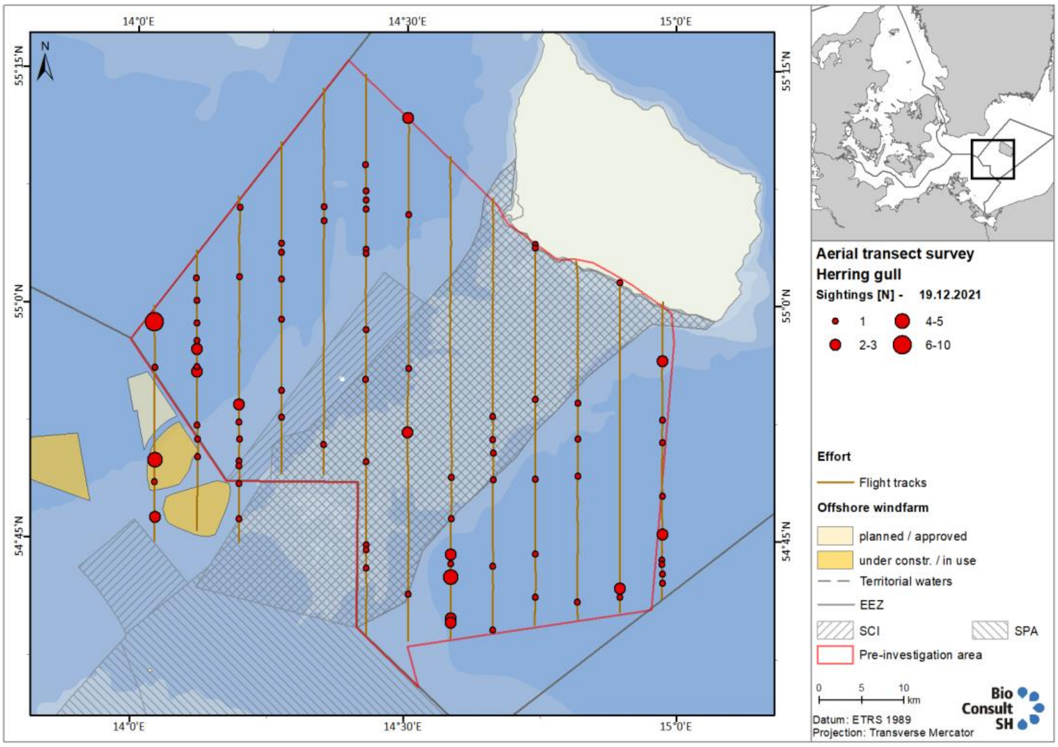


Figure 75. Herring gull distribution in the pre-investigation area counted during the digital aerial survey on 19.12.2021. Counts are given as absolute numbers.

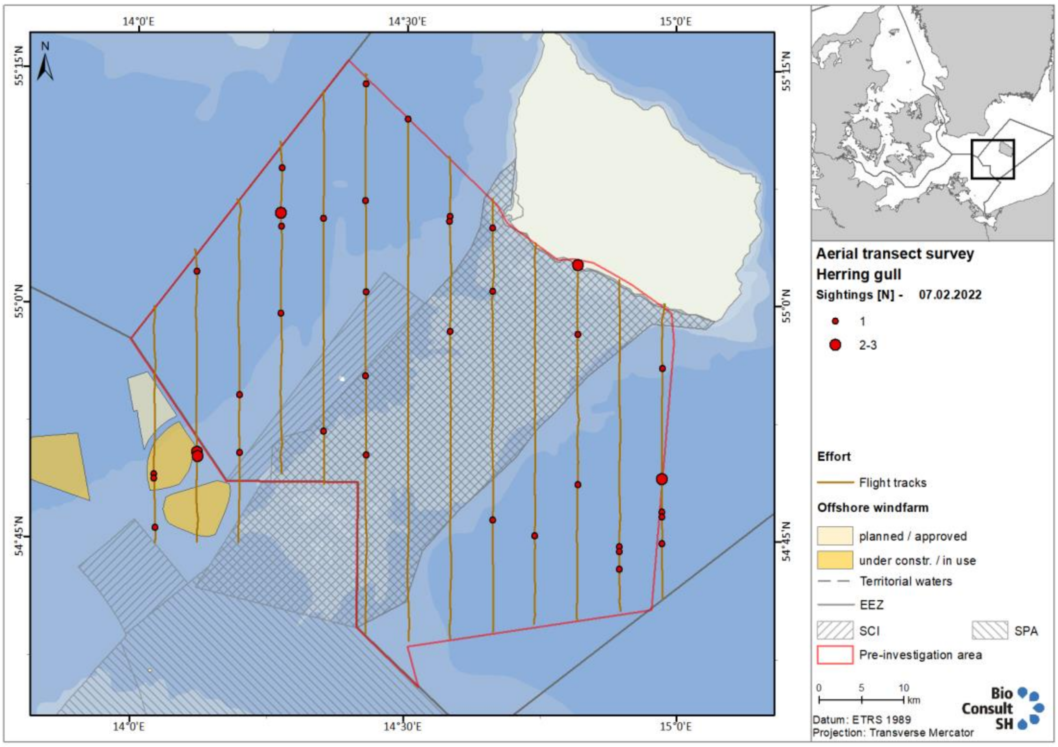


Figure 76. Herring gull distribution in the pre-investigation area counted during the digital aerial survey on 07.02.2022. Counts are given as absolute numbers.

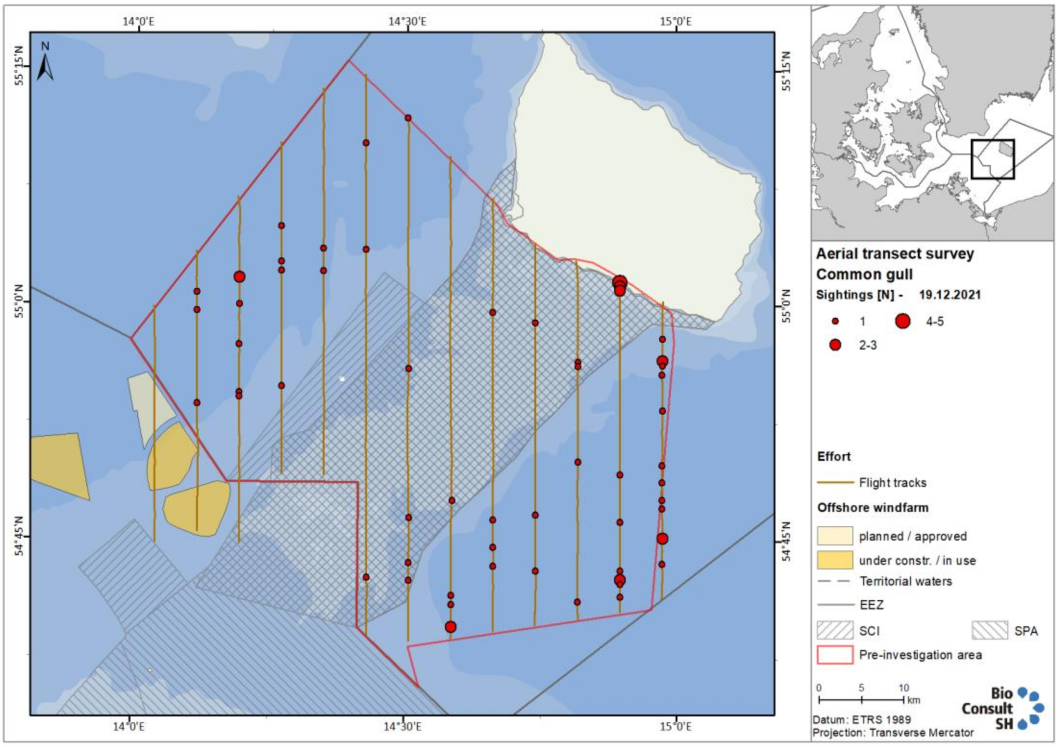


Figure 77. Common gull distribution in the pre-investigation area counted during the digital aerial survey on 19.12.2021. Counts are given as absolute numbers.

PART B

MIGRATING BIRDS

1 SUMMARY

1.1 INTRODUCTION

Migrating birds alternate between breeding and non-breeding regions. They can travel over long distances twice a year. Although this is a regular, annually recurring phenomenon, the magnitude of migration can vary strongly from year to year and is subject to great variability. The distance covered during migration varies among species as well, some migrate over long distances of several 100 or 1,000 km, others travel short distances of only a few dozen kilometres. Among some species, only parts of the population migrate while the rest resides in their main areas of distribution.

In addition to classic migratory birds that cross the pre-investigation area on their migration route between breeding and wintering areas, this report also considers all bird species that cross the pre-investigation area in flight on their way between different resting and feeding areas. The majority of these birds are seabirds, which are analysed in terms of their distribution at sea in Part A Resting birds. Since these birds are strongly dependent on the existing resources of the areas they remain in, their abundance and presence are closely correlated with the presence/proximity of suitable (feeding and resting/wintering) habitats. Three important shallow sandbanks are found inside or close to the pre-investigation area: Rønne Banke, Adlergrund and Odra Bank. Further south of the pre-investigation area within the German EEZ lies the SPA Pomeranian Bay (no. 1552-401), which is also a Natura 2000 site with a size of approximately 200,000 ha. Rønne Banke is characterized by its shallow waters (5-20 meters of depth). Since these banks are often covered by mussels, they provide important habitats especially for sea ducks such as common and velvet scoters, common eiders and long-tailed ducks (Käppeler et al. 2012).

Accordingly, only flying birds are considered in this report and analysed with regard to their flight direction, flight altitude and migration intensity.

1.2 METHODOLOGY

Studying bird migration requires a combination of different methods to be able to gather information on different taxa as well as diurnal and nocturnal migration, flight directions and flight altitudes. Horizontal and vertical radar surveys were applied to collect information on species composition, phenology, flight altitudes and directions. Flight altitudes were also measured via a laser rangefinder. To measure migration intensity, as well as altitudinal distribution, visual observations were conducted. For identification of birds and counting numbers, observers equipped with binoculars and spotting scopes were deployed. Additionally, weather radars were utilised to detect birds and thus provide information on migration intensity, as well.

Between September of 2021 and November of 2023, a total of 42 surveys were conducted at three land-based and one offshore radar location to observe migrating birds. These surveys included two days of vessel-based surveys per month during the migration period (spring and autumn, respectively), with anchoring for two days southwest of Bornholm between the planned future wind farm areas inside the protected Natura 2000 area. Land-based visual as well as radar observations were conducted on Bornholm from autumn 2021 until autumn 2023. Migrating birds were observed in autumn and spring from observation sites on Bornholm at Rønne harbour and Nexø harbour. Observations on the German island of Rügen took place in spring 2022 and 2023 with the overall aim to observe birds leaving land to cross the Baltic Sea during their annual migration to their breeding quarters.

During these onshore and offshore surveys, visual observations were conducted from sunrise to sunset by two observers. Migration intensity was estimated as birds per hour, extrapolating from 30 minutes of observations per hour. During the migration seasons (March to May and August to November), horizontal and vertical radars (25 kW/ 9.410 MHz) were used during daytime and at night to record intensity and directionality as well as altitudinal distribution, respectively.

Additionally, weather radars, which are mainly used for meteorological forecasting, were used to extract bird signals from raw meteorological data using special algorithms. European weather radars are united into the network of European Operational Program for Exchange of Weather Radar Information (EUMETNET/OPERA). Originally, the analysis started with all 25 weather radars located in north-west Europe. In the end, however, only the two stations *sehem* (on the island of Gotland, Sweden) and *sekaa* (near Karlskrona, Sweden) were chosen due to their proximity to the location of the Energy Islands planning area in the Baltic Sea.

1.3 EXISTING DATA

The western Baltic Sea is part of the migration route for many Scandinavian and Siberian breeding birds with estimates suggesting that up to 750 million birds belonging to 200 different species are estimated to cross the western Baltic Sea every year (Bundesamt für Seeschifffahrt und Hydrographie 2021).

Existing data were obtained from published research to provide information on the most relevant species or species groups. This selection was based on species or species groups that either cross the pre-investigation area regularly during their migration or are of special conservation concern. Altogether, data for eight species groups and two species is presented. This includes divers, geese and swans, sea ducks, birds of prey, gulls, terns, auks and songbirds, as well as great cormorants and common cranes. Among those, geese, ducks and songbirds are the most common species groups occurring in the pre-investigation area. Based on the existing data, information regarding migration routes, general migration patterns and biology of the selected species and species groups is presented. Additionally, a summary of predominant threats and conservation status is given. For seabirds like sea ducks, gulls, terns and auks only additional information regarding their migratory behaviour is given, since the general biology, distribution, habitat, and prey preferences as well as population sizes and predominant threats are already summarised in Part A Resting Birds.

According to the literature reviewed, a crossroad of songbirds migrating nocturnally in a broad front in a NE-SW direction exists, as well as a large number of seabirds migrating in E-W direction, and cranes and birds of prey migrating diurnally in N-S direction. Most species appear to use the same route in reverse direction during return migration in spring. Apart from taxonomic preferences, their flight direction and altitude appear to be strongly weather-dependent.

The review of existing data also included a behavioural study of cranes carried out in 2022 and 2023. Also, the study included a few species of raptors that were observed during the surveys (WSP & BioConsult SH 2024). A key aspect of this study was to analyse avoidance behaviour of cranes towards OWFs in the southwestern part of the Baltic Sea. Avoidance behaviour was differentiated at the macro-, meso-, and micro-scale.

Moreover, 17 cranes were successfully fitted with GPS transmitters during late summer 2022 and late summer 2023. Afterwards the transmitters have provided real time transmissions of the crane’s migratory movements across the Baltic Sea area and their corresponding flight altitudes.

Despite a high number of observations of migrating cranes approaching the wind farms, no collisions or critical near incidents were observed during the surveys. This suggests a very low collision risk for cranes passing the wind farms during their migration twice a year. This finding was also supported by the flight patterns of the GPS-tagged cranes, where more individuals displayed a clear avoidance response at the macro scale, either vertically or horizontally.

1.4 SURVEY DATA

Over 190,000 migrating birds were recorded during the surveys performed from autumn 2021 until autumn 2023.

The species composition recorded during the visual observations of the land- and vessel-based surveys was dominated by a few predominant species groups and varied only a little between the four study sites and the five migration seasons: Waterbirds such as cormorants, geese, ducks, and auks dominated during autumn and spring migration and, in addition, gulls in autumn and waders in spring. Among the landbirds, the predominant species groups were cranes, pigeons, and songbirds.

In general, the plotted migration intensity (MTR) for day and night periods for the two periods analysed (March to May and August to November) show that migration does not occur equally at all dates, but peaks at some dates, most probably coinciding with favourable weather conditions (Alerstam, 1990). Weather conditions influence migration, as this may affect the energy costs of flights as well as visibility, thus affecting the survival of migrating birds (Alerstam 1990, Newton 2010). Autumn migration intensity peaked in October, for the land-based observation sometime in early November and for the vessel-based observations sometime already in late September. Spring migration intensity peaked mostly in late March to April with vessel-based intensities a little later in April. In general, the migration intensity was regularly about 5-10 times higher near the islands of Bornholm and Rügen than offshore. This was true both for monthly means as well as on a day-by-day basis.

General flight directions were typical for migrating birds crossing the Baltic Sea. During, spring individuals were mainly headed northeast to east, whereas birds were mainly headed southwest to west during autumn. Analysing diurnal flight altitudes showed, that based on land-based observations birds were mainly flying above 20 m, but below 100 m. Vessel-based observations revealed that individuals were mainly observed above sea surface level not flying above 5 m. Vertical radar data confirm this pattern at all land-based stations with highest intensities in lower altitudes during the day and a more heterogenous picture during night. At the offshore location generally higher migration intensity occurred at lower altitudes during day and night.

The land-based observations carried out at Bornholm and Rügen confirmed the general flight directions and species composition of the migrating birds that were also observed offshore.

During autumn migration, the predominant species groups were cormorants (great cormorant), geese (such as greater white-fronted goose, bean goose, and barnacle goose), ducks (such as Eurasian wigeon, common scoter), cranes (common crane), pigeons (such as wood pigeon) and songbirds (such as common starling and various finch species). Smaller numbers of gulls (such as common gull and black-headed gull) and auks (such as razorbill and guillemot) were observed as well.

During spring migration, the predominant species groups were cormorants (great cormorant), geese (such as greater white-fronted goose, and barnacle goose), ducks (such as common scoter), cranes (common crane), pigeons (such as wood pigeon), auks (such as razorbill), waders (such as Eurasian curlew), and songbirds (such as common starling, finches, and barn swallow). Large numbers of migrating birds of prey were observed only on Rügen.

Onshore, a total of 1,374 unique migration tracks were produced by using horizontal radar, of which 193 were intentionally focusing on common crane. Unique tracks were produced for a total of 40 different (identified) species. The most numerous species group was cormorants (n = 292) followed by cranes (n = 193), grey geese (Anser spec., n = 157) and black geese (Branta spec., n = 149).

From weather radar data only, limited statements are possible since no useful data were available from the nearest and thus most relevant radar station on Bornholm. The altitude distribution determined by weather radar data showed that hardly any bird signals were recorded above approx. 1000 m above the ground. Furthermore, the weather radar data recorded continuously from 2020 to 2022 showed that the migration periods in this region are between March and May and July and November. The highest migration rates are consistently observed at all weather radar stations in September and October and thus in autumn. This is also consistent with the radar surveys carried out locally.

1.5 CONCLUSION

Overall, the results of this report confirm the information provided by the existing data. Numerous studies have shown that the western Baltic Sea in general, but also the regions around the pre-investigation area are a crossroad of bird migration. Several different species frequent this area both during spring and autumn migration in various directions. Apart from taxonomic preferences, flight direction and altitude appear to be strongly weather-dependent, but highest proportion of birds crossing the area at altitudes below 1,000 m.

As expected, based on the reviewed literature, the most relevant species groups passing the pre-investigation area during their migration were divers, cormorants, geese, ducks, birds of prey, cranes, waders, gulls, terns, auks and songbirds. The calculated migration intensity rates showed that both diurnal and nocturnal migration peaks during certain days, most likely related to favourable weather conditions. The analysis of flight altitude distribution confirmed known patterns as well. Migrating birds were mainly observed in heights below 2 km with highest numbers below 1,000 m so that the vertical radar covers main parts of the bird migration with a range of 1,000 m.

All in all, the western part of the Baltic Sea provides the crossroads that connect millions of Scandinavian breeding birds twice a year with their wintering quarters.

2 INTRODUCTION

With the Climate Agreement for Energy and Industry dated 22nd of June 2020, the majority of the Danish Parliament decided that Denmark will become the first country in the world to develop two energy islands. One of these islands will be the island of Bornholm located in the Baltic Sea ("Energioe Bornholm"), with wind farms located south-west of Bornholm with an installed capacity of up to 3.8 GW. The planned future wind farm areas consist of Bornholm I South (118 km²), Bornholm I North (123 km²) and Bornholm II (410 km²). The island of Bornholm will house the transformer station and serve to distribute the produced energy.

Due to these political decisions, a series of environmental pre-investigations were carried out for a well-defined pre-investigation area. Part B of the present report focuses on migrating birds crossing the pre-investigation area twice a year on their seasonal movements between breeding and wintering ground and is thus separated from the part of the report, describing the resting birds. Since many species of seabirds are also resting birds, the grouping is fluid, and the present report considers all seabirds which use the pre-investigation area for stopping over during migration.

The pre-investigations included a compilation of data based on already available publications, as well as several methods applied to investigate species composition, migration intensities, flight altitude and flight directions or migratory species.

Figure 1 shows the pre-investigation area for Energy Island Bornholm with the planned future wind farm areas Bornholm I (OWF1) North and South (B1N and B1S), Bornholm II (OWF2) and the cable corridor area (CC).

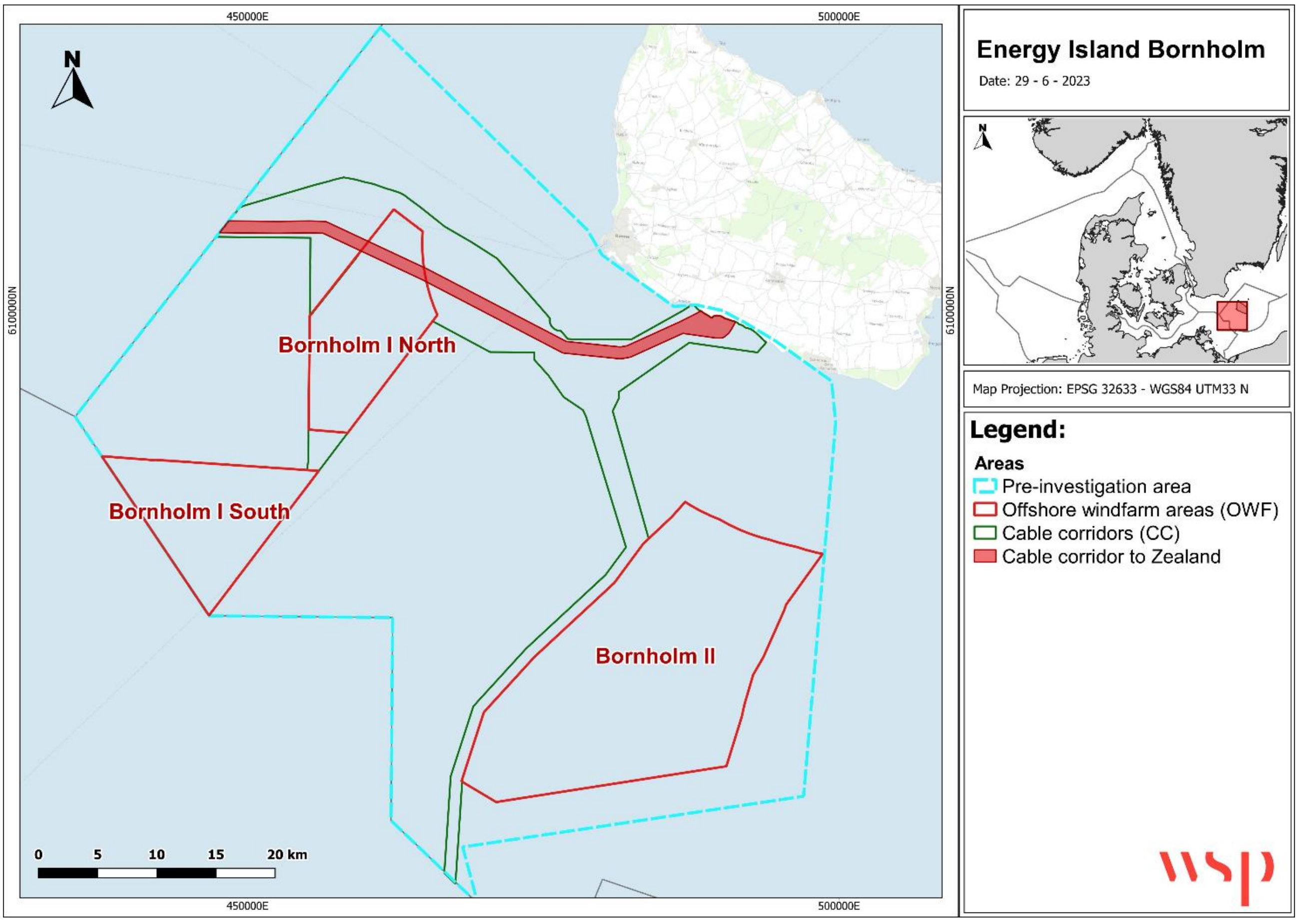


Figure 1. The pre-investigation area for Energy Island Bornholm.

3 METHODOLOGY

This chapter outlines the employed data collection methods and analytical approaches used to investigate the occurrence of migrating birds within and around the pre-investigation area of Energy Island Bornholm.

3.1 EXISTING DATA

A desktop study has been conducted by reviewing relevant literature including both peer-reviewed journals as well as publicly available "grey literature". The considered publications included information on migration routes, as well as on general migration pattern and biology of migratory bird species. Species were selected as relevant, when they either regularly cross the pre-investigation area on their way to or away from their breeding grounds or have a special conservation status. A detailed description of available information for the most relevant groups of migrating bird species expected to be present in the pre-investigation area is given, supplemented by a brief overview regarding potential threats of anthropogenic impacts.

The desktop study on migrating birds also included a study with the objective to observe and analyse avoidance behaviour of common cranes approaching offshore wind farms (OWFs) in the southwestern part of the Baltic Sea. The study was based on several surveys carried out in autumn 2022 and spring 2023. As part of the study, 17 cranes were also fitted with GPS transmitters during late summer 2022 and late summer 2023. Afterwards the transmitters have provided real time transmissions of the crane's migratory movements across the Baltic Sea area and their corresponding flight altitudes (WSP & BioConsult SH 2024).

3.2 RADAR SURVEYS

Radar is originally an acronym standing for "radio detection and ranging". Radar devices emit electromagnetic waves that are reflected by objects, helping to locate them. Detection depends on object size, distance to the radar, and object movement. Birds, being small, need shorter wavelengths for detection. Therefore, devices with 25 kW power in the X-band range (9,410 MHz) were used to detect birds effectively. Radar devices were used for both vertical and horizontal radar surveys.

Figure 2 Example setup of a bird radar station: Two radar units per station were used for this study. A horizontal radar is mounted on the roof of a caravan and is used to determine the flight direction of seasonally migrating bird species. A mobile vertical radar standing next to the trailer also collects data to determine flight altitude and migration intensity.

Data from the radar surveys provided information on the species composition, phenology, which is the daily or seasonal process of the local migration (migration altitude and -direction of migrating birds).

Both vertical and horizontal radars were used in the surveys. In vertical surveys, the radar had a rotating antenna adjusted manually to align with the assumed migratory direction. In horizontal surveys, the antenna was simply aligned horizontally. For offshore surveys, radars were mounted on vessels, and onshore on trailers with the land-based antennas several meters above sea level. An overview of the locations of the three land-based and the single vessel-based radar locations are given in Figure 3.

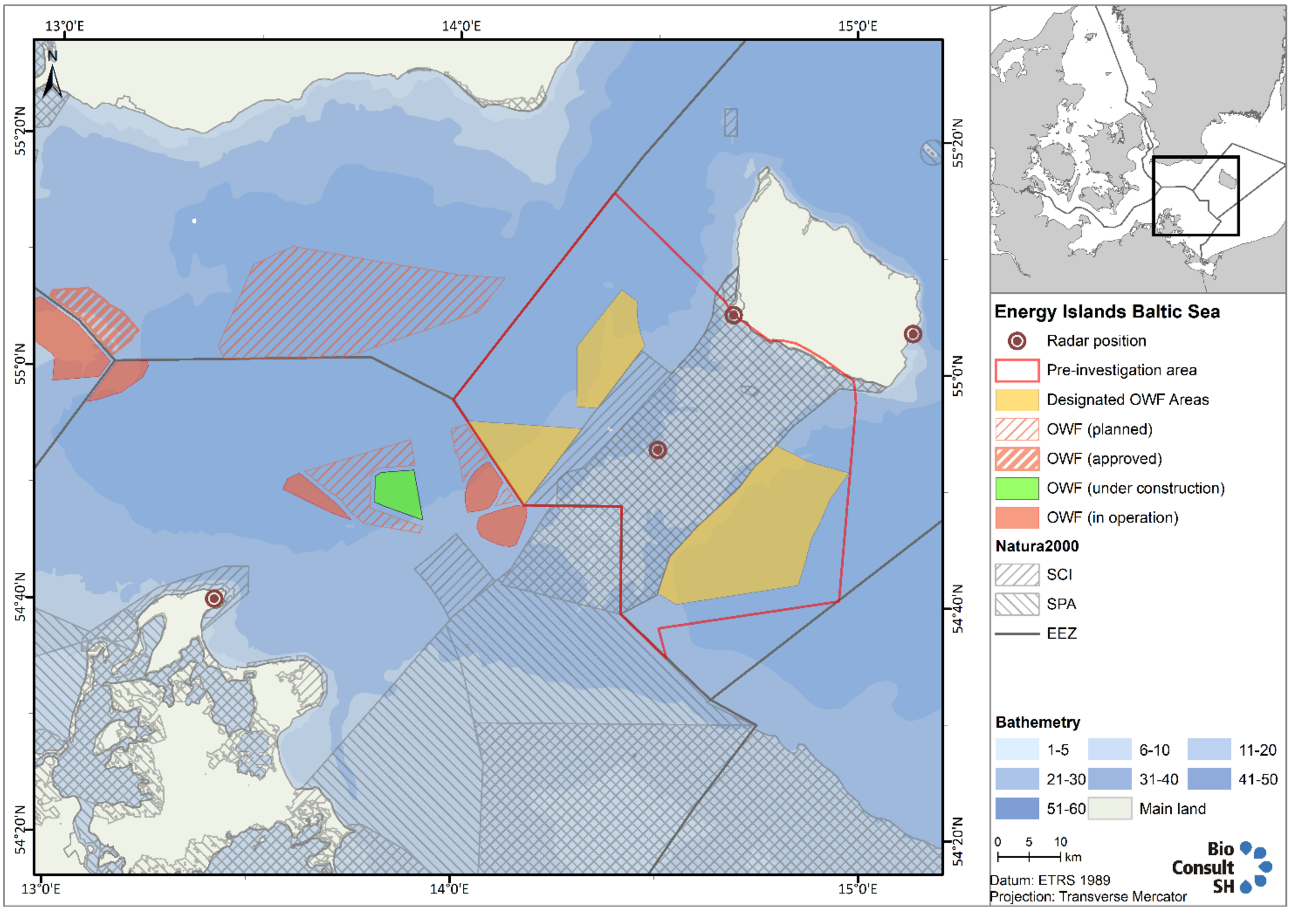


Figure 3 Overview of the locations of the three land-based (two on Bornholm in Nexø and Rønne, one on Rügen) and the single vessel-based radar positions. The pre-investigation area is outlined in red.

For visual identification of bird species and counting number of individuals during horizontal radar surveys, binoculars (8- and 10-times fixed magnification) and spotting scopes (25- to 50-times variable magnification) were used. All data from the visual observations were entered into project tablets and uploaded to a central database for later analysis.

For altitude measurements, a laser rangefinder was used from the manufacturer Safran Vectronix AG - model Vector 21 Aero. The laser rangefinder was placed on a tripod and connected to a laptop with the geographic software system Vectronix LRF Data Viewer ver. 1.1.24.4 installed. The cable connecting the laser rangefinder and laptop had a tricker mechanism which activated measurements of distance (range), azimuth and inclination at the same time.

The software Vectronix LRF Data Viewer converts this information, by trigonometry, into an altitude (from distance & inclination) as well as a latitude and longitude position (from distance, azimuth and the known geographical position of the observer).

In the following chapters, the methodology of horizontal radar surveys on land (onshore), at sea (offshore) and finally vertical radar surveys on land and at sea are described.

3.3 HORIZONTAL RADAR SURVEY ON LAND

The horizontal radar on land provides information on flight direction of migrating birds, and the visual observations provide information about species. The detection range of migrating birds for the horizontal and radar is approximately 15-20 km under good conditions.

The land-based radar setup consisted of two radars of the model: FURUNO FAR 2117 ARPA X Band Marine Radar, per site.

The interface of the radar involved a computer using Geographical Information System (GIS) software. In this way the processed sweeping radar signal could be overlayed a georeferenced background, and signals identified as bird movement could be manually plotted with information on latitude and longitude, as well as species and number of individuals. A track was constructed by manually plotting a series of nodes following the processed sweeping radar signal. The nodes of each bird track were separated by a unique identifier for subsequent processing and analysis.

For identification of bird species and counting number of individuals binoculars (8- & 10-times fixed magnification) and spotting scopes (25- to 50-times variable magnification) were used. Migration intensity was measured based on observations beginning at dawn (civil morning twilight) at a given date and continued for two to five 24-hour cycles. Civil twilight is defined as the moment when the sun is six degrees below the horizon. Nocturnal migration intensity is measured between evening civil twilight and morning civil twilight.

The land based horizontal radar surveys were completed as a collaboration between two observers. One observer handling the radar interface for tracking, and the other observer handling binoculars and telescope for species identification and estimation of flock size of the active tracks.

In this way, the second observer could verify, if it indeed was bird flock movements on the radar interface, as well as provide information on species and flock size number. Because the horizontal radar does not have the capability to measure altitude of the returning signals, the second observer also had to apply a rangefinder. However, since the second observer simultaneously also had to enter data into the project-tablets, rangefinder measurements were prioritized for focus species (common cranes and birds of prey), and only for other species when there was sufficient time to first discover, identify, count and enter data in the tablet.

The horizontal radar surveys were carried out during the bird migrating seasons (March to May & August to November) and placed at two locations running simultaneously.

Initially a position was proposed as a horizontal radar survey position in Sweden – in the harbour city Kåseberga. However, this position was withdrawn from the survey plans, to move the survey location closer to the project area. The Swedish location was replaced by a new at the harbour city Nexø, located on the eastern part of Bornholm. The initial planned locations at Rønne (Bornholm) and Rügen (Germany) remained unchanged, see Figure 4.

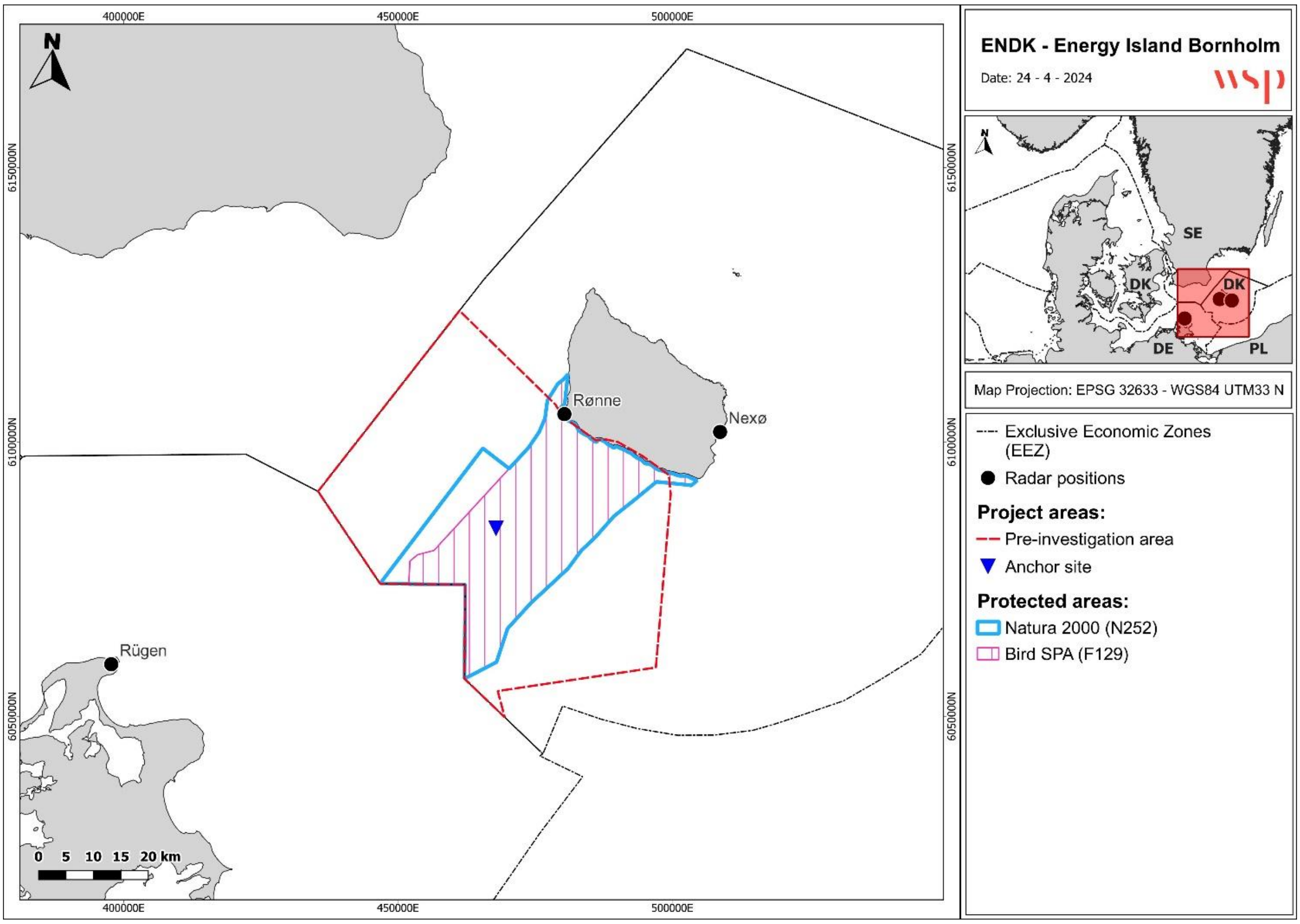


Figure 4. Map providing overview of positions for horizontal radar surveys. The two stations placed at the Danish island Bornholm (Rønne and Nexø) and the station placed during spring in Germany (Rügen).

During the period from the end of 2021 to the end of 2023, a total of eight horizontal radar surveys were completed (Table 1). A total of 1,374 unique tracks were produced, of which 193 were intentionally focusing on common crane.

Unique tracks were produced for a total of 40 different (identified) species. The most numerous species group was cormorants (n = 292) followed by cranes (n = 193), grey geese (Anser spec., n = 157) and black geese (Branta spec., n = 149). Unfortunately, the species group of birds of prey proved to be very difficult to track with the horizontal radar, as the birds produced very weak, if any, returning signals. Only a total of 3 tracks were produced of birds of prey including a white-tailed eagle (n = 1), a common buzzard (n = 1), and a Eurasian hobby (n = 1). Because the horizontal radar can detect large bird flocks, returning strong signals up to 20-25 km distance, it was not possible to identify all tracks to species level or even identify them as anything other than birds. Therefore, some tracks have been categorized at family/genus level (n = 212) or as 'Unknown' (n = 144).

	2021	2022		2023	
	Autumn	**Spring**	**Autumn**	**Spring**	**Autumn**
Rønne	Completed	Completed	Completed	Completed	Completed
Nexø			Completed		Completed
Rügen		Incomplete		Completed	

Table 1. Overview of horizontal and vertical radar surveys.

3.4 HORIZONTAL RADAR SURVEY AT SEA

Data from horizontal radar surveys at sea provide information on flight direction.

Offshore, the radar setup was the same as on land, but consisted of different models mounted on vessels in advance and used different methods with fixed settings and automatic recording of images.

The detection radius of the radar was set to 3,000 m and the sensitivity (gain) of the radar antenna to 70 %. The afterglow duration was prolonged to 90 seconds to record flight paths of birds, which were used to determine the flight direction. Filters for rain and waves were turned off as they would also suppress an unknown number of bird signals. The horizontal radar devices were operated in “north up” mode, the radar screen therefore always displayed north to the top independently of the ship’s orientation. Every four minutes, an image of the radar screen was captured and stored.

The recorded radar screenshots were visually scanned for bird signals, which were identified based on their size and the flight paths visible due to the afterglow period. Head (current position of a bird) and tail (end of the visible flight path) of each track were marked using the software “GSA Bird Counter 1.17” and stored as image coordinates, which were then converted into flight directions in relation to the north direction.

Horizontal radar screenshots are very often affected by sea clutter and therefore cannot be analysed. This also applied to most screenshots at the offshore location of this study. In total, only 5 radar images held information on bird flight direction. Thus, we cannot provide information on flight directions of bird migration at sea from the radar data. Nonetheless, we provide information on bird migration intensity, altitudes, and phenology from vertical radar information at the offshore location of the years 2022 (spring and autumn) and 2023 (spring).

3.5 VERTICAL RADAR SURVEY ON LAND AND AT SEA

For the vertical radar surveys, marine radar devices with a transmission power of 25 kW and 9,410 MHz wavelength (X band range) were used, but in this case, the antenna was aligned vertically towards the assumed bird migration direction. Data from vertical radar surveys provide information on migration intensity and altitudinal distribution of migrating birds. The data are used to show variation within migration traffic rates over the course of the year (annual phenology, with day and night separately shown) as well as its distribution over 24 hours (spring and autumn separately, when possible).

For the vertical radar surveys, radar antennas were installed rotating vertically which continuously scanned the airspace above and to both sides of the ship or observation sites on land, respectively, with a range of 1.5 km. Offshore, the antenna and thus the coverage area was aligned perpendicularly to the assumed main direction of bird migration to register as many birds crossing the area as possible. The correct alignment was checked every hour. Onshore, the antenna alignment was set once at the beginning of the continuous recordings.

The antenna gain (i.e. sensitivity) was set to 70 % and filters for rain and sea clutter were deactivated, as these would also filter out an unknown number of bird signals. A radar trail function set to 45 seconds allowed to identify bird signals by the combination of the current signal and an afterglow trail of former positions. The recorded data was stored as screenshots every four minutes. Vertical radar surveys were conducted in parallel to the horizontal radar studies (Figure 5).

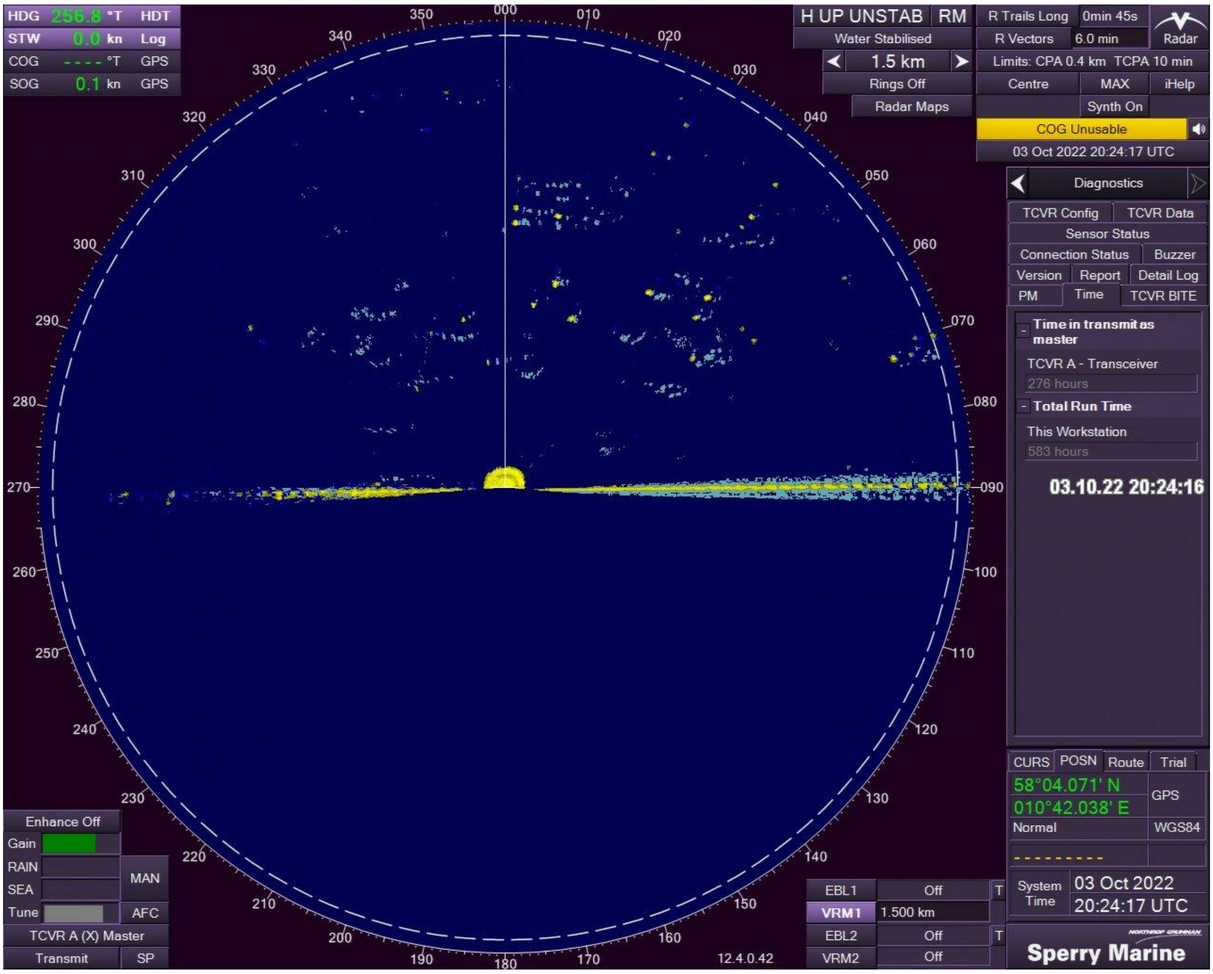


Figure 5. Example of a screenshot from vertical radar. Bird signals can be recognized by the blue tracks in the wake of the current yellow signal.

The recorded screenshots were visually scanned for bird signals, which were identified based on size and the trail caused by the time of afterglow. The bird signals were marked, and their image coordinates were converted into flight altitudes and distance to the radar unit. The number of individual birds that correspond to a bird signal cannot be determined. A bird signal thus represents at least one bird. Images were not evaluated if more than 25 % of the radar screen was obscured by rain clutter as this might superimpose bird signals.

Distance correction of the recorded data was conducted prior to data analysis, as the detectability of bird signals is highly dependent on the distance to the radar. For this, empirical bird signal data of 50 to 150 m altitude were selected. The distance from the radar unit was determined for all signals in this altitude band and a distance-dependent detection probability was calculated, using the R software 4.2.2, “Distance” package (Miller et al. 2019, R Core Team 2021). “Half normal” and “hazard rate” models up to 5th order were tested, choosing the best-fitting model per radar device based on Akaike information criterion. As the close vicinity around a radar device generally does not record ”signals“ of birds in an area of 100 m around, the devices were not considered for the determination of the correction functions.

Using the distance functions derived from the 50 – 150 m data, individual distance correction factors were calculated for all recorded signals of the whole detection range up to 1 km height, and the number of signals at each given altitude was corrected accordingly.

The **migration intensity** was calculated as migration traffic rate (MTR, number of signals/km/h). This is the number of signals that cross a virtual stretch of 1,000 m perpendicular to the migration direction every hour. Migration intensity was calculated for all hours of the recording periods for which at least three valid radar images were available. For each day and night, the mean migration intensity was determined from the corresponding hourly results. Only days or nights for which hourly migration intensities were available for at least 70 % of the time, were taken into consideration.

To represent the **altitude distribution**, the relative proportion of signals was determined for each 100 m height increment up to 1,000 m. The evaluation was carried out separately for diurnal and nocturnal migration and for spring and autumn migration. In order to show potential differences in altitude distribution between days/nights with high and low migration intensity, this evaluation was additionally conducted separately for the five days/nights with the highest migration intensities compared to the rest of days and nights sampled.

3.6 VISUAL SURVEYS

Data from visual observations provide information on migration intensity, altitudinal distribution and flight direction of migrating birds at species or species group level during daytime.

From September 2021 onwards, a total of 42 observation surveys were conducted until the end of November 2023 (Table 2). This included two vessel-based surveys of two days each per migration period (spring and autumn, respectively) at an anchoring position southwest of Bornholm at the centre of the pre-investigation area. Furthermore, in autumn 2021, land-based visual observations as well radar observations began on Bornholm. At the observation site at Rønne harbour, migrating birds were observed in the autumn and the in spring. In autumn 2022 and 2023, additional observations took place at Nexø harbour. Observations at Rügen took place in spring 2022 and 2023. The overall aim was to observe birds leaving land for the Baltic Sea crossing during their annual migration. Locations of the different survey positions (visual as well as radar) are indicated in Figure 3.

Table 2. Observation effort 2021-2023. Start and end date/time of surveys including visual observations and horizontal radar tracking during daytime as well as 24h vertical radar recording offshore. Onshore (Rügen and Bornholm), vertical radar data was recorded outside of these phases as well. Time of day is provided to indicate, whether diurnal or nocturnal migration was recorded.

Observation Site	Start	End
Bornholm	27.09.2021, 07:45	30.09.2021, 14:00
Bornholm	11.10.2021, 05:15	14.10.2021, 13:02
Offshore	28.10.2021, 12:30	31.10.2021, 13:50
Bornholm	31.10.2021, 05:45	05.11.2021, 14:00
Offshore	09.11.2021, 22:00	12.11.2021, 10:20
Rügen	16.03.2022, 05:30	19.03.2022, 13:30
Bornholm	16.03.2022, 06:50	22.03.2022, 13:00
Rügen	29.03.2022, 04:30	31.03.2022, 13:00
Bornholm	01.04.2022, 05:40	03.04.2022, 12:10
Rügen	11.04.2022, 04:15	14.04.2022, 12:30
Offshore	24.04.2022, 15:00	27.04.2022, 13:00
Rügen	25.04.2022, 03:38	27.04.2022, 11:37
Bornholm	25.04.2022, 04:40	28.04.2022, 13:10
Rügen	03.05.2022, 07:00	06.05.2022, 12:00
Bornholm	09.05.2022, 04:40	12.05.2022, 13:00

Observation Site	Start	End
Rügen	12.05.2022, 05:00	13.05.2022, 11:00
Offshore	12.05.2022, 08:45	15.05.2022, 14:45
Bornholm	22.08.2022, 05:00	25.08.2022, 13:05
Bornholm	26.08.2022, 08:00	31.08.2022, 12:07
Bornholm	15.09.2022, 05:00	21.09.2022, 13:00
Offshore	25.09.2022, 17:45	28.09.2022, 14:00
Bornholm	03.10.2022, 05:00	07.10.2022, 14:00
Bornholm	18.10.2022, 06:55	19.10.2022, 13:24
Offshore	24.10.2022, 16:40	27.10.2022, 13:15
Bornholm	14.11.2022, 07:00	18.11.2022, 14:55
Bornholm	13.03.2023, 06:23	19.03.2023, 14:25
Rügen	16.03.2023, 05:30	19.03.2023, 13:35
Rügen	22.03.2023, 05:30	24.03.2023, 13:31
Bornholm	03.04.2023, 05:00	07.04.2023, 13:00
Rügen	04.04.2023, 05:00	06.04.2023, 13:00
Offshore	07.04.2023, 13:30	09.04.2023, 20:00
Rügen	18.04.2023, 05:00	21.04.2023, 13:16
Bornholm	26.04.2023, 05:00	27.04.2023, 13:00
Offshore	01.05.2023, 08:00	04.05.2023, 04:30
Rügen	10.05.2023, 08:27	12.05.2023, 11:15
Bornholm	11.05.2023, 05:00	16.05.2023, 13:00
Rügen	16.05.2023, 05:10	18.05.2023, 12:23
Bornholm	01.08.2023, 05:00	04.08.2023, 13:05
Bornholm	27.08.2023, 05:00	31.08.2023, 13:00
Bornholm	25.09.2023, 05:00	29.09.2023, 13:30
Bornholm	23.10.2023, 05:00	26.10.2023, 13:30
Bornholm	**30.10.2023, 06:00**	04.11.2023, 14:00

To complement the nocturnal radar studies, offshore visual observations were conducted during the daylight hours, starting during civil morning twilight until civil evening twilight. Every hour, two15-minute intervals were recorded, during which two observers scanned the surrounding area for flying birds with bare eyes and binoculars. Each observer covered a 180° area. Species and numbers of individuals of flying birds or bird flocks were noted, as well as estimations of flight altitude and flight directions (subdivided in eight directions: N, NE, E, SE, S, SW, W, NW). Observers also annotated if birds were visibly associated with the observer vessel or other (especially fishing) vessels, as in those cases birds were assumed to be foraging instead of migrating.

Data evaluation focused exclusively on observations of flying birds not associated with ships. In a first step, the minimum number of **bird species** that appeared was determined and the dominance of systematic groups and individual species was shown based on the percentage of the total registered individuals.

Migration intensity was calculated as birds per hour, extrapolating from 30 minutes of observations per hour. Based on this, both the annual and daily pattern of migration intensity was presented for all birds combined as well as for single species groups. Only data from days during which the observations spanned to at least 70 % of the daylight period were used.

To evaluate **flight altitude** distribution, recorded data were depicted for several altitude ranges: 0 – 5, 5 – 10, 10 – 20 m, 20 – 50 m, 50 – 100 m, 100 – 200 m and > 200 m, as well as for all observations combined and for single systematic groups. Likewise, recorded flight directions were displayed in 45°-increments.

Onshore visual observations basically followed the same methodology but included continuous observations by one observer for eight hours beginning at sunrise, while the second observer tracked bird flocks via horizontal radar.

3.7 LASER RANGE SURVEY

Laser rangefinder measurements were primarily conducted to measure flight directions and altitudes at Rügen during spring 2022. In addition to providing information on altitudes the laser rangefinder survey could deliver information on flight directions at this location where the horizontal radar could not be installed before May 2022. Since information provided by the horizontal radar is also qualitative (flight directions of migrating birds), results of laser rangefinder are complementary and partially comparable. Furthermore, laser rangefinder provides additional important information on flight altitudes.

The focus of laser rangefinder surveys was mainly on common cranes and different species of birds of prey, as they were regarded as the focal species of the area of the Bornholm-Rügen-Baltic Sea region including the pre-investigation area. This means that if there were several groups of birds migrating simultaneously, the observers would concentrate on those species. Nonetheless, all species would be measured whenever possible.

Measurements were made by two observers in parallel with the visual observations. While one observer was using the rangefinder to measure altitudes and distances of the path travelled by a bird or a flock of birds, the other observer was noting the relevant information on the laser rangefinder interface (Figure 7.). A laser rangefinder (Vector 21 Aero, Vectronix AG, Heerbrugg, CH, Figure 6.) can measure the distance, azimuth, and inclination to a certain object (in this case a bird). It is then able to calculate the altitude for this object as well as its geographical position (using the known position of the observer). A series of measurements of the same individual or flock form a “track”, which represents the flight path in 3D.

Figure 6. Rangefinder Vector 21 Aero der Firma Vectronix.

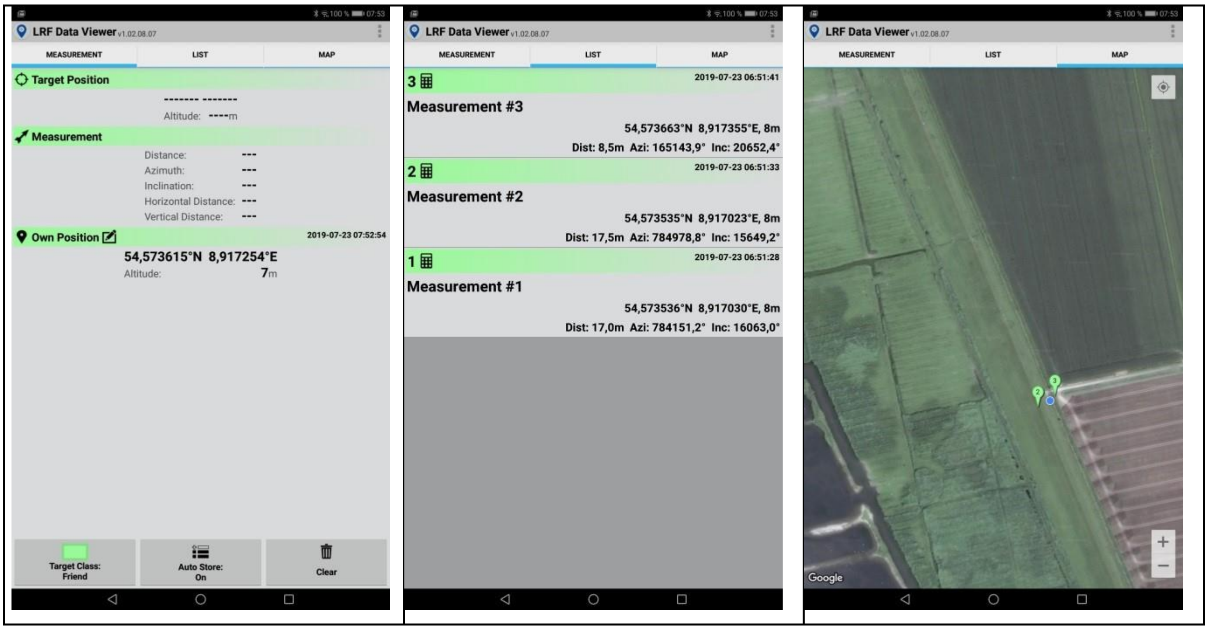


Figure 7. User interface of the rangefinder app.

Data collection with the rangefinder was conducted during 19 days between March and May 2022. Measurements of rangefinder were done in parallel to the visual observations.

Before the analysis, a screening procedure was done to detect erroneous measurements. The screening was conducted in R (ver. 4.2.2) using an in-house built function, which detected measurements with an unrealistic high velocity for a flying bird (> 30 m/s) or measurements outside the track. A visual screening of the data set was also done to confirm corrections made by the in-built function. Thus, measurements within a track or sometimes complete tracks were discarded. Of a total of 368 tracks, 360 were left for analysis. Most of the tracks were done for four species (common scoter, 73, common cranes, 72, Eurasian sparrowhawks, 43 and red kites, 41, (Table 3). Most tracks had between 5 and 12 single measurements with a median of eight measurements. The maximum number of measurements for a track was 68 (a track of common cranes).

Table 3. Dates of collection together with number of tracks measured and analysed. Erroneous measurements were not analysed. See text for more details.

2022	Total number of days	Dates	Observation time [h:min]	Total number of tracks measured	Total number of tracks analysed
March	7	16. – 19.03 & 29. – 31.03	54:39	184	177
April	7	11. – 14.04 & 25. - 27.04	56:15	115	115
May	5	03 – 06.05 & 12. – 13.05	48:00	69	68
Total	**19**		**158:54**	**368**	**360**

Rangefinder measurements provide the latitude and longitude (calculated from measured azimuth, distance, and the known position of the observer) of the flying object as well as its altitude. If the position of two consecutive measurements is known, the direction of flight can be calculated. For every track, an average direction was calculated and plotted for every species or species group respectively.

In addition, altitude of flight was plotted for every measurement. Mean altitudes of flight were calculated for every track and averaged for each species. Differences between flight altitudes over sea and over land were also shown through graphs.

3.8 WEATHER RADAR SURVEY

Data from weather radars can be used to detect birds and thus provide information on migration intensity as migration traffic rates.

In recent years, large advances in information technology and open data policies have enabled the use of weather radars not only to survey weather parameters but additionally detect and measure aerial movements of different types of animals, mostly birds, bats and insects (DOKTER ET AL. 2018). Even if the idea of using weather radars for this purpose dates back several decades, they remained largely inaccessible because of the computational challenges in analysing the data. A few years ago, however, a scientific method was developed, which allowed extraction of relevant data from weather radars and openly provided tools for exploring the biological information contained in weather radar data (R package bioRad (Dokter et al. 2018)). Currently, radars in two areas of the world can be accessed and analysed easily: in Europe through the OPERA network and in the United States through the NEXRAD network.

European weather radars are united into the network of European Operational Program for Exchange of Weather Radar Information (EUMETNET/OPERA). OPERA has coordinated radar co-operation among national weather services in Europe for over 20 years (Saltikoff et al. 2019). There are more than 30 members and over 200 radars included in OPERA. Each country may have weather radars operating at different wave lengths (the majority use C-bands, but there are also S- and X-bands), and different hardware and software providers may be used (Saltikoff et al. 2019). Thus, in comparison to weather radars in the US which are homogenous, those of Europe are subject to greater variation. One of the many objectives of OPERA is to facilitate the download and the use of these rather heterogeneous sources of weather radars making them available through a general type of data file.

Most of the weather radars used in this study were previously not used for bird migration analyses, therefore the first objective was to evaluate the quality of the data and to establish whether data from these stations are suitable for the detection of migrating birds. The overall objective was to determine migration patterns in the focal area and to estimate migration intensity obtained from the weather radar analysis.

All European weather radar stations utilize UTC, which means that all their radar data are time-stamped to Greenwich Mean Time. Therefore, the local time in the pre-investigation area is +1 hour in winter and +2 hours in summer. To keep the weather radar data comparable, the horizontal and vertical radar recordings are presented in UTC as well, e.g. for the analysis of the phenology (daily or seasonal process of the local migration).

The working cycle of a weather radar consists of several rotations of the radar antenna, or scans, at different altitudes starting from the lowest elevation of the antenna to the highest. Angles of elevations of antenna vary between radars. One working cycle of the radar happens once in 5 or 15 minutes depending on the individual settings on each radar location or country. The function “vol2bird”, included in the R package bioRad (Dokter et al. 2018), was used to extract biological signals from the original radar data. The extracted bird data together with vertical profile (VP) files were available at the ENRAM (European Network for the Radar surveillance of Animal Movement) data repository (https://aloftdata.eu/browse/).

Historical VP files were downloaded from all-weather radars for spring and autumn 2020, spring and autumn 2021, autumn 2022 and spring 2023. VP files for spring 2022 were not available at the data repository. Integrating the individual vertical profiles over time, migration intensities (migration traffic rates, MTR) and flight height distributions were calculated and visualized for the given time periods (see below). All these analyses were done with the R package bioRad (Dokter et al. 2018).

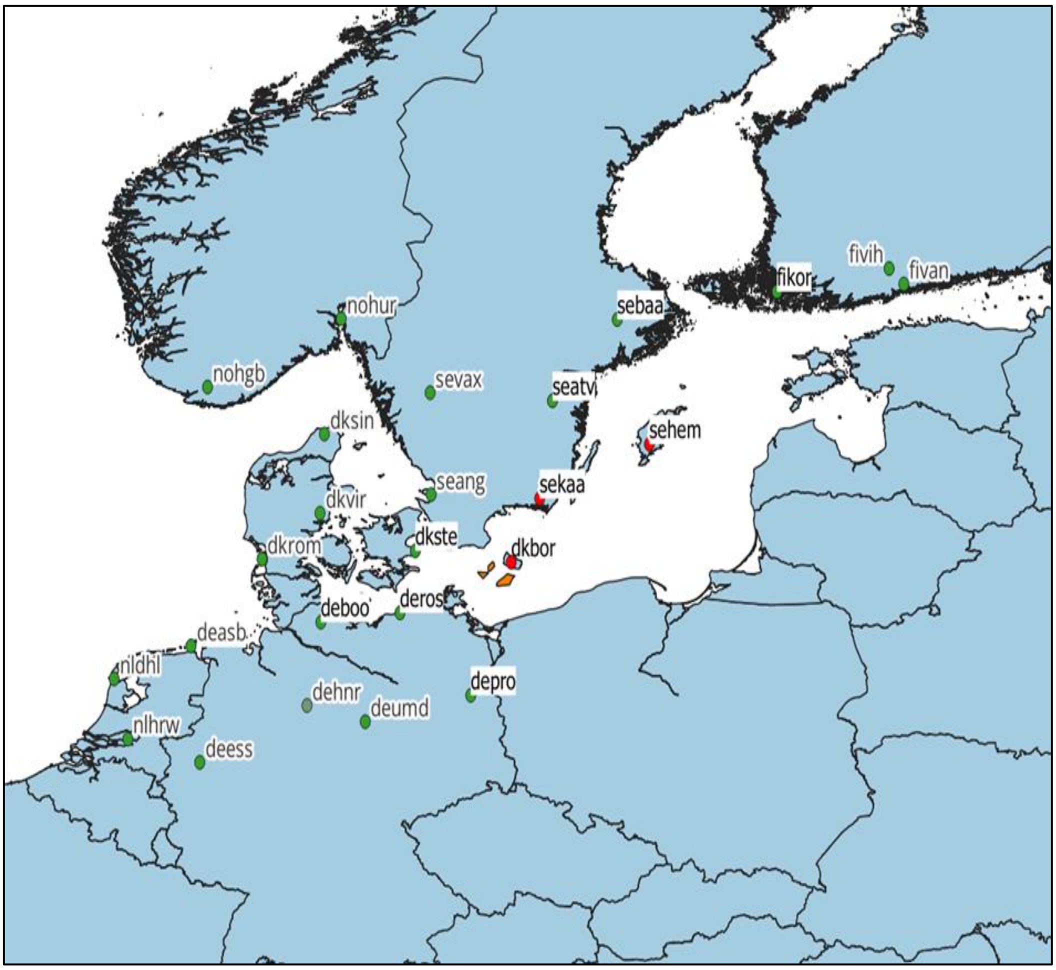


Figure 8. Location of weather radars used for the weather radar survey. Green dots show radars used only for general correlation analysis, red dots mark radars that were also used for more detailed description of the migration through the pre-investigation area. Orange marks the location of planned wind parks.

We started the analysis of all 25 weather radars located in north-west Europe (Figure 8). The two stations sehem (Gotland, Sweden) and sekaa (Karlskrone, Sweden) were chosen near the location of the Energy Islands planning area in the Baltic Sea for a more detailed description of migration there. All weather radars have a maximum range of about 240 km. For the estimation of bird migration, the radar data covers a range of 5 km to a maximum distance of 35 km from the location of the radar itself. Distances outside this range are not recommended (Dokter et al., 2018).

Data exploration, consisting mainly of graphically inspecting the data and looking for possible outliers, especially in the quantity of migration traffic rate (MTR), was conducted before further analyses. For most of the analyses we present the 2020-2023 data separately for the two main migration seasons: autumn (August to November) and spring (February to June) and within each period for day and night. To analyse large-scale relations between weather radars we calculated correlation matrices of daily median MTR values. Due to methodological difficulties of signal filtering under severe weather conditions MTR values are sometimes much higher than normally expected. To minimize the influence of outliers median instead of mean values of MTR were used for correlational analysis.

Bird migration measured from weather radar data can be expressed in terms of reflectivity-related measures or in terms of number of individual-related measures (Dokter et al. 2018). Here, migration measurements are expressed in terms of numbers of individuals. The parameter “radar cross section” (RCS), which represents the size of a bird´s body reflecting radar radiation, was set to 11 cm². This is the seasonal average for C-band radars in western Europe for nocturnal passerine migration (Dokter et al. 2018). Migration can then be expressed as migration traffic rate (MTR), which is defined as the number of individuals (of passerine birds) crossing a line of one kilometer perpendicular to the flight direction within one hour (birds * km^{-1} * h^{-1}, Zehnder et al., 2001; Dokter et al., 2018). MTRs were calculated with the following formula:

$$MTR (t, h1, h2) = \int dens (t, h) ff (t, h) dh$$

Where t is time, h1 the lower altitude and h2 the upper altitude band, dens (t ,h) and ff (t, h) the animal density and speed at altitude h and time t, respectively (Dokter et al. 2018). When summed over all altitude bands, one obtains the MTR for the whole vertical plain. When the MTR is integrated over a period of time, this will become the total migration for a period of time, e.g., a day, a month, a season, a year.

Migration traffic rates were calculated for each cycle of radar work (every 5 or 15 minutes) and each station data were available from and plotted using the function plot.vpi of the package bioRad. These measurements were recalculated into MTR (birds per hour per km), although the measurement itself lasted only 5 or 15 minutes. In addition, the mean migration traffic rates were calculated for each night (defined as the period between sunset and sunrise) and each day of data collection. Average MTRs were computed for each season for diurnal and nocturnal migration separately.

For each radar station and each period of migration, the three highest peaks of the total migration for the season (day, nights separately) were listed to demonstrate the highest migration intensity.

In order to analyse altitude distribution of bird-like echoes, we plotted MTR values of each working cycle of the radars against altitude. These are the raw data, and such a representation is one of the best tools to estimate quality and reliability of bird detection. According to the literature, most birds migrate at a height of up to 1.5 km above the ground, and few migrate above 3 km of altitude (Newton 2010). Typically, bird migration mostly occurs at lowest few hundred meters with very few detections higher than 2 km, and MTR values vary from few hundreds to few thousand birds per hour per km. If a profile of altitude distribution is very different from this pattern, then data are most likely cluttered with non-bird signals and should not be used.

4 RESULTS

4.1 EXISTING DATA

Migrating birds alternate between breeding and non-breeding regions. They can travel over long distances twice a year. Although this is a regular, annually recurring phenomenon, the magnitude of migration can vary strongly from year to year and is subject to great variability. The distance covered during migration varies among species as well, some migrate over long distances of several 100 or 1,000 km, others travel short distances with only a few km. Among some species, only parts of the population migrate while the rest resides in their area of distribution.

Estimates suggest that about half a billion birds belonging to approximately 200 different species cross the western Baltic Sea during autumn and roughly ~ 250 million birds cross the area during spring (Bundesamt für Seeschifffahrt und Hydrographie 2021). The majority of these are songbirds (> 95 %). The rest is composed of seabirds and other waterfowl such as divers, grebes, ducks, geese, waders, gulls, terns and auks. Thermal gliders such as birds of prey and cranes cross these areas during their migration as well (Bundesamt für Seeschifffahrt und Hydrographie 2021).

As previously mentioned, bird migration is very variable and thus hard to predict. However, the timing of migration is influenced by weather conditions such as temperature, precipitation, fog, wind speed and direction, as energetic costs necessary for flying itself are related to the presence and magnitude of these parameters. Thus, migration mostly takes place during only a few days of the migration period when the most favourable weather conditions occur (Bundesamt für Seeschifffahrt und Hydrographie 2021).

For many Scandinavian and Siberian breeding bird species, the Baltic Sea including the pre-investigation area is part of their annual migration routes (Figure 9.). Numerous night-migrating songbirds are thought to cross the Baltic offshore area in a broad front mainly with a south-western orientation, but local aggregations and deviating directions are also possible. Most day-migrating birds follow landmarks from Falsterbo in Sweden over Danish islands such as Zealand and Lolland and German Fehmarn to the mainland of Europe, but fractions of those populations also directly cross the open water. Waterfowls like geese, ducks or divers predominantly migrate through the western Baltic Sea including the pre-investigation area in an east-west direction (Bellebaum et al. 2010a).

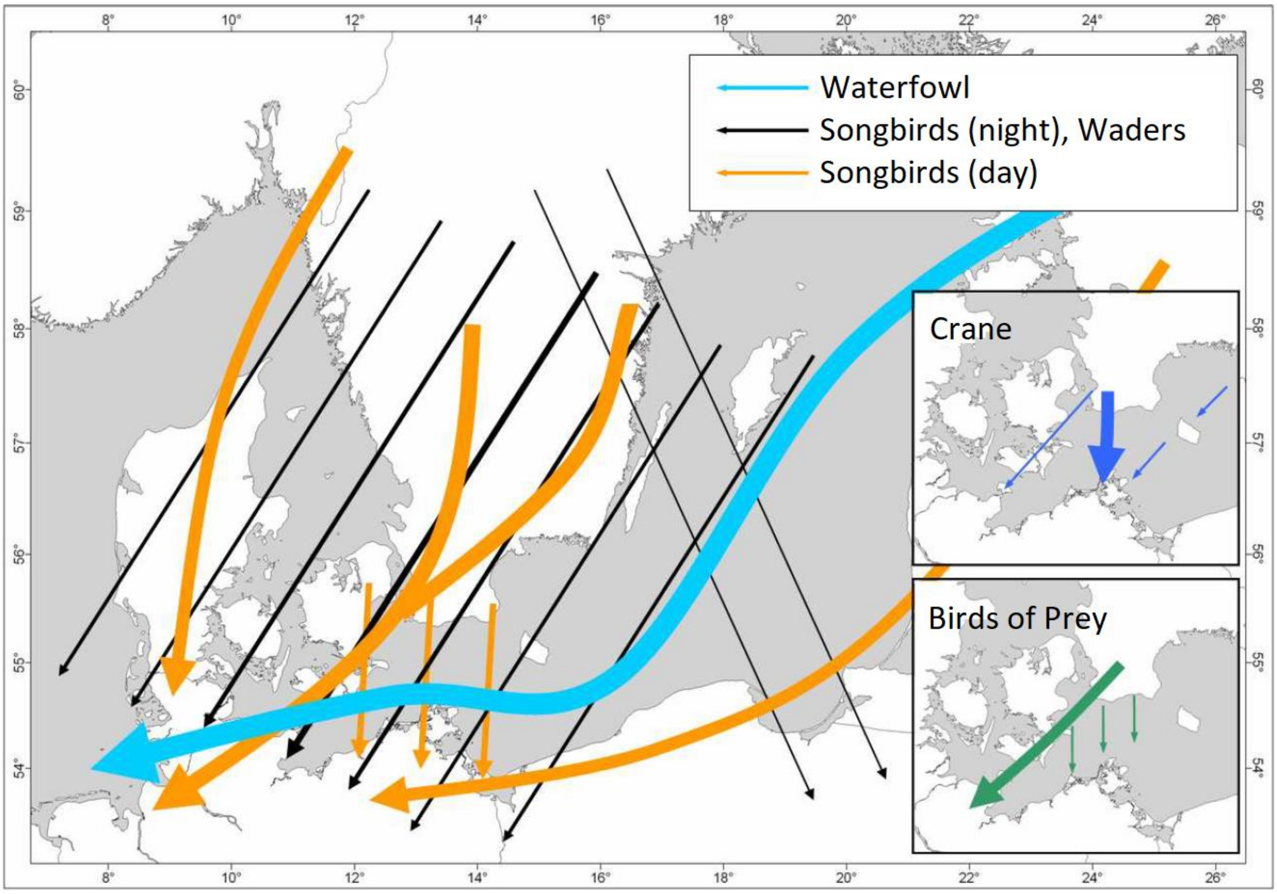


Figure 9. Most important migration routes in the Baltic Sea during autumn. From Bellebaum et al. (2010a). Arrow thickness indicates frequency with which routes are used.

DIVERS (RED-THROATED DIVER AND BLACK-THROATED DIVER)

Divers, also called loons, include five species of fish-eating birds strongly linked to aquatic environments that inhabit the taiga and tundra regions of the Holarctic. All divers are migratory, breeding in freshwater lakes and spending the winter season at sea (Hemmer 2020). Two diver species are commonly found in the Baltic Sea, the red-throated diver (*Gavia stellata*) and the black-throated diver (*Gavia arctica*). While black-throated divers choose fish-rich inland lakes for breeding, red-throated divers prefer small fish-devoid water bodies and search for their food at larger waterbodies or at sea (Eriksson 2010, Hemmer 2020). Both species mainly breed in Scandinavia and in Russia (Durinck et al. 1994).

Both species are widely distributed in the Baltic Sea. Most individuals occur in the Gulf of Riga at waters less than 30 mof depth (Durinck et al. 1993). Other important areas are located off the coast of Lithuania and the Pomeranian Bay (Durinck et al. 1994). According to both studies, most divers winter offshore at waters with depth ranging between 5 and 30 m.

Estimates of wintering populations inhabiting northwest Europe of red-throated divers ranged from 150,000 to 450,000 and 250,000 – 500,000 for black-throated divers (Mendel et al. 2008, Skov et al. 2011). Both species show a declining population trend. More recent evaluations estimate 210,000 – 340,000 wintering red-throated divers individuals in NW Europe (WETLANDS INTERNATIONAL 2022, AEWA CSR 8, accessed on 30.04.2024). The population of black-throated divers inhabiting northern and western Europe and Siberia is estimated at 390,000 – 590,000 individuals (WETLANDS INTERNATIONAL 2022, AEWA CSR 8, accessed on 30.04.2024).

Whereas the largest densities of diver species are reported for the Gulf of Riga (> 10 ind./km², Durinck et al. 1994), densities at Rønne Banke have been estimated as intermediate (1-2 ind./km², Durinck et al. 1993). Both diver species are also often found at the Adler Grund and Odra bank (Durinck et al. 1993). A monitoring study conducted for the preliminary site O-1.3 (now named 'Windanker'), located southwest of the pre-investigation area found that highest densities of divers occur at areas that are relatively shallow and located closely to the Adlergrund (BioConsult SH et al. 2020a). During the year, divers are expected in the pre-investigation area from June to November. Large densities are expected in winter (January and February), followed by a decrease as individuals will leave the pre-investigation area to migrate to their breeding grounds. From July to September both divers are expected to occur in the pre-investigation area only sporadically.

Besides very few black-throated divers also being present during summer in the SPA Pomeranian Bay south of Bornholm (Mendel et al. 2008), both species use the western Baltic Sea including the pre-investigation area almost exclusively as wintering and staging grounds and as a migration corridor to wintering areas further south and west, such as the North Sea or Atlantic coastal waters. These are predominantly divers breeding in northern Russia (Mendel et al. 2008, Dorsch et al. 2019), which will arrive in or cross the pre-investigation area from October to January, and leave in June. Bellebaum and colleagues (2010a) reported higher numbers of migrating red-throated divers near the coast as opposed to areas further offshore for the western Baltic Sea, assuming a more southward concentration of spring migration along the German coast and an autumn migration further north with counts of 4,000 individuals passing between the Swedish Skåne coast and Bornholm. GPS tracks of about 20 tagged red-throated divers (Dorsch et al. 2019) suggest that individuals are rather evenly spread across the western Baltic Sea including the pre-investigation area and did not confirm these patterns.

Flight heights of both diver species are generally estimated to be low. Especially during headwind situations divers tend to fly close to the water surface. They will usually not be observed flying higher than 50 m-, and often just up to 10 m off the water surface (Krüger & Garthe 2001, Bellebaum et al. 2010b, BioConsult SH et al. 2020b).

Both diver species are not considered threatened at a global scale. The IUCN categories and the recent Birdlife International Red List for Europe (BirdLife International 2021) considered them as species of least concern. Nevertheless, their populations have decreased and since they are among the seabird species most vulnerable to many anthropogenic factors, they are included in the Annex I of European Union (EU) Birds Directive (Council Directive 2009/147/EC on the conservation of wild birds, European Union 2010) and in the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA, UNEP/AEWA Secretariat 2019). Moreover, their wintering populations are considered critically endangered (CR) by HELCOM (HELCOM 2013b).

Oil spills, habitat degradation and being bycaught by fishing nets are the most common threats for divers (Mendel et al. 2008). Additionally, contamination in lakes for example by mercury pollution may affect their reproduction (e.g., Eriksson 2015). Ship traffic and offshore wind farms (OWFs) have been shown to have detrimental effects on divers in terms of displacement. They display strong avoidance behaviour towards OWFs (Dierschke et al. 2016), which can be noticeable up to a distance of 16 km away from OWFs (Mendel et al. 2019).

GREAT CORMORANT

Two of the six subspecies of the great cormorant (*Phalacrocorax carbo*) may occur in Northern Europe: *P. carbo carbo* and *P. carbo sinensis*, the latter is the subspecies that may occur in the pre-investigation area. Cormorants are diving birds that mainly feed on Atlantic herring, European perch, European eelpout, cyprinids and European sprat among other species found in the Baltic Sea (e.g. (Boström et al. 2012a b, Larsson 2017).

According to population estimates by Birdlife, 828,000 – 1,030,000 great cormorant individuals are found across Europe (BirdLife International 2021). In the Baltic Sea they occur during the whole year but mainly associated to coastal habitats. Great Cormorants can be attracted to OWFs and other man-made structures, as these provide them with resting sites, thus allowing them to expand their foraging grounds further offshore (Dierschke et al. 2016).

During the 19th century, the species went almost extinct. After protection measures established in the mid-20th century the population increased in the Baltic with a total of 190,000 – 210,000 breeding pairs occurring in the entire region and around 27,000 breeding pairs in Denmark in 2012 (Herrmann et al. 2014). Recent IUCN assessments consider them as a least concern (BirdLife International 2021). Besides the common threats affecting most sea birds like oil spills, habitat degradation and fishing nets, great cormorants may suffer from conflicts with the fishing industry. Since their diet includes fish also utilised by humans, they have been blamed for potentially reducing fish stocks. Although a reduction of perch was associated to the colony size of cormorants, no significant results were observed for other species (Östman et al. 2012). Most probably, the relationship between cormorants and fish is more complex and further research is needed (Ovegård et al. 2021).

GEESE AND SWANS

At least three goose species of the *Anser* genus, two “black” *Branta* species of barnacle and brent goose, and three species of swans migrate annually through the Southern Baltic region. In general, these species are either polytypic (except for *Branta leucopsis* and two of the swan species), or if monotypic, have populations that rarely exchange genetic material. Most geese breed on lakes, pools, rivers and in a variety of wetland habitats and winter on farmland in open country or in swamps, lakes, saltmarshes and coastal lagoons further south than their breeding areas (Scott & Rose 1996). Moreover, the subspecies or populations of geese and swans that may be encountered in the southwestern Baltic Sea have all increased in size in the last decades partly because of protection of their main wintering and staging sites in northwestern Europe, and also a reduction of hunting pressure on some of these species (for example, *Branta leucopsis*).

Whereas the specific biology and requirements of each of the species mentioned here varies, mostly all of them follow the same migration pattern. They start their migration towards the wintering areas (e.g., close to the Pomeranian Bay, or further southwest in Denmark and the Netherlands) by September, reaching peak numbers in January and February in their winter quarters and migrate back to their breeding areas from March onwards (Scott & Rose 1996).

Only the greylag goose (*Anser anser*) breeds relatively close to the pre-investigation area (Southern Sweden, Northern Germany) and migrates further south in winter, whereas some of the populations of the barnacle goose (*Branta leucopsis)* have recently established new breeding sites in these regions (Feige et al. 2008). Details on the distribution and abundance of the species (i.e., subspecies to occur in the pre-investigation area) are provided in Table 4.

Table 4. Breeding and wintering regions, as well as estimates of population size and conservation status for the most common geese and swan species expected to migrate over the pre-investigation area. *LC: Least Concern, VU: Vulnerable.* INC: Increasing, STA: Stable, DEC: Decreasing

Species (subspecies/ Population) [1]	Breeding region[1]	Wintering region[1]	Most recent population estimate[2] (Trend) [2] Pop. 1% level[2]	Conservation status		
				European Birds Directive	AEWA	Red List Birdlife 2021
Bean goose (5 subspecies) *Anser fabalis fabalis*	The taiga zone from northern Scandinavia and northwest Russia to the west Siberian	The coasts of Poland and Eastern Germany, and in Southern Sweden,	82,000 – 97,000 (INC?) **520**	II/A	A 3c*	LC

	lowlands east of the Ural Mountains	Denmark and the Netherlands				
Greater white-fronted goose (5 ssp): *Anser albifrons albifrons* (western population)	In the Arctic tundra from the Kanin Peninsula in European Russia east to the Kolyma River	Northwest Europe from Germany to France and Britain, with the major concentrations in the Netherlands; in central Europe	1,000,000 – 1,200,000 (STA) 12,000	III/B	C1	LC
Greylag goose (2 ssp): *Anser anser anser* (population NW Europe/South-west Europe)	Breeds west of the Urals (Norway, Sweeden, Denmark and Germany)	Throughout southern and western Europe south to North Africa (Morocco to Tunisia).	710,000 – 780,000 (2016 – 2018) (STA) 9,600	II/A, III/B	C1/B1	LC
Barnacle goose (monotypic) *Branta leucopsis*	Greenland, Svalbard and northern Russia	In northwest Europe (mainly Ireland, Britain, Germany and the Netherlands).	1,400,000 (2018) INC 12,000	I	C1	LC
Brent goose (four ssp) *Branta bernicla bernicla*	High latitudes in Eurasia	*B. b. Bernicla* migrates through the White Sea and Baltic to staging areas in the Dutch, German and Danish Wadden Sea and wintering areas mainly in England and France	211,000 (2011) INC? 2,100	II/B	B 2b	LC
Whooper swan (monotypic, but four populations) *Cygnus cygnus*	Population breeding in Fennoscania and northwest Russia	Winters in northwest continental Europe	138,500 (2015) INC 1,200	I	C1	LC
Bewick's swan (three ssp) *Cygnus columbianus bewickii*	Northwest Russia	Denmark, the Netherlands, Britain, Ireland	21,000 (2015) DEC 220	I	A2	VU

Mute swan (monotypic) *Cygnus olor*	Western and central Europe (populations largely sedentary)	Eventually in cold winters moving further south	260,000 – 300,000 INC/STA 2,000	II/B	C1	LC

[1] From Scott & Rose (1996)

[2] Columns from population sizes taken from Wetlands International (2022, AEWA CRS 8, retrieved on 24.02.2022).

In general, the number of geese and swans migrating across the western Baltic Sea and potentially through the pre-investigation area may vary considerably. A preliminary survey of migrating birds between 2016 and 2018 in a nearby site (the site O-1.3, south-west of the pre-investigation area) has shown that geese may comprise a large proportion of the total number of birds during the autumn migration. In 2016, similar numbers of geese were observed during the spring and autumn migration (700 – 1,100), but in 2017, a much higher number was noted during the day autumn migration (> 12,000 geese) representing more than 50 % of all registered migrating birds observed in that season (BioConsult SH et al. 2020b).

Regarding observed migration altitudes geese often fly at high altitudes. The barnacle goose is for example known to fly at faster speeds and higher altitudes in spring than in autumn (341 m vs 215 m, Green & Alerstam 2000).

As already mentioned, the populations of these species have increased in recent years. However, this increase has also resulted in some conflict with humans. *B. b. bernicla* has increasingly turned to new food sources grazing on cultivated crops near the coast, causing a conflict with farmers, for example in Britain (Salmon & Fox 1991). As a result, and a possible solution, studies have been conducted to evaluate whether an increase of the hunting bag for some of these geese species could help to control their populations without representing a threat. Similar conflicts arise with many of the other species, and except for the barnacle goose no other species of these waterbirds is listed under the Annex I of the Birds Directive.

Similarly due to their relative large sizes and heavy bodies, their large numbers during migration and their socially interactive nature makes them largely susceptible to collision risk with wind turbines (Rees 2012). Nevertheless, there is relatively little information of the collision risk for these birds and much of it is neither available nor reported (Rees 2012). Geese and swans are known to show avoidance behaviour to wind farms. Almost 95 % of pink-footed geese (*Anser brachyrhynchus*), a species which is more often encountered in the North Sea, showed strong vertical and horizontal avoidance behaviour as a response to offshore wind farms (Plonczkier & Simms 2012). Moreover, these authors also showed that during periods of reduced visibility geese tended to fly at lower altitudes (100-150 m) compared to periods of good weather conditions when they flew higher (250-300 m). Nevertheless, they said that in their study most of the migration took place early in the afternoon under favourable conditions, thus possibly reducing the risk of collision (Plonczkier & Simms 2012).

SEA DUCKS

Sea ducks spend their non-breeding season in marine environments feeding mainly on bivalves (Madsen 1954, Meissner & Bräger 1990, Mendel et al. 2008). The Baltic Sea offers important moulting and wintering sites for sea ducks with individuals mainly located in coastal waters and shallow offshore banks, where they can easily dive to obtain their food (e.g. (Bräger et al. 1995)). Among the most common and abundant sea ducks that may occur in the survey area are long-tailed ducks, common eiders, common scoters and velvet scoters. In general, all sea duck populations have suffered from declines in recent years (e.g., Durinck et al. 1993, Mendel et al. 2008, Bellebaum et al. 2012, Nilsson & Haas 2016). They are subject to many anthropogenic threats including oil pollution, risk of being bycaught in fishing nets and habitat degradation (Mendel et al. 2008, Bellebaum et al. 2012, Nilsson 2016). In addition, breeding populations may suffer predation from gulls and other different raptor species such as white-tailed eagle (Bellebaum et al. 2012). Some sea duck species such as common scoters are strongly disturbed by ship traffic showing long escape distances, while others may be less disturbed (Fliessbach et al. 2019). The same applies to the disturbance caused by OWFs, as the reaction differs among species as well (e.g. PETERSEN & FOX 2007; PETERSEN ET AL. 2014; DIERSCHKE ET AL. 2016).

LONG-TAILED DUCK

Large numbers of long-tailed ducks (*Clangula hyemalis*) frequently rest in the pre-investigation area either during migration or to spend the winter there. Therefore, long-tailed ducks are presented in detail in the first part of this report that deals with resting birds.

COMMON EIDER

Large numbers of common eiders (*Somateria mollissima*) frequently rest in the pre-investigation area either during migration or to spend the winter there. Therefore, common eiders are presented in detail in the first part of this report that deals with resting birds.

During this migration, individuals are generally headed north. Large flocks have been continuously observed crossing the areas of Fyn and Sjælland, as well as the Kalmar sound located between Öland and the Swedish mainland (Alerstam et al. 1974). In an extensive study combining data from 1975 until 2001 of wintering common eiders in southern Scandinavia, Peterz (2003) found that the majority of birds was migrating through the Öresund, then following the southeastern coasts of Sweden.

COMMON AND VELVET SCOTER

Large numbers of common and velvet scoters (*Melanitta nigra* and *M. fusca*) frequently rest in the pre-investigation area either during migration or to spend the winter there. Therefore, the two scoters are presented in detail in the first part of this report that deals with resting birds.

During migration, thousands of common scoter individuals pass the areas along the Baltic Sea coast crossing the Fehmarn Belt to reach their moulting grounds (Berndt & Busche 1993). Leaving their breeding grounds, they migrate to their wintering areas mainly located in the western Baltic Sea, as well as the North Sea and the northern parts of the Atlantic coast (Mendel et al. 2008).

Information regarding migration routes of velvet scoters is scarce. So far, it has only been determined that two populations are wintering in the Baltic Sea: individuals from the White Sea and northern Russia, as well as local breeding populations from Estonia, Finland and Sweden (Paakspuu 1989, Meissner et al. 2012).

BIRDS OF PREY

Birds of prey, also known as raptors, are all top predators. About 39 species of breeding diurnal birds of prey are inhabiting Europe (Stroud 2003). More than half of the species known worldwide (at least 62 % or 183 species) undertake seasonal migrations with many of them being long-distance migrants undertaking sometimes intercontinental flights (Bildstein 2006). Most birds of prey can soar, meaning they are able to maintain flight without flapping their wings by making use of the rising air currents and thereby reducing energetic costs. Soaring is an efficient form of transport, both during and outside of long-distance migration (Bildstein 2017). Especially long-distant migrants are strongly dependent on soaring flight. Other species such as ospreys, harriers and most accipiters and falcons migrate with powered flight by flapping their wings. Most raptors are day migrants, but few species such as peregrine falcons, ospreys and merlins also migrate during nights.

The migration corridors of raptors, which often travel in flocks, are well-known (Bildstein 2006). Their most important flyway in Europe is the Western European-Western Africa flyway (Bildstein 2017). A comparative study of satellite tracking and ring recoveries for four common raptor species gathered detailed information on the taken routes (Strandberg et al. 2009).

Close to the pre-investigation area at Falsterbo in South Sweden, raptor autumn migration has been studied since the early 1940s (Kjellén & Roos 2000), whereas standardized counts of raptors and other migratory birds have been conducted since 1973 (Kjellén 2019). An average of 46,000 migrating raptors and falcons are observed annually. The most common species there are the Eurasian sparrowhawk (*Accipiter nisus)*, the Common Buzzard (*Buteo buteo)* and the Red Kite (*Milvus milvus)* (Kjellén 2019). Species with more southerly distribution breeding close to Falsterbo are more commonly observed compared to species with northerly distributions (Kjellén 2019). Similarly, thermal migrants tend to be more concentrated than active flyers at Falsterbo. Since raptors tend to fly at lower altitudes in these regions, the concensus at Falsterbo have been particularly important for raptor studies (e.g., Kjellén 1997).

The numbers of the most common birds of prey have either increased or remained stable within the last decades (cf. Kjellén 2019). Three species show negative trends at Falsterbo: the European honey buzzard (*Pernis apivorus),* the rough-legged buzzard (*Buteo lagopus)* and the northern gosshawk (*Accipiter gentilis)* (Kjellén 2019). In comparison to a previous study on the trends of raptors from 1940s to the late 1990s in the same area, there seems to be a slight recovery of raptors currently migrating through Falsterbo (Kjellén & Roos 2000, Kjellén 2019).

There is, however, a large variation in the number of raptors being observed during the autumn migration every year. This may not only be linked to more birds being counted under favourable weather conditions. When birds fly against the wind, they tend to fly at lower altitudes and may be more easily observed and thus counted. It could also be caused by changes in population numbers due to changes in reproduction. Species like the Eurasian honey buzzard and the rough-legged buzzard are known to produce varying numbers of juveniles depending on the availability of prey such as wasps or rodents during the breeding season (Kjellén 2019).

Table 5. Population size estimates, trends and average numbers of raptors observed at Falsterbo in Sweden between 1942-1960 and 1973-2019. The conservation status for the most common raptor species expected to migrate over the pre-investigation area is given as well. ***LC: Least Concern, VU: Vulnerable***

Species	Most recent population estimate (Trend)[1]	Annual average numbers at Falsterbo (1942-1960)[2]	Average autumn migration numbers at Falsterbo[3]	Conservation status		
				European Birds Directive	CITES	Red List Birdlife 2021
Eurasian sparrowhawk (*Accipiter nisus*)	728,000-1,150,000 (STA)	5,944	20,364	I (only ssp *granti*)	II	LC
Common buzzard (*Buteo buteo*)	1,760,000-2,460,000 (INC)	17,086	14,383		II	LC
European honey buzzard (*Pernis apivorus*)	241,000-350,000 (STA)	7,979	6,491	I	II	LC
Red kite (*Milvus milvus*)	65,100-76,600 (INC)	51	1,305	I	II	LC
Rough-legged buzzard (*Buteo lagopus*)	57,600-11,700 (STA)	139	889		II	LC
Common kestrel (*Falco tinnunculus*)	823,000-1,270,000 (DEC)	271	690		II	LC
Western marsh harrier (*Circus aeruginosus*)	303,000-485,000 (STA)	28	659	I	II	LC
Osprey (*Pandion haliaetus*)	19,200-27,100 (INC)	68	270	I	II	LC
Hen hHarrier (*Circus cyaneus*)	112,000-174,000 (DEC)	46	264	I	II	LC
Merlin (*Falco columbiarius*)	40,100-83,400 (DEC)	128	236	I	II	VU

[1] Population sizes taken from Birdlife International (2021)

[2] Average numbers observed at Falsterbo between 1942-1960 from (Bijleveld 1974)

[3] Average numbers observed at Falsterbo between 1973-2019 from (Kjellén 2019)

Bornholm is not known as an important migration site for raptors. However, a variety of species, some of them in considerable numbers, are observed at Dueodde, the southern tip of the island during autumn. Particularly the number of Rough-legged buzzard is noteworthy in some years, see Table 6.

Table 6. Numbers of migrating raptors at Dueodde at Bornholm 2010-2021. The numbers are "maximum numbers", i.e. the highest number of raptors observed during a year in the period. Data from DOF-basen (2022).

Species	Max number 2010-2021
Eurasian sparrowhawk (*Accipiter nisus*)	202
Goshawk *(Accipiter gentilis)*	3
Common buzzard (*Buteo buteo*)	370
European honey buzzard (*Pernis apivorus*)	54
Rough-legged buzzard *(Buteo lagopus)*	211
Red kite (*Milvus milvus*)	14
Hobby *(Falco subbuteo)*	3
Red-footed falcon *(Falco vespertinus)*	2
Merlin (*Falco columbiarius*)	15
Hobby *(Falco subbuteo)*	23
Common Kestrel (*Falco tinnunculus*)	128
Peregrine *(Falco peregrinus)*	2
Hen harrier (*Circus cyaneus*)	3
Marsh harrier (*Circus aerginosus*)	11
Pallid harrier *(Circus macrourus)*	1
Osprey (*Pandion haliaetus*)	9
White-tailed eagle (*Haliaeetus albicilla)*	1
Bonelli's eagle (*Aquila fasciata*)	1
Golden eagle (*Aquila chrysaetos*)	1
Total	**1,054**

As top predators, most birds of prey are k-selected species , meaning they have relatively little annual reproduction and their young require many years to mature before breeding (Dwyer et al. 2018). Thus, they have naturally low densities. The population sizes of raptor species are relatively small compared to other breeding birds. Their life-history traits and their high trophic level make them extremely susceptible to anthropogenic threats such as land use change, direct killing, poisoning and environmental contaminants, electrocution and climate change. They are among the most threatened group of birds in the world (McClure et al. 2018). In Europe, the most influential impacts affecting the populations of the most vulnerable diurnal raptor species include habitat loss/change, intensification of agricultural habitats, direct persecution (e.g. shooting), pesticide contamination, disturbance of nest sites and many others (Stroud 2003).

Due to the particular vulnerability of birds of prey and the reduction of their population sizes caused by numerous threats during the first half of the last century (Bijleveld 1974, Bildstein 2017), they are among the rarest birds in Europe: 46 % of European birds with less than 1,000 breeding pairs are birds of prey (Stroud 2003). Thus, many of the species are protected by European legislation and have also been included in other conventions (see Table 5) for the most common species likely crossing through the Baltic Sea).

Direct mortality from collisions with wind turbines are relatively common in birds of prey. The killing of hundreds of individuals by wind turbines were already observed with the first large wind farms placed in Altamont Pass in California and have been documented in many other places ever since. In Germany, in March 2013 at least 37 % of all reported bird collisions corresponded to birds of prey confirming that they made up a disproportionately large amount of all collisions (Hötker 2017). Some species were especially susceptible. Among them were red kites whose breeding populations in Germany have been rapidly declining since 1991 (Mammen et al. 2017).

Despite the estimates of collision rates being very variable and the difficulty of obtaining reliable data, some overall findings and conclusions have been achieved from a German database (Rasran & Dürr 2017). According to this study, most frequently killed birds were red kite and common buzzards, but other species such as white-tailed eagles, common kestrels and black kites were also often reported as victims. Most collision victims were adult birds mainly occurring in spring and late summer (Rasran & Dürr 2017). The collision risk directly depends on the rotor swept area. red kites often flew at heights within the rotor swept area. It was found that up to 50 % of all recorded red kite flights led into the risk area of wind turbines (Mammen et al. 2017).

Whereas collisions have been documented for at least 34 species of birds of prey, the effect this may have on population level has been explored for comparatively fewer species. For example, a study modelling the population of red kites in Germany has predicted a further decline due to additional mortality from collisions with wind turbines (Bellebaum et al. 2013). Indirect effects such as modifying flight altitudes to avoid wind farm collision and displacement and effective habitat loss have also been studied for different species. Golden eagles for example are apparently able to detect and avoid turbines during migration after the construction of wind farms (Johnston et al. 2014). Black kites have been found to reduce the use of areas up to 674 m away from turbines with an estimated loss of 3-14 % of the suitable areas at the migratory bottleneck of the Strait of Gibraltar (Marques et al. 2019). Further examples of study cases of the effects of wind turbines on different birds of prey are reviewed by Watson and colleagues (2018).

COMMON CRANES

The population of common cranes breeding in Northwest Europe and Scandinavia increased and is estimated to support approximately 350,000 individuals (Wetlands International 2022, AEWA CSR 8, retrieved on 25.02.2022). Especially for cranes inhabiting Finland and Sweden, the Southwestern Baltic Sea is an integral part of their migration route to and from wintering quarters in Southwestern Europe. The Rügen-Bock region in Germany is an important resting area, hosting temporarily up to 40,000 individuals (Bundesamt für Seeschifffahrt und Hydrographie 2021). A huge part of these birds crosses the Arkona basin in a 1–2-hour flight. Especially in autumn, a proportion of cranes will also move in a southwestern direction over the area of Bornholm (Figure 10). A study by Skov et al. (2015) reported that telemetry data obtained from cranes showed that individuals used a broader corridor crossing the area anywhere between Bornholm and the coast of Sjælland, Møn and Falster.

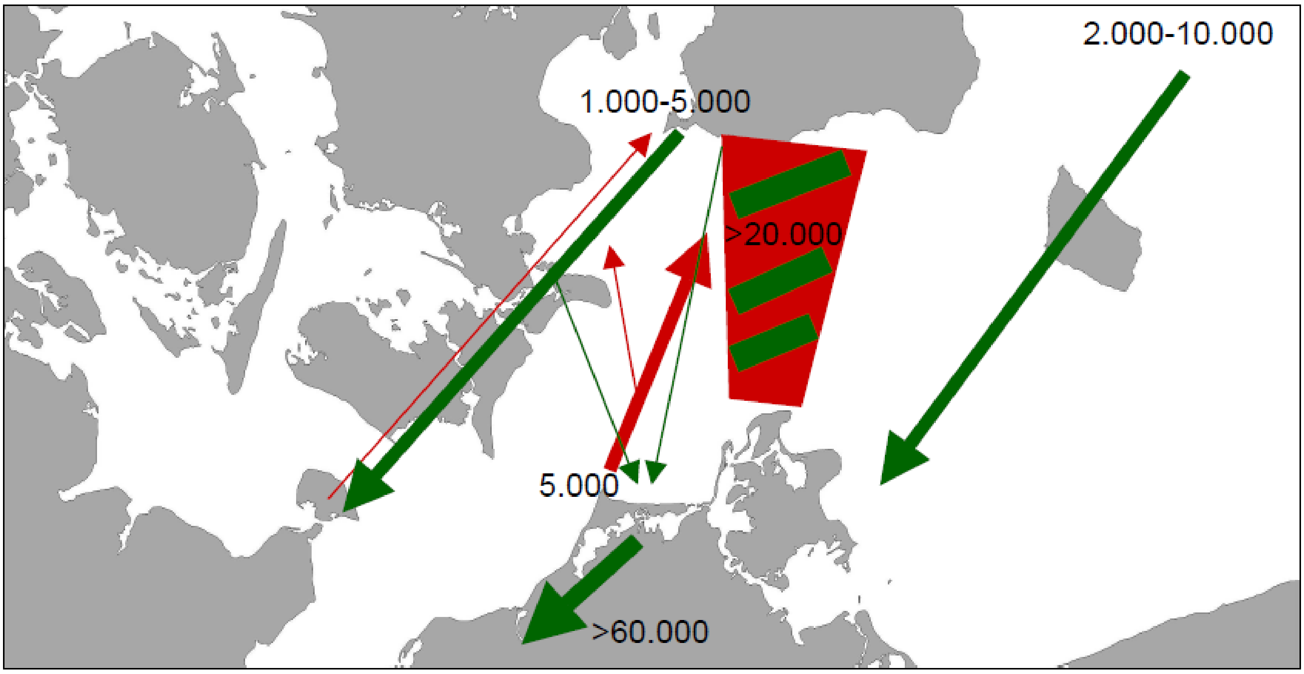


Figure 10. Migration routes of common cranes in the southern Baltic area (BSH 2021 based on Falsterbo, Bornholm and other observation data). Estimated numbers may be higher today due to an increasing population trend.

At Bornholm, the common crane is a relatively common breeding bird, and the island probably holds the densest population of breeding pairs in the country. During the latest Danish breeding bird atlas, at least 70 pairs were counted in a population still increasing (Vikstrøm & Moshøj 2020). The number of migrating cranes is highly dependent on wind conditions with the highest number observed during periods with westerly winds and generally more birds counted during autumn compared to spring (Table 7).

Table 7. Monthly distribution of the number of common cranes observed at Bornholm 2010-2022. The numbers are "maximum numbers", i.e. the highest number of birds observed on a day each month (DOFbasen 2022).

Month	Max number
January	14
February	55
March	200
April	220
May	35
June	13
July	45
August	126
September	3,814
October	8,885
November	200
December	3
Total max number per year (2010-2022)	13,610

Due to the increasing population, the common crane currently is listed as a species of least concern (BirdLife International 2021). However, its susceptibility to increasing offshore wind power generation remains unclear. One important behavioral trait in this regard might be the flight height of cranes crossing the Baltic Sea. They tend to use soaring flight over land, but due to the lack of thermal updrafts over the open water, they have to gain or hold their altitude in powered flight after leaving the coasts (Alerstam 1990). Studies of flight altitudes of cranes in the Baltic offshore region so far revealed a certain variety, with cranes observed flying clearly below 200 m of height as well as far above (Schulz et al. 2013, Skov et al. 2015).

GULLS

The general term 'gulls' groups different species of small-bodied and larger gulls (genus *Larus*). The first include two species that may occur frequently in the pre-investigation area: the black-headed gull (*Chroicocephalus ridibundus)* and little gull (*Hydrocoloeus minutus*). All gull species are opportunistic and omnivore feeders. Little and black-headed gulls feed mainly on insects and crustaceans whereas large gulls feed mainly on small or medium-sized fish (Mendel et al. 2008). Except for the great black-backed gull (L*arus marinus*) they tend to be gregarious. While little gulls may be slightly affected by offshore wind farms avoiding these areas, other species are known to be attracted by OWF structures (Dierschke et al. 2016).

COMMON GULL

In the Baltic Sea, common gulls (*Larus canus*) breed along the coast mainly in Sweden and Finland. These gulls are mainly migratory; some birds winter in the northeast and southern Baltic Sea, but most overwinter in the North Sea (Durinck et al. 1994).

Common gulls may occur in the area throughout all year but might be more numerous in winter. West of Bornholm they may be found at mid to high densities (1-5 ind./km^2, Durinck et al. 1994), but south of it and in most part of the pre-investigation area they may not be so numerous (BioConsult SH et al. 2020a). Previous surveys indicated they were distributed over most of the Baltic Sea (Durinck et al. 1993). On Græsholm for example, there were colonies with around 5,000 pairs of common gulls by the 1920s. Forty years later no more breeding individuals could be found in this region. The decline was probably caused by competition with herring gulls for nesting sites (Lyngs 1992). They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021).

LESSER BLACK-BACKED GULL

Lesser lack-backed gulls are distributed throughout Europe. Three subspecies exist: the eastern variation *Larus fuscus fuscus,* which breeds from Sweden to Northern Norway and eastwards to Russia. The western variation *L. f. graelssii* breeding from Southwest Greenland to Iceland to Spain and the intermediate form *L. f. intermedius* mainly occuring in the Netherlands and Denmark (Mendel et al. 2008). In Denmark, two of these subspecies may occur (*L. f. fuscus* and *L. f. intermedius*). Almost two decades ago, estimates suggested a population of 300,000 to 350,000 breeding pairs of lesser black-backed gulls (Mendel et al. 2008).

In the Baltic Sea, close to the pre-investigation area, comparatively fewer lesser back-backed gulls are expected than along the coasts of the North Sea. In the Pomeranian Bay, they may be seen mainly in summer and autumn (Mendel et al. 2008). They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021).

GREAT BLACK-BACKED GULL

The great black-backed gull *(Larus marinus*) occurs in small numbers in the Baltic Sea east of Rügen throughout the year. The highest populations are observed in winter when birds migrate southward from northern sites. One of the important wintering areas for this species is the Bornholm deep located west of the island of Bornholm (Durinck et al. 1994). In the preliminary site O-1.3 directly west of the pre-investigation area, densities of around 0.1 ind./km² were observed during digital aerial surveys flown in winters (BioConsult SH et al. 2020a). They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021).

HERRING GULL

The numbers of herring gulls (*Larus argentatus*) have increased in Denmark during the last decades. While the first censuses of 1920 estimated a population of around 3000 pairs, more recent counts in 2010 estimated roughly 87,000 pairs. Currently, declining population trends of partially significant magnitude in the Baltic region for example in Finland have been reported (Hario & Rintala 2016, Wetlands International 2022, retrieved on 03.03.2022). Most of the growth of the population occurred after the 1960s and parallels the growth observed in north-western Europe, apparently linked to an increase due to protection measures and the availability of additional food resources for example by garbage dumps and fisheries discards (Bregnballe & Lyngs 2014).

The development of the population of herring gulls differed between eastern and western Denmark. Before the mid-seventies, most herring gulls bred in the eastern part of Denmark (61 %, Bregnballe & Lyngs 2014), with the colony of Ertholmene being the second largest colony in Denmark (Lyngs 1992). Around 1974, the government installed culling programmes in the largest colony, which resulted in a decline of the entire breeding population and shifted their centre of distribution towards the western part of the country (Bregnballe & Lyngs 2014). Although herring gulls breeding at Ertholmene have reduced from about 20,000 pairs in 1970s (Lyngs 1992) to about 9,000 pairs (Bregnballe & Lyngs 2014), the breeding colony is still important. They are considered as a species of least concern based on the recent IUCN Red List (BirdLife International 2021), but listed as vulnerable in the HELCOM Red List (2013a).

Herring gulls arrive to the colony between mid-January and late February. Egg laying starts in April peaking at the end of the month and individuals leave the colony from mid to late August (Lyngs 1992). Herring gulls are regarded as the most common gull species in the offshore sites of the German Baltic Sea. In a previous study of the preliminary site O-1.3, herring gulls were widely distributed over the pre-investigation area during all seasons with exception of one summer (BioConsult SH et al. 2020a). Thus, their occurrence is expected in the pre-investigation area.

TERNS

Terns are in general not common in the Baltic Sea and thus around the pre-investigation area. Most common species are the sandwich tern (*Thalasseus sandvicensis*), the Arctic tern (*Sterna paradisea*) and the common Tern (*Sterna hirundo*). Sandwich terns were not breeding in the Baltic Sea region at the beginning of the 20th century (Herrmann et al. 2008). The Danish population of sandwich terns was estimated at 4,700 breeding pairs in 2006, but the majority bred in the North Sea region (Herrmann et al. 2008). The population breeding in the Baltic Sea (mainly Kattegat area) varied from 500 to 2,000 breeding pairs between 1993-2007 (see Herrmann et al. 2008). Except a possible breeding attempt of sandwich tern in 2012, there have been no records of breeding terns on Bornholm or Ertholmene in recent time (Vikstrøm & Moshøj 2020, DOFbasen 2022). In the Pomeranian Bay they may be observed sporadically between August and October, but mainly close to the coast (Mendel et al. 2008).

In an extensive study investigating the migration patterns of European Sandwich Terns, Møller (1981) described that this species typically migrates close to the coast flying a few meters above water level. Sandwich Terns are diurnal migrations with migration peeking during the morning and evening (Møller 1981). Arctic and Common Terns both migrate along the west coast of continental Europe following the East Atlantic Flyway (e.g. (Alerstam et al. 2019).

The Arctic and the common tern may also be observed close to the pre-investigation area, but mainly close to the coast and in the summer months. Although none of the tern species are expected to occur abundantly, they are seabirds requiring protection (all species are listed in Annex I of the European Birds Directive and under the AEWA), and at least the sandwich tern seems to react negatively towards OWF (Dierschke et al. 2016).

AUKS

Auk species typically found in the Baltic Sea are common guillemots (*Uria aalge*) and razorbills (*Alca torda*). Occasionally, other auks such as the Atlantic puffin (*Fratercula arctica*) and the black guillemot (*Cepphus grylle*) may appear as well. The black guillemot is one of the species for which Rønne Banke is considered an important bird area (Rasmussen et al. 2000). Over two thirds of the population of common guillemots and 30 % of the populations of razorbills breed on Störa Karlso (and Lilla Karlsö), two small islands located west of the island of Gotland, which are famous for hosting the largest fish-eating seabird colonies of the Baltic Sea (Olsson & Hentati-Sundberg 2017). Other colonies are located at different areas of the Baltic Sea, but most are relatively small. The second largest colony of common guillemots in the Baltic Sea is found on Græsholmen, a very small island north of the island of Bornholm, which hosts about 2,000-3,000 breeding pairs (Olsson et al. 2000). Lyngs (1992) suggests that there were 2,000 pairs of common guillemot and around 450 pairs of razorbills breeding in Græsholmen in the 1980s. In the early 2000s, the breeding pairs of razorbills had increased to 780 pairs (Lyngs 2001). The archipelago of Ertholmene is one of the Danish important bird areas and the only site in Denmark known to have breeding colonies of both auk species (Rasmussen et al. 2000).

Guillemots reach the colonies earlier than razorbills. While they may arrive as early as December, razorbills arrive by late February and early March. Common guillemots therefore occupy the breeding site earlier and start breeding earlier, too. Lyngs (1992) also mentions that chicks of common guillemots leave the colony from mid to late June, while razorbill chicks may remain until mid-July. It is therefore very likely that these birds will occur in the area in noticeable densities, especially in deeper waters. Previous digital aerial surveys conducted at the preliminary site O-1.3 south of Bornholm I found low to mid-densities of auks in the area. Especially during winter, they were widely spread throughout the pre-investigation area (BioConsult SH et al. 2020a).

Black guillemots may also concentrate in the Rønne Banke area, although they were only observed in relatively low numbers during the national Danish midwinter surveys (Petersen et al. 2016). An old census found areas with mid densities of Black guillemots in Rønne Banke (1.6 ind./km²) during winter (Durinck et al. 1993). Even larger densities of this species may occur in the Pomeranian Bay and south of Rønne Banke (Ode Bank, Adlergrund Bank; Durinck et al. 1994; Mendel et al. 2008). Compared to the other two auk species, black guillemots prefer shallower waters (depths < 25 m, Durinck et al. 1994). During the surveys conducted for the baseline study of preliminary site O-1.3, 25 and 74 individuals of black guillemots were counted on the digital aerial surveys of 2016/2017 and 2017/2018 respectively (BioConsult SH et al. 2020a).

While the two most common auk species have relatively stable populations or are increasing, other auk species are threatened (HELCOM HELCOM 2019a). In general, auks are long-lived, but start reproducing only after several years of life. Moreover, these species were heavily hunted by humans, and their populations almost got extinct. Both the common guillemot and the razorbill are listed a species of least concern under the IUCN Red List (BirdLife International 2021). Among the two other species that may rarely occur in the area, the black guillemot is listed as a species of least concern as well, whereas the Atlantic puffin is considered endangered (BirdLife International 2021).

SONGBIRDS (PASSERINES)

Passerines include more than half of all described bird species in the world and are also referred to as songbirds or perching birds, due to the arrangements of their toes, which facilitates perching.

Since songbirds include a very large number of species, it is not surprising that they also comprise most of the bulk of migrating birds. One of the best studied bird migration systems is the one involving the Palearctic-African flyway. The first evaluation of the number of passerine birds migrating between Europe and Africa birds by Moreau in 1972 estimated 4.3 billion (Hahn et al. 2009). Newer estimations suggest only half of this number (~ 2.1 billion birds) migrating from Europe to Africa every autumn with almost three quarters of those birds corresponding to the migration of 16 passerine bird species (Hahn et al. 2009).

This estimation corresponds to numbers of birds migrating from largest parts of Europe not only crossing the Western Baltic Sea, but it gives an impression of the importance of songbirds during migration. European songbirds show a variety of migration patterns and strategies of which a lot is still unknown (Busse 2001). European migrating songbirds typically travel from their breeding sites often located in the north of Europe to their wintering quarters located in warmer regions in southern Europe or northern Africa. Migration is often occurring in broad fronts instead of corridors (see Figure 11 for an example).

Songbirds can be long-distance migrants with their breeding wintering sites geographically separated by an area which the species is only crossing or using as a stopover site during migration. Other species are short-distance migrants with their wintering grounds being close to or overlapping with their breeding sites. For several species it is known that their populations only partially migrate. For example, there may be different migration patterns between sexes or ages or even populations (e.g., only northern populations of European robins are migratory, southern populations are resident and populations at intermediate distributions are partially migratory). According to the review by Busse (2001), at least 63 species of European songbirds are long-distance migrants, whereas 69 species can be classified as short-distance migrants (Busse 2001).

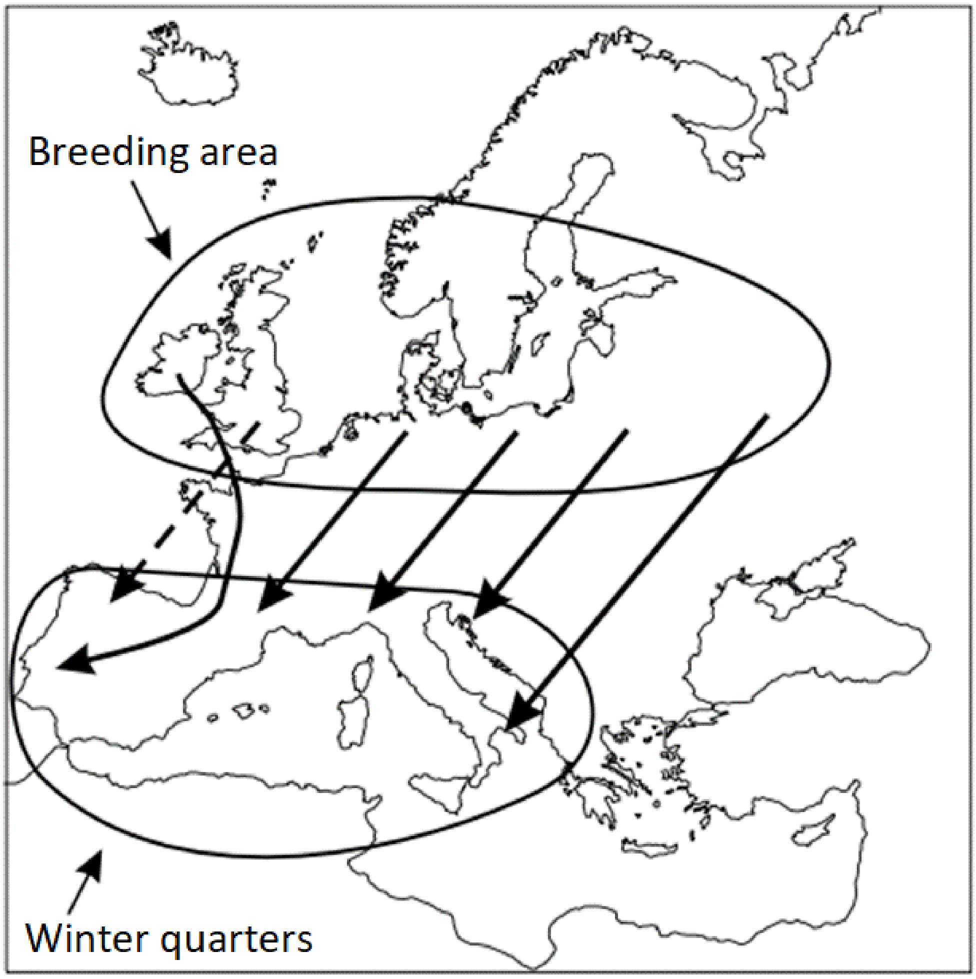


Figure 11. Example of broad front migration from the breeding region to the wintering quarter. Taken from Busse (2001, who modified it from Zink, 1973).

Most recent interpretations of migration studies and routes suggest that there might be four main passerine flyways in the Western Palearctic: 1) the Western/Atlantic flyway, 2) the Central/Apennine flyway, 3) the South-Eastern (Balkan-SE) flyway and 4) the Eastern (Indian) flyway, which are shown in Figure 12 (Busse et al. 2014). The different lines shown, connect breeding sites with wintering quarters (as summarized from ringing recovery studies). Most songbirds fly on these routes across broad fronts, but there are some passages with bottlenecks.

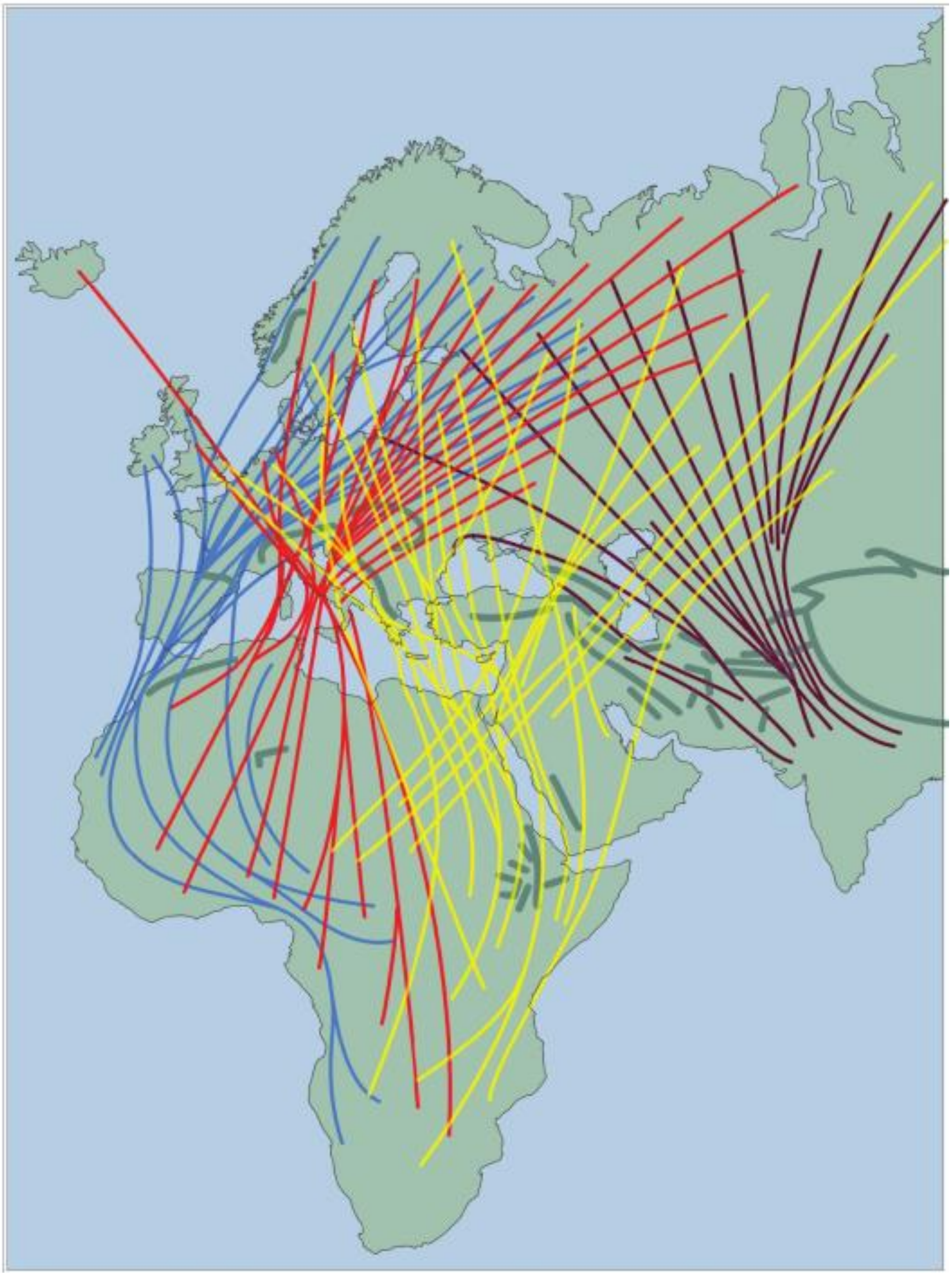


Figure 12. The four main fly way routes occurring in the Palearctic: 1) the Wwestern/Atlantic (blue), 2) the Central (Apennine, red), 3) South-Eastern (Balkan, yellow) and 4) Eastern (Indian, brown). Taken from Busse et al., 2014.

Migration of passerine birds occurs during day and night with species having adapted to migrate at a particular time of day. Most diurnal migrating species include low and mid-distance migrants, such as finches and wagtails, which are more dependent on visual orientation cues. Birds migrating during night are mid-distance migrants, such as thrushes and robins, as well as long-distance migrants such as warblers. They often travel in broader fronts (Bellebaum et al. 2010a). In Table 8, the most important passerine birds in terms of migrating numbers are shown.

As seen in Figure 11 and Figure 12, most common migrating songbirds cross the Western Baltic Sea in a SW direction in autumn (the flyway 1), Nevertheless there are some migrating in a SE direction (Bellebaum et al. 2010a).

Table 8. Breeding and wintering regions, as well as estimates of population size and conservation status for the most common day and night passerines potentially migrating over the pre-investigation area. LC: Least Concern, DEC: Decreasing, STA: Stable, INC: Increasing.

Species (subspecies/ Population)[1]	Day/ Night (D/N)	Breeding region[1]	Wintering region[1]	Most recent population estimate (Trend) [2]	Average autumn migration numbers at Falsterbo (1973-2019)[3]	Conservation status	
						European Birds Directive	Red List BirdLife 2021
European robin (8 subspecies) *Erithacus rubecula rubecula*	N	Fennoscandia and parts of Eastern/Central Europe	Southern Spain, NW Africa. The species is resident in southern distribution	109,000,000-168,000,000 STA	Not available		LC
Willow warbler (3 races) *Phylloscopus trochilus trochilus*	N	Central Europe (another race breeds northern Fennoscandia)	South Africa	106,000,000-161,000,000 DEC	Not available		LC
Goldcrest (> 12 ssp described) *Regulus regulus regulus*	N	North Fennoscandia	Southern Europe. Partially migrating (northern populations)	29,100,000-50,400,000 DEC	Not available		LC
Eurasian blackcap (5 spp) *Sylvia atricapilla atricapilla*	N	Central/Eastern Europe, South Fennoscandia	NW Africa/Southern Europe	88,400,000-138,000,000 INC	Not available		LC
Eurasian skylark (at least four ssp) *Alauda arvensis arvensis*	D/N	Fennoscandia and Eastern Europe	Southern Europe/NW Africa Southern populations are resident	87,800,000-132,000,000 DEC	1871		LC
Common chaffinch (a dozen of ssp) *Fringilla*	D	Fennoscania/East Europe / West Siberia	W/South Europe, Northern Africa	308,000,000-462,000,000	844,621 (for both *Fringilla* species)		LC

coelebs coelebs				STA			
Brambling (monotypic) *Fringilla montifringilla*	D/N	Taiga (north Scandinavia across Siberia)	Central Europe/North Mediterranean	14,000,000-26,000,000 DEC			LC
Song thrush (3 subspecies) *Turdus philomelos philomelos*	N	North / Central Eastern Europe	Southern Europe, Nnorthern Africa	47,300,000-77,900,000 STA	948		LCc
Redwing (2 ssp) *Turdus iliacus iliacus*	N	Northern Europe/Russia	Central Europe	16,200,000-28,100,000 DEC	4,235		LC
Yellow wagtail (numerous subspecies) *Motacilla flava flava*	D	Northern Central Europe	Tropical Africa	26,700,000-36,000,000 DEC	39,768		LC
Meadow pipit (monotypic) *Anthus pratensis*	D	Northern/East Europe/Siberia	Central/Souther n Europe	22,000,000-29,800,000 DEC	10,653		LC

[1] Breeding and wintering distribution and information on subspecies from Shirihai & Svensson (2018) and Svensson & Shirihai (2018).

[2] Population sizes taken from Birdlife International (2021).

[3] Average numbers observed at Falsterbo between 1973-2019 from (Kjellén 2019).

Given the large number of passerine birds potentially crossing the Baltic Sea and thus the pre-investigation area especially during the autumn migration, they are potentially affected by wind turbines, especially during (mass) migration. Some studies have shown that many species and a large proportion of birds killed by turbines correspond to passerine birds. For example, in South Africa, a fourth of all species and all individuals killed by wind turbines corresponded to songbirds. Apart from raptors, songbirds are the second most common species group affected by fatal collisions with wind farms (Perold et al. 2020).

In temperate waters and during migration the proportion of migrating passerines that may be affected by direct collisions with wind turbines may be much larger. Hüppop and colleagues (2006) found that over 98 % of all carcasses recovered at FINO1, an offshore research platform in the North Sea, belonged to passerine birds. Despite the study by Hüppop and colleagues covering the German North Sea, some of the overall findings may also be expected for the Baltic Sea. Migration intensity concentrates on certain days of the whole migration period (75 % of all songbirds were observed during 17-33 % of the migration days in the study). These results obtained from visual observations were also confirmed from the study of radar echoes. With regards to flight altitudes during migration, it was observed that almost half of the radar echo signals (registered up to an altitude of 1,500 m) corresponded to the first 200 m of altitude (within the range at which wind turbines may be in operation).

CRANE AVOIDANCE BEHAVIOUR STUDIES AT EXISTING OFFSHORE WIND FARMS

The migration of cranes across the western Baltic Sea is known to be distributed over a broad front. Although migration intensity can be higher at specific departure points on land, migrating cranes tend to disperse over a wide area when crossing the open sea.

The breeding populations of cranes in Finland and Sweden are known to cross the southwestern Baltic Sea, in which the pre-investigation area is situated, during migration towards their wintering areas. The Rügen-Bock region in Germany is an important resting and stop-over site, hosting up to 40,000 cranes (Bundesamt für Seeschifffahrt und Hydrographie 2021). The majority of these birds cross the Arkona basin during a flight of 1–2 hours. In autumn, flocks of cranes migrate in a south to south-westerly direction over the Baltic Sea with a fraction of the migrating population passing over the island of Bornholm.

At departure points on land, cranes are utilizing thermal upwind to increase their flight height prior to the onset of a prolonged flight over the open sea. In this way, cranes reduce the energy required to undertake migration relying on gliding rather than powered active flight. Studies of flight altitudes of cranes in the Baltic Sea reveal a large degree of variation of flight heights both within and above the typical range of turbine rotors (Schulz et al. 2013, Skov et al. 2015).

In 2022 and 2023, a behavioural study of cranes was conducted at an offshore location by (WSP & BioConsult SH 2024). A key aspect of this study was to analyse avoidance behaviour of cranes towards OWFs in the southwestern part of the Baltic Sea. Avoidance behaviour was differentiated at the macro-, meso-, and micro-scale. Macro-avoidance is an avoidance response towards the wind farm perimeter occurring at some distance from the wind farm. Meso-avoidance is defined as adjustments in flight undertaken to avoid individual turbines inside the wind farm array whereas micro-avoidance is defined as the last second evasive movements performed by a bird to avoid collision with rotor blades.

A study with the objective to observe and analyse avoidance behaviour of cranes approaching OWFs in the Southwestern part of the Baltic Sea was also carried out in autumn 2022 and spring 2023 (WSP & BioConsult SH 2024).

The study differentiated between avoidance behaviour at the macro-, meso, and micro scale. Macro-avoidance is an avoidance response towards the wind farm perimeter occurring at some distance from the wind farm. Meso-avoidance is defined as adjustments in flight undertaken to avoid individual turbines inside the wind farm array, whereas micro-avoidance is defined as the last second evasive movements performed by a bird to avoid collision with rotor blades.

Also, the study included a few species of raptors that were observed during the surveys.

Assessments of avoidance behaviour were performed either directly in the field by visual observations of changes in the flight behaviour of migrating cranes or by assessment of the spatial pattern of collected radar and laser range-finder tracks. For bird tracks that were not visually assessed in the field (other than species id), the spatial pattern of track marks of migrating cranes relative to turbine positions was used to assess the avoidance response.

Moreover, 17 cranes were successfully fitted with GPS transmitters during late summer 2022 and late summer 2023. Afterwards the transmitters have provided real time transmissions of the crane’s migratory movements across the Baltic Sea area and their corresponding flight altitudes.

To estimate the potential risk of collision for migrating cranes in the Kriegers Flak offshore wind farm, the 'Extended' version of the Band Model (Band 2012) was used. This version of the model considers a species-specific flight height distribution, rather than a proportion of birds flying at rotor height. Season-specific flight height distributions of migrating cranes were estimated based on the laser rangefinder measurements collected during the surveys as well as the flight heights estimated visually. The number of collisions was then estimated for the migration passage (no. of migrating individuals) observed during the surveys in spring and autumn, respectively, and for a range of realistic avoidance rates between 0.980 – 0.999 (Drachmann et al. 2021). The model was also used to estimate the passages required to obtain exactly one collision per year.

During the spring and autumn survey campaigns, a total of 4,466 cranes distributed over 84 flocks were recorded migrating through, over or outside the Kriegers Flak and Baltic 2 OWFs. Most commonly, cranes showed avoidance behaviour at the macro scale with several clear cases of vertical macro-avoidance. This was further supported by the flight height measurements, which indicated that cranes tended to fly slightly higher inside or above the wind farm compared to outside. Clear avoidance reactions could not be detected for a fairly large proportion of the observed flocks of cranes. However, given that no collisions were observed during the two survey campaigns, the cranes must have performed some degree of avoidance at some spatial scale.

A total of 14 individuals of raptors were observed during the autumn 2022 survey. Five of these individuals expressed possible avoidance behaviour, whereas one (red kite) expressed avoidance behaviour in the micro zone. In total, this corresponds to 43 % of the migrating birds of prey recorded during the survey. The remaining eight individuals showed no clear avoidance response towards the OWFs.

Despite the large number of observations of migrating cranes approaching the wind farms, no collisions or critical near incidents were observed during the surveys. This suggests a very low collision risk for cranes passing the wind farms during their migration twice a year. This finding was also supported by the flight patterns of the GPS-tagged cranes, where more individuals displayed a clear avoidance response at the macro scale, either vertically or horizontally.

The study indicates that migrating flocks of cranes are largely able to recognise OWFs and to avoid colliding with the turbines. This low risk of collision with offshore turbines was confirmed by application of the Band Model (Band 2012).

The detailed methodology, the collected data and the results of these surveys are summarized and reported in detail in a separate publication (WSP & BioConsult SH 2024).

4.2 SURVEY RESULTS

In the following paragraphs, the results gained from the different survey methods applied are presented in detail. The results have been grouped to answer the questions underlying the report and are thus structured as follows:

(i) Describing **species composition** to identify migratory species including the most common ones,
(ii) Describing **migration intensity** to analyse migration patterns and migration frequencies,
(iii) Describing **flight direction** to analyse migration patterns including certain potential migration corridors or specific routes,
(iv) Describing **flight altitudes** to identify flight heights of migrating individuals and screen for potential preferences,
(v) Describing results in more detail for **relevant species and species groups**, which were previously identified based on the literature research,

(vi) Data based on **laser rangefinder studies**, which enable identification of flight directions and flight heights on a species level.

GENERAL SPECIES COMPOSITION

The study of bird migration requires the use of numerous methods for different taxa migrating at night or in daylight as explained in the previous chapter on methodology. Rather than listing the results method by method, they will be presented either by taxon (bird group) or by migration season (spring vs. autumn). The results are illustrated by exemplary figures with additional figures displayed in the Appendix, Figure 50 to Figure 213.

Diurnal bird migration was observed visually at all four locations, Rønne and Nexø on the island of Bornholm, from ship and on the island of Rügen, during all five migration seasons, autumn 2021, spring and autumn 2022, and spring and autumn 2023 (for locations of observation/radar positions see Figure 3). Over 190,000 migrating birds were recorded and subsequently analysed.

In general, bird migration does not only vary between spring (before breeding, i.e. only adults) and autumn (after breeding, i.e. with a large proportion of recent fledglings), but also between day- and nighttime, among years and taxa, between offshore and onshore locations, and even between different onshore locations (such as Rügen, Rønne, and Nexø). To cover natural variation across time and space, it was necessary to collect data at three different onshore sites and over two years.

During **autumn** migration, the predominant species groups were cormorants (great cormorant), geese (such as greater white-fronted goose, bean goose, and barnacle goose), ducks (such as Eurasian wigeon, common scoter), cranes (common crane), pigeons (such as wood pigeon) and songbirds (such as common starling and various finch species). Smaller numbers of gulls (such as common gull and black-headed gull) and auks (such as razorbill and guillemot) were observed as well (Figure 13 to Figure 16).

During **spring** migration, the predominant species groups were cormorants (great cormorant), geese (such as greater white-fronted goose, and barnacle goose), ducks (such as common scoter), cranes (common crane), pigeons (such as wood pigeon), auks (such as razorbill), waders (such as Eurasian curlew), and songbirds (such as common starling, finches, and barn swallow) (Figure 13 to Figure 16).

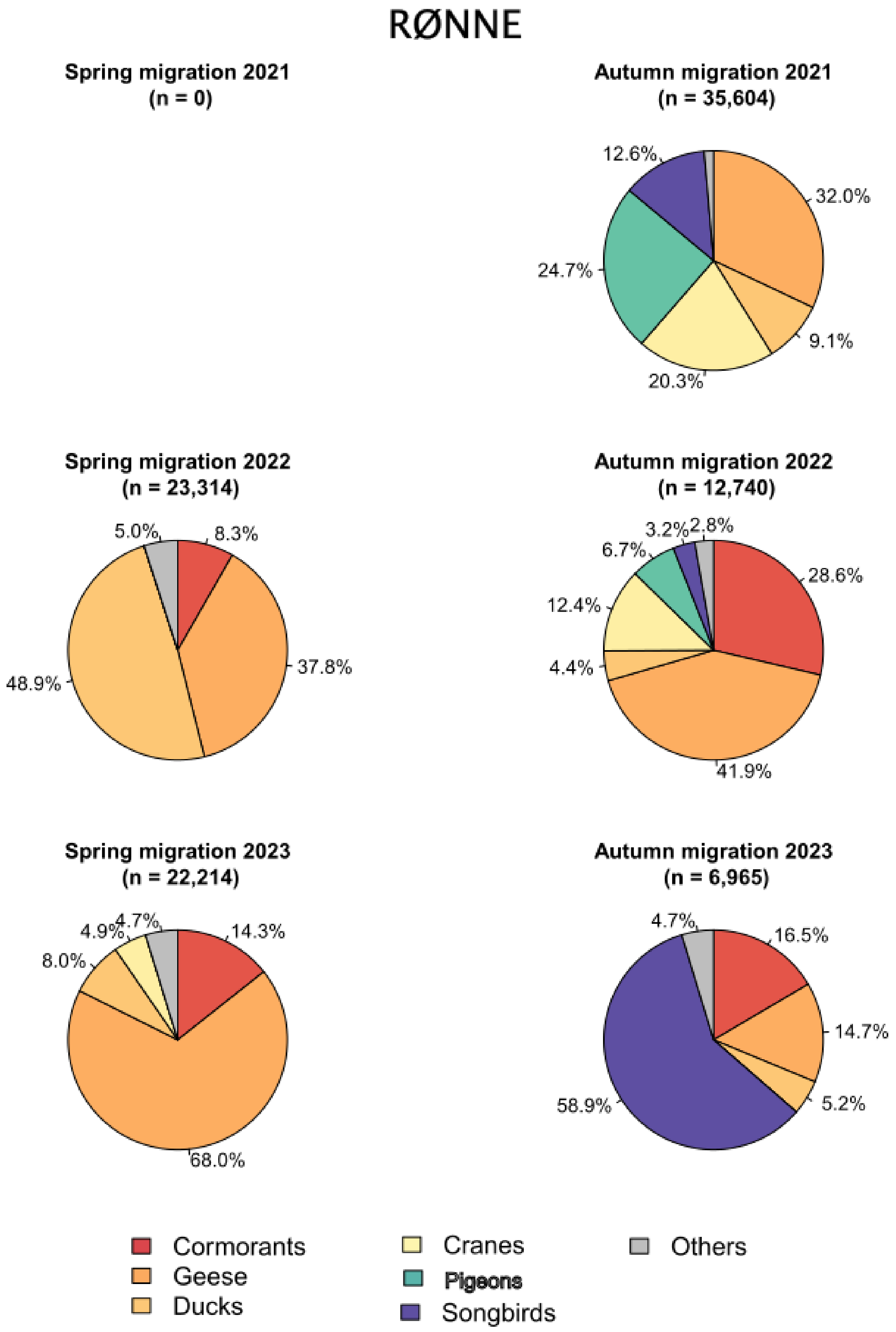


Figure 13. Proportion of observed diurnal migratory species grouped according to species groups between 2021 and 2023 on Bornholm (Rønne). The category "others" includes all other observed bird taxa. The sample size is provided as n = the number of individuals recorded.

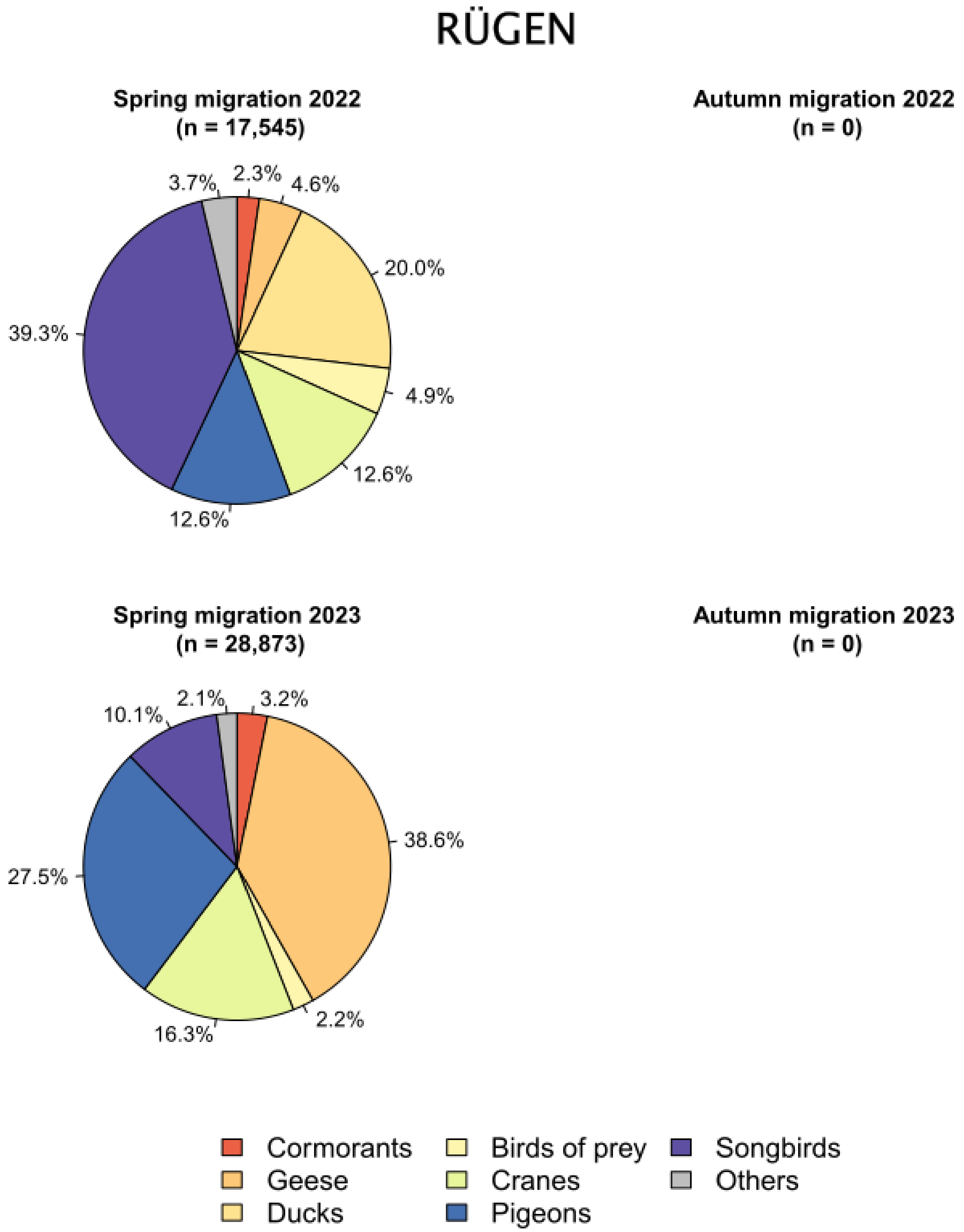


Figure 14. Proportion of observed diurnal migratory species grouped according to species groups in spring 2022 and in spring 2023 on Rügen. The category "others" includes all other observed bird taxa. The sample size is provided as n = the number of individuals recorded.

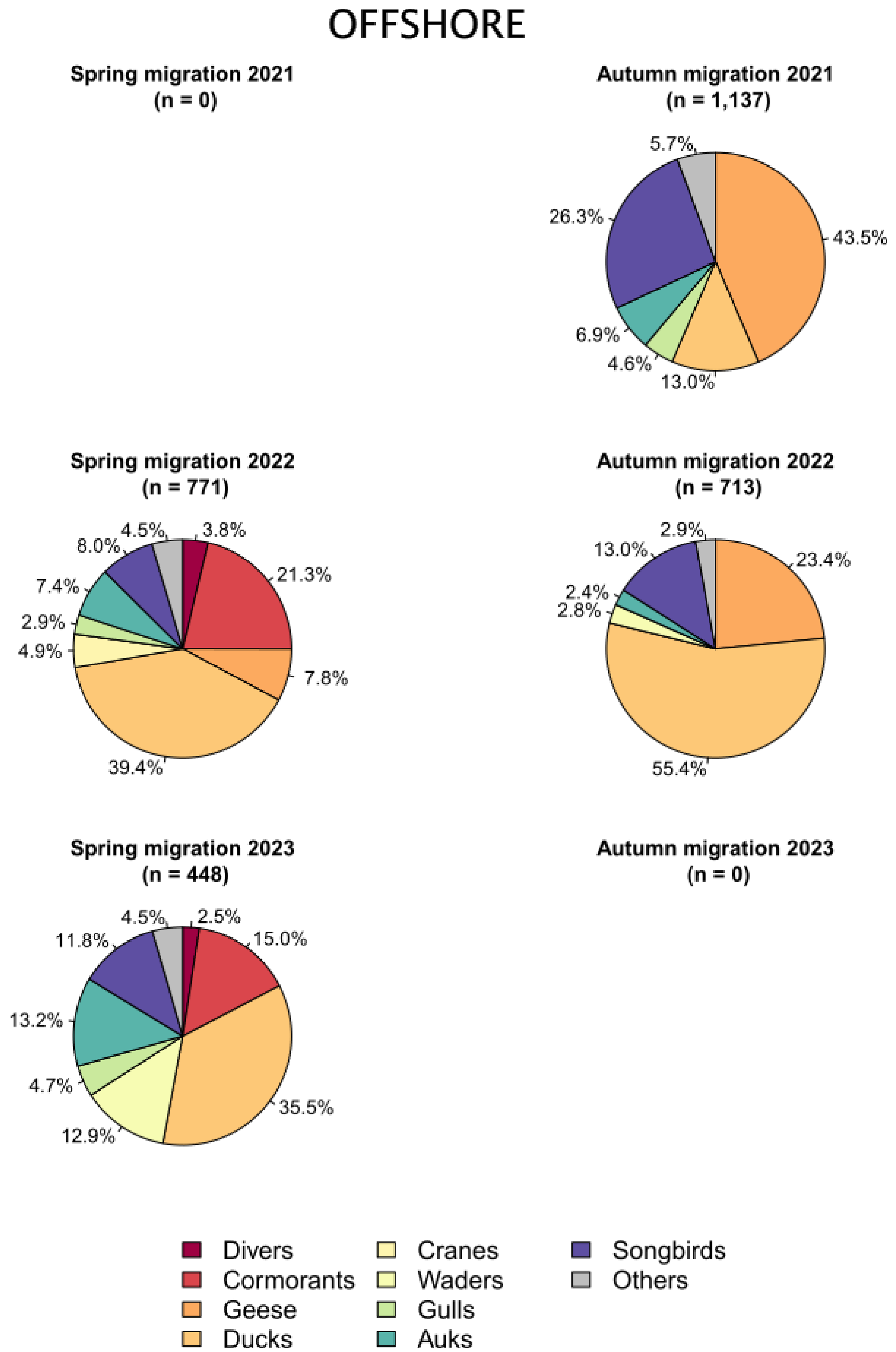


Figure 15. Proportion of observed diurnal migratory species grouped according to species groups from vessel-based surveys between 2021 and 2023. The category "others" includes all other observed bird taxa. The sample size is provided as n = the number of individuals recorded.

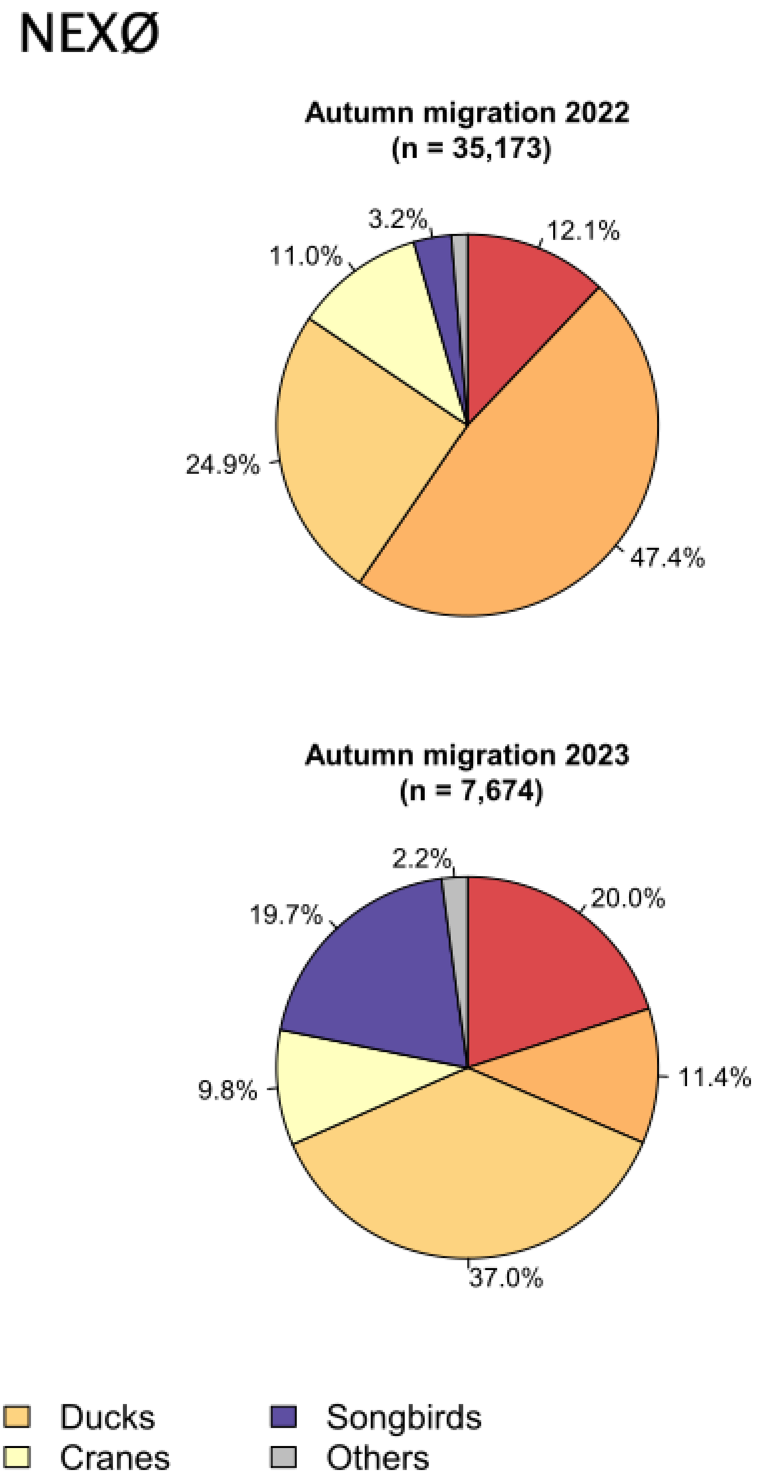


Figure 16. Proportion of observed diurnal migratory species grouped according to species groups in autumn 2022 and in autumn 2023 on Bornholm (Nexø). The category "others" includes all other observed bird taxa. The sample size is provided as n = the number of individuals concerned.

GENERAL MIGRATION INTENSITY

Data from both vertical radar and visual observations show characteristic bird migration patterns at all three land-based locations as well as offshore. Typically, night migration is more pronounced and numerous than daytime migration, but both day and night migrations occur in waves. Migration peaks lasting one or several days are followed by long periods with less intensive migration or no migration at all (Figure 17). Nocturnal migration between evening civil twilight and morning civil twilight usually appears to be two to five times as intense as diurnal migration, and due to numerous young-of-the-year, autumn migration is frequently twice as strong as spring migration. Table 9 to Table 14 indicate the predominance of nocturnal migrant numbers over diurnal migrant numbers as well as the higher bird numbers migrating in autumn compared to spring.

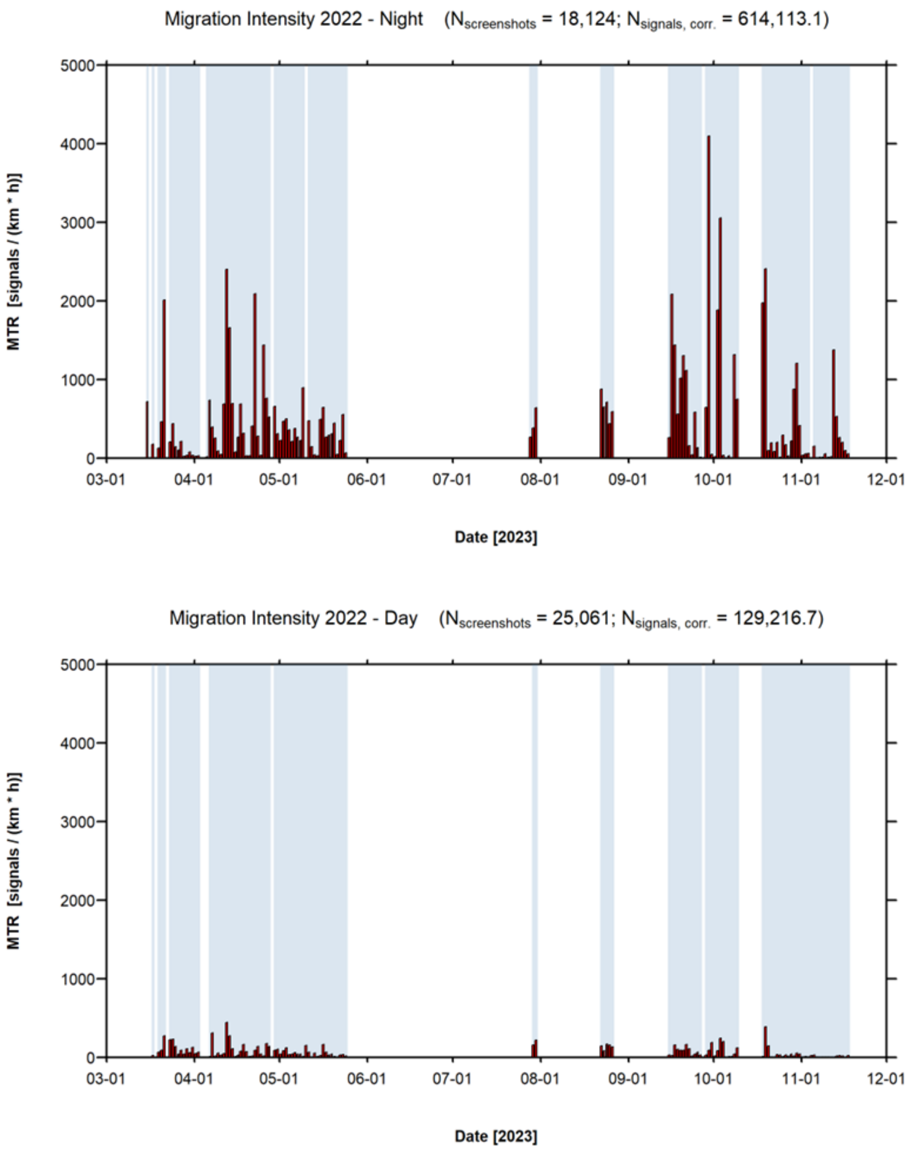


Figure 17. Seasonal pattern of migration intensity during the night (upper panel) and day (lower panel) as recorded by vertical radar at Rønne in 2022. (For the calculation of migration intensity, the number of bird echoes [signals] was used rather than the number of photographs of the radar screen).

The autumn bird migration starts in August and culminates in October (with more than 4,000 signals/[km and h] in single nights) to end in November (e.g. Figure 17). Spring migration lasts from March to May and peaks in mid- to late April (with rates of 2,000 -4,000 signals/[km and h]) (e.g., Fig. 19 and Appendix, Section 2.8).). Vessel-based results show substantially lower migration intensities, particularly during autumn (Table 9 and Table 10).

The bell-shaped development of diurnal migrant numbers over the four autumn months and over the three spring months, respectively, is very similar throughout all years and study locations with considerable variation from day to day as was recorded for consecutive days. For a graphical presentation of the results, please consult the respective figures in Appendix.

Table 9. Monthly and seasonal migration intensities [signals/km/h] during daylight calculated based on vertical radar observations on Bornholm (Rønne and Nexø), Rügen and vessel-based surveys (offshore). Data from the vessel-based survey in 2021 could not be analysed and has been excluded. "n/a" = not available/no survey.

Month	Mean daytime migration intensity (MTR [signals/km/h])			
	Rønne	Nexø	Rügen	Offshore
		2022		
March	115.3	n/a	n/a	n/a
April	98.9	n/a	n/a	**67.9**
May	49.1	n/a	274.0	**22.3**
July	185.8	n/a	n/a	n/a
August	137.4	670.7	n/a	n/a
September	80.5	424.8	n/a	**28.0**
October	66.7	357.7	n/a	**10.9**
November	10.4	142.5	n/a	n/a
Average spring	87.8	n/a	274.0	**45.1**
Average autumn	96.2	398.9	n/a	**19.5**
		2023		
March	189.1	n/a	385.4	n/a
April	170.9	n/a	172.1	22.2
May	41.7	n/a	65.2	14.0
July			n/a	n/a
August	102.7	657.2	n/a	n/a
September	130.1	387.6	n/a	n/a
October	n/a	360.3	n/a	n/a
November	n/a	371.3	n/a	n/a
Average spring	133.9	n/a	207.6	18.1
Average autumn	116.4	444.1	**n/a**	n/a

Table 10. Monthly and seasonal migration intensities [signals/km/h] during nighttime calculated based on vertical radar observations on Bornholm (Rønne and Nexø), Rügen and vessel-based surveys (offshore). Data from the vessel-based survey in 2021 could not be analysed and has been excluded. "n/a" = not available/no survey.

Month	Mean nocturnal migration intensity (MTR [signals/km/h])			
	Rønne	Nexø	Rügen	Offshore
		2022		
March	340.6	n/a	n/a	n/a
April	553.2	n/a	n/a	834.9
May	327.6	n/a	1,773.4	128.3
July	429.2	n/a	n/a	n/a
August	652.5	1,829.4	n/a	n/a
September	899.1	1,345.4	n/a	32.8
October	663.2	1,689.3	n/a	20.4
November	182.4	434.1	n/a	n/a
Average spring	407.1	n/a	1,773.4	481.6
Average autumn	565.3	1,324.6	n/a	26.6
		2023		
March	1,161.8	n/a	1,511.7	n/a
April	955.5	n/a	985.1	33.9
May	226.5	n/a	397.4	286.0
July	174.4	529.6	n/a	n/a
August	1,042.4	2,068.4	n/a	n/a
September	1,143.2	1,254.8	n/a	n/a
October	n/a	2,123.1	n/a	n/a
November	n/a	640.4	n/a	n/a
Average spring	781.3	n/a	964.7	160.0
Average autumn	786.7	1,323.3	**n/a**	n/a

Results from visual observations show that the mean autumn rates at the three land-based observation sites, culminate in October and November (with 201-753 ind./h), whereas the mean vessel-based rates culminate in September and October (with 49-83 ind./h), i.e., a fraction (approximately 11-24 %) of the land-based counts.

During spring migration, the mean rates culminate in March/April (with 229-405 ind./h), whereas the mean vessel-based rates culminate in April (with 20-39 ind./h), approximately 8-9 % of land-based counts.

Table 11. Monthly and seasonal migration rates [ind./h] calculated based on the visual observations on Bornholm (Rønne) for the migration periods from August to November (autumn) and from March to May (spring).

Year	Migration intensity [ind./h]			Number of individuals	Number of observation days
	Mean (± SE)	Median	Maximum		
			2021		
September	74.6 (± 38.3)	40	189	2,088	4
October	753.5 (± 236)	825.7	1,348	27,090	5
November	209.3 (± 105.5)	179.1	462.8	6,426	4
Average/ Sum	377.2 (± 125.4)	189	1,348	35,604	13
			2022		
March	193.9 (± 107.6)	45.4	795.9	9,248	7
April	249.4 (± 191.3)	32.8	1,384.8	13,195	7
May	18.8 (± 9.6)	6.8	56.9	871	6
Average/ Sum	160.8 (± 76.3)	31.4	1,384.8	23,314	20
August	14.6 (± 2.8)	12.8	22.8	450	4
September	121.5 (± 37.6)	109.4	209.8	3,732	5
October	250.5 (± 133.9)	37.5	601.6	6,531	5
November	168.9 (± 72)	146.8	303.2	2,027	3
Average/ Sum	142.7 (± 44.8)	56.8	601.6	12,740	17
			2023		
March	148.1 (± 107.4)	40.1	788.6	4,452	7
April	351.6 (± 101.3)	248.1	787.6	17,276	7
May	11 (± 2.5)	11	21.1	486	6
Average/ Sum	178.2 (± 58.5)	49.3	788.6	22,214	20
August	36.8 (± 21.2)	16.3	100.3	951	4
September	21.8 (± 5)	21.9	33.9	586	4
October	37.2 (± 18.1)	26.4	72.6	606	3
November	380.4 (± 298.4)	380.4	678.8	4,822	2
Average/ Sum	85.1 (± 50.1)	21.9	678.8	6,965	13

Table 12. Monthly and seasonal migration rates [ind./h] calculated based on the visual observations on Bornholm (Nexø) for the migration periods from August to November.

Year	Migration intensity [ind./h]			Number of individuals	Number of observation days
	Mean (± SE)	Median	Maximum		
			2022		
August	141.8 (± 33.5)	158.6	265.6	4,291	6
September	368.9 (± 85.9)	352.9	602.5	7,697	5
October	678.9 (± 264.5)	663.5	1,384	22,484	5
November	87.6 (± 42.4)	87.6	130	701	2
Average/ Sum	348.1 (± 90.8)	166.7	1,384	35,173	18
			2023		
August	34 (± 10.1)	28.2	80.6	1,446	6
September	87.8 (± 33.5)	59.3	219.2	2,650	5
October	65.9 (± 36.7)	44.6	137.3	1,183	3
November	201.4 (± 113.1)	201.4	314.5	2,395	2
Average/ Sum	77.7 (± 20.6)	51.7	314.5	7,674	16

Table 13. Monthly and seasonal migration rates [ind./h] calculated based on the visual observations on Rügen for the migration periods from March to May.

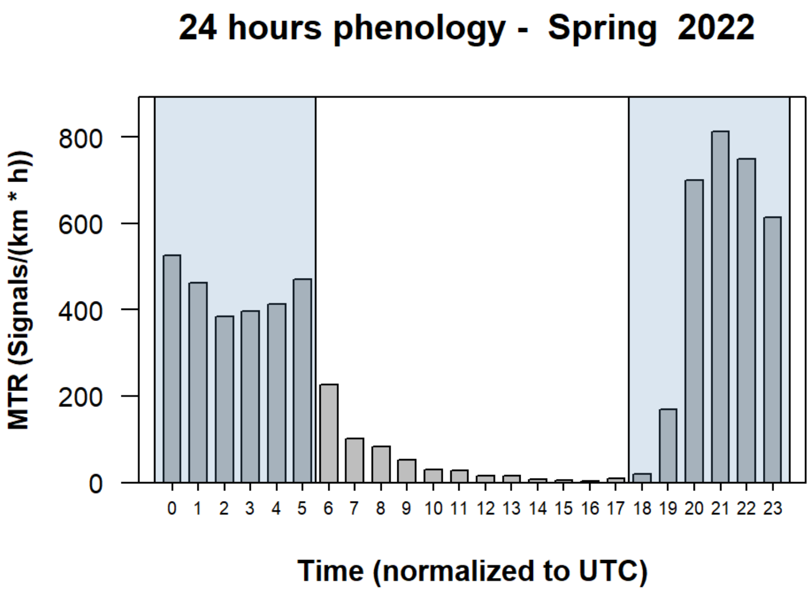
Year	Migration intensity [ind./h]			Number of individuals	Number of observation days
	Mean (± SE)	Median	Maximum		
			2022		
March	229.4 (± 58.9)	196.8	448.9	7,859	7
April	161.4 (± 97.8)	71.1	742.5	8,486	7
May	26.3 (± 10.5)	14.1	70.7	1,200	6
Average/ Sum	144.7 (± 42.5)	70.9	742.5	17,545	20
			2023		
March	405.6 (± 189.3)	190.7	1,464.7	19,487	7
April	135.1 (± 37)	167.2	239.5	7,272	7
May	47.8 (± 32.7)	15.9	210.5	2,114	6
Average/ Sum	203.6 (± 73.6)	112.4	1,464.7	28,873	20

Table 14 Monthly and seasonal migration rates [ind./h] calculated based on the visual observations from vessel-based surveys for the migration periods from August to November and from April to May.

Year	Migration intensity [ind./h]			Number of individuals	Number of observation days
	Mean (± SE)	Median	Maximum		
			2021		
October	83.2 (± 19.6)	83.2	102.9	874	2
November	28.5 (± 2)	28.5	30.4	263	2
Average/ Sum	55.9 (± 17.7)	47	102.9	1,137	4
			2022		
April	39.7 (± 22.9)	39.7	62.5	595	2
May	10.4 (± 0)	10.4	10.4	176	2
Average/ Sum	25 (± 12.6)	13.6	62.5	771	4
September	49.4 (± 3.3)	49.4	52.6	617	2
October	8.9 (± 0.2)	8.9	9.1	96	2
Average/ Sum	29.1 (± 11.7)	27.6	52.6	713	4
			2023		
April	20.7 (± 9)	20.7	29.7	297	2
May	9.4 (± 1.2)	9.4	10.6	151	2
Average/ Sum	15.1 (± 4.9)	11.2	29.7	448	4

The occurrence of bird migration does not only show a typical pattern throughout the seasonal migration period but also throughout day and night. This diel pattern is usually summarized under the term phenology. Depending on the species group, some birds such as birds of prey, pigeons, or common cranes are exclusively migrating in daylight, whereas others such as different ducks and geese migrate either at night or during the day. Moreover, songbird species are migrating predominantly between dusk and dawn, even though some groups such as finches also migrate during the day.

Migration intensity considered in a course of 24 hours also emphasized higher activity during the night than during the daylight phase (Figure 18 and Figure 19). At the offshore location in both spring seasons (2022 and 2023), a steep rise at about one hour after sunset was observed and higher intensities were observed rather in the first half of the night. In autumn (2022), migration intensity was much lower in general, and there was a less strong contrast between diurnal and nocturnal migration across hours with comparatively still large migration intensities during the first hours after sunrise. Similar patterns were also observed at the land-based locations (see Appendix, Section 2.8 for illustrations).



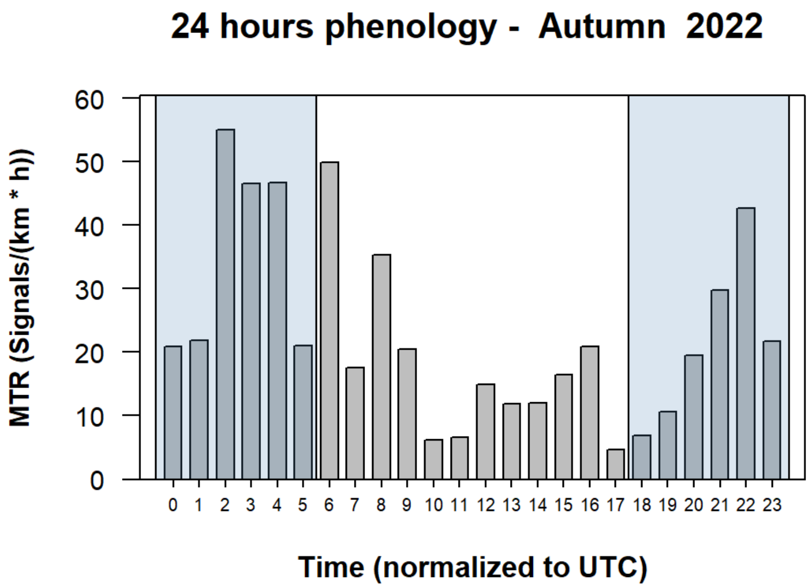


Figure 18. Pattern of 24 h migration intensity, vertical radar data at an offshore location in spring (top) and autumn (bottom) 2022. The sample sizes are 1,432 and 1,188 radar screen shots, respectively. As daylength varies over the year, nocturnal (blue shaded) and diurnal observations of the single survey dates are depicted stretched/compressed to a "normalised" length of 12 hours each. Time data in UTC (local time minus 1 hour (Oct.-March) and minus 2 hours (March-Oct.), respectively.

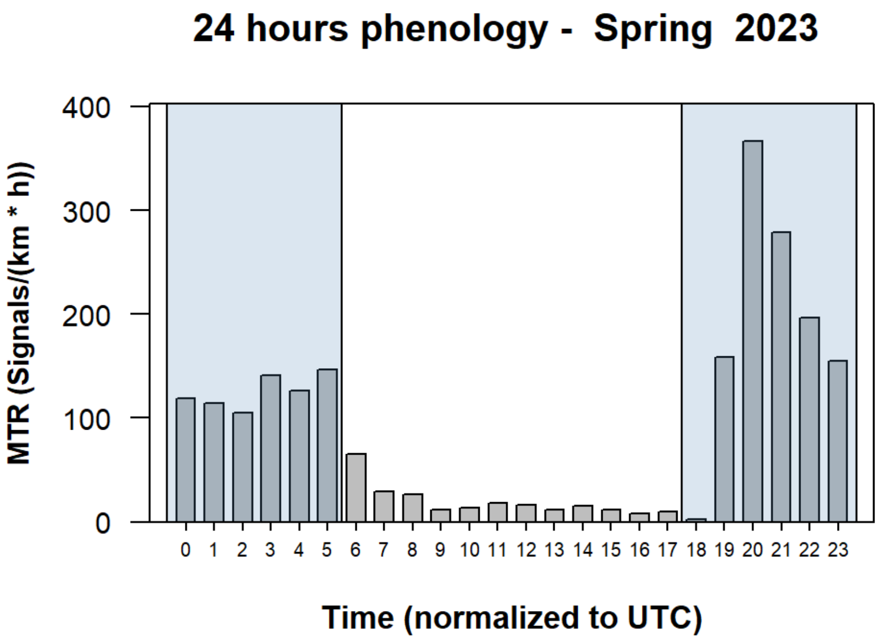


Figure 19. Pattern of 24 h migration intensity, vertical radar data at an offshore location in spring 2023. The sample size is 1,466 radar screen shots. As daylength varies over the year, nocturnal (blue shaded) and diurnal observations of the single survey dates are depicted stretched/compressed to a "normalized" length of 12 hours each. Time data in UTC (local time minus 1 hour (Oct.-March) and minus 2 hours (March-Oct.)).

GENERAL FLIGHT DIRECTION

During spring, the main migration direction of visually observed birds of all species was northeast, with some flying directly north or even east to southeast. In autumn the main directions were southwest and south, with a few flying West. The exact direction is likely to depend on the species group and the predominant weather conditions (especially wind direction) at the time. Waterbirds generally prefer to stay over water (and hence migrate in east-western direction), whereas landbirds generally prefer to cross the Baltic Sea along the shortest route (and hence rather in north-southerly direction during daytime). Beyond this very general pattern, it appears impossible to predict migration routes around Bornholm. Close to land (e.g., Rønne, Nexø, or Rügen), many migrants, especially when flying in lower altitudes, might divert from their general migration route. Such a deviation is frequently positive (i.e., towards land) for terrestrial species and negative (i.e., away from land) for marine species or seabirds. Therefore, land-based radar data are not necessarily indicative for offshore migration and should be interpreted carefully. For a graphical presentation of the results, please consult the respective figures in Appendix, Section 2.8.

Furthermore, visualisations of individual tracks are presented within the chapter on the relevant species groups: great cormorants (n = 292), common cranes (n = 193), *Anser* geese (n = 157) and *Branta* geese (n = 149).

GENERAL FLIGHT ALTITUDE

The flight altitude of migrating birds can vary from a few centimetres above sea level to several thousand meters above ground depending mostly on taxon, geography and – at times most importantly – the ambient weather. To study migratory flight altitudes, three different methods were employed, each covering different conditions and altitudes:

- visual observation of migrating birds during daytime at altitudes of 0 m to >200 m,
- vertical radar survey of nocturnal migrants at altitudes of up to 1,000 m, and
- weather radar survey of nocturnal migrants at altitudes of up to 5,000 m.

The diurnal migration was observed at seven altitudinal levels ranging from ground level to above 200 m altitude. All land-based observations of migrating birds (Figure 20 to Figure 22 for Rønne; Figure 23 for Nexø; Figure 24 for Rügen) culminated in the top four levels (>20 m), except for the autumn observations of 2023 at Nexø. In contrast, all vessel-based recordings of diurnal offshore migration clearly culminated at the lowest level between sea surface and 5 m altitude (Figure 25 and Figure 26).

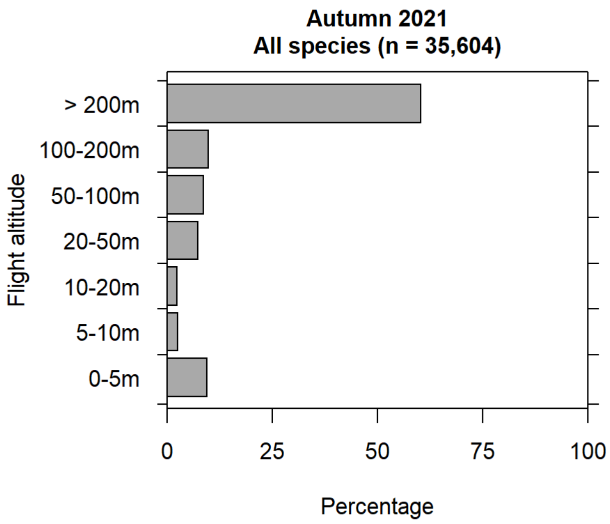


Figure 20. Flight altitude distribution of all visually observed birds during visual observations in autumn 2021 on Bornholm (Rønne).

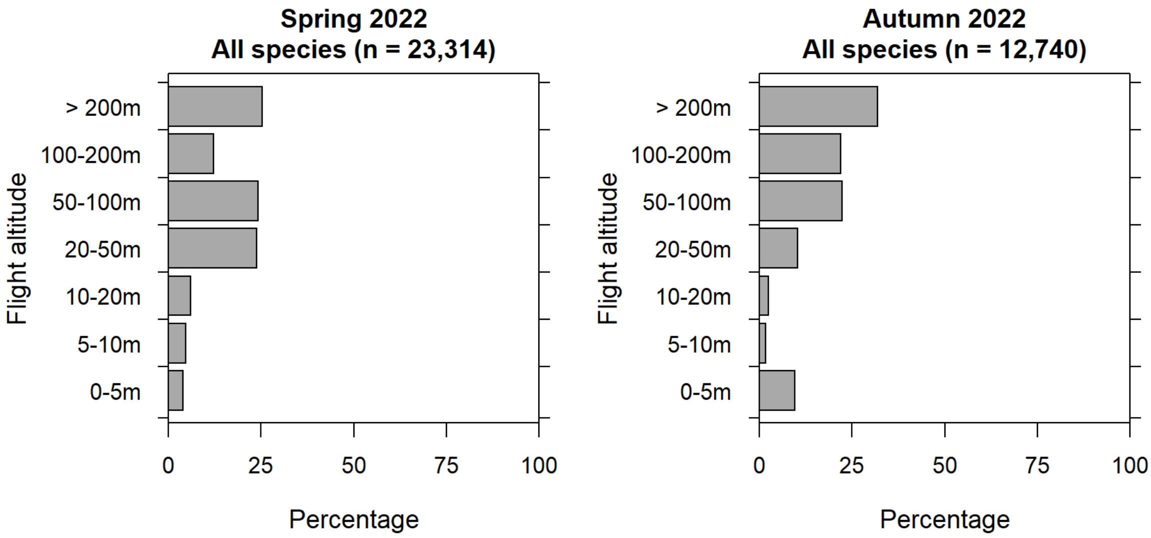


Figure 21. Flight altitude distribution of all visually observed birds during visual observations in spring and autumn 2022 on Bornholm (Rønne).

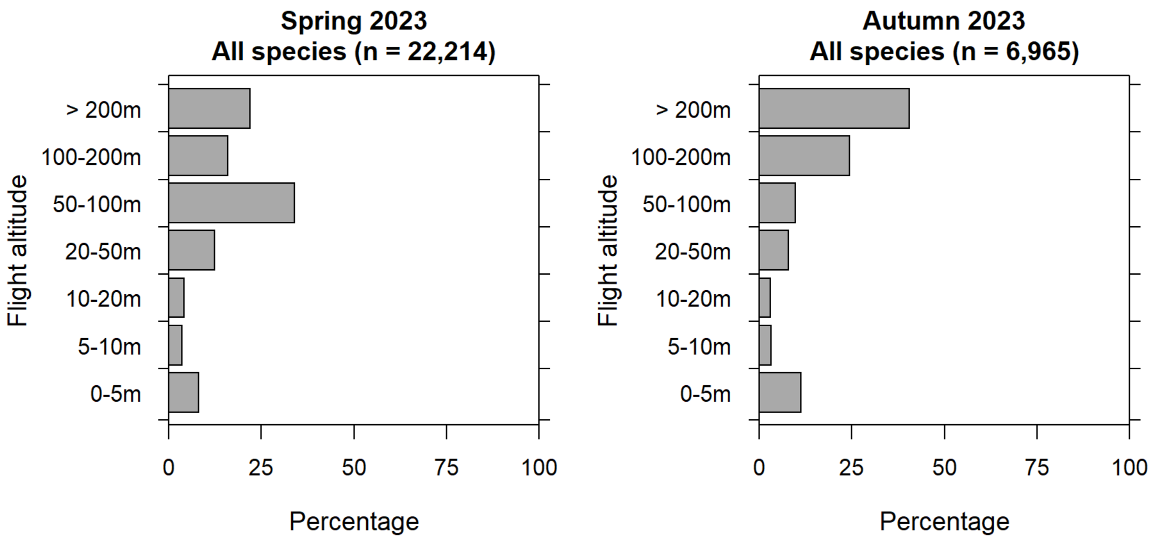


Figure 22. Flight altitude distribution of all visually observed birds during visual observations in spring and autumn 2023 on Bornholm (Rønne).

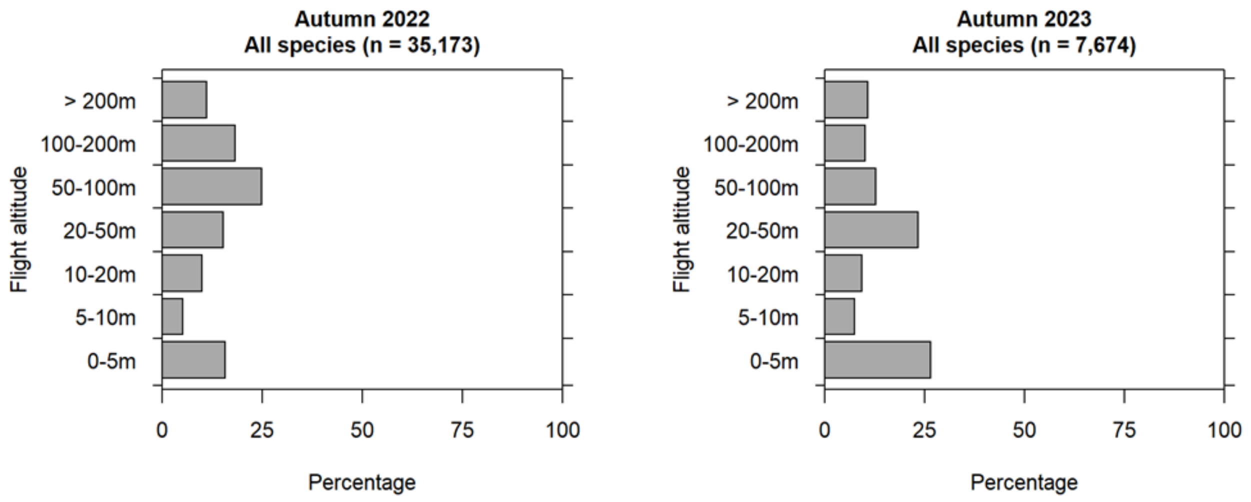


Figure 23. Flight altitude distribution of all visually observed birds during visual observations in autumn 2022 and 2023 on Bornholm (Nexø).

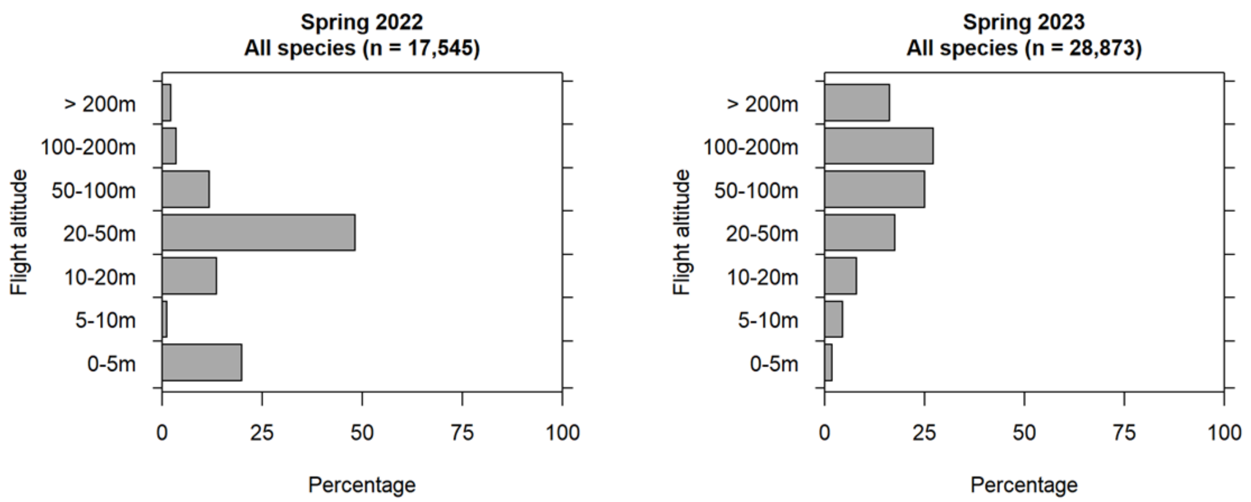


Figure 24. Flight altitude distribution of all visually observed birds during visual observations in spring 2022 and 2023 at Rügen.

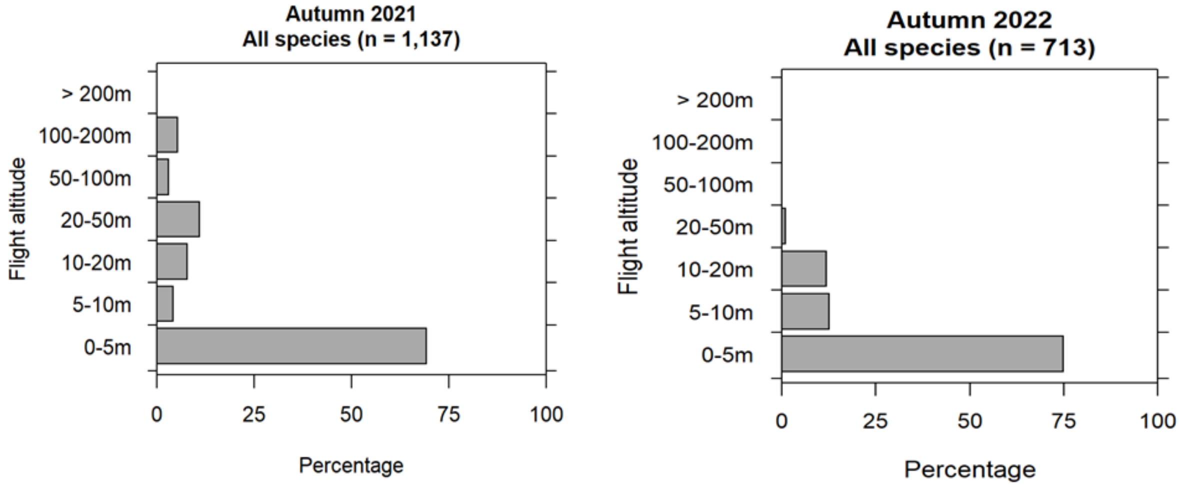


Figure 25. Flight altitude distribution of all visually observed birds during visual observations in autumn 2021 and 2022 from vessel-based surveys.

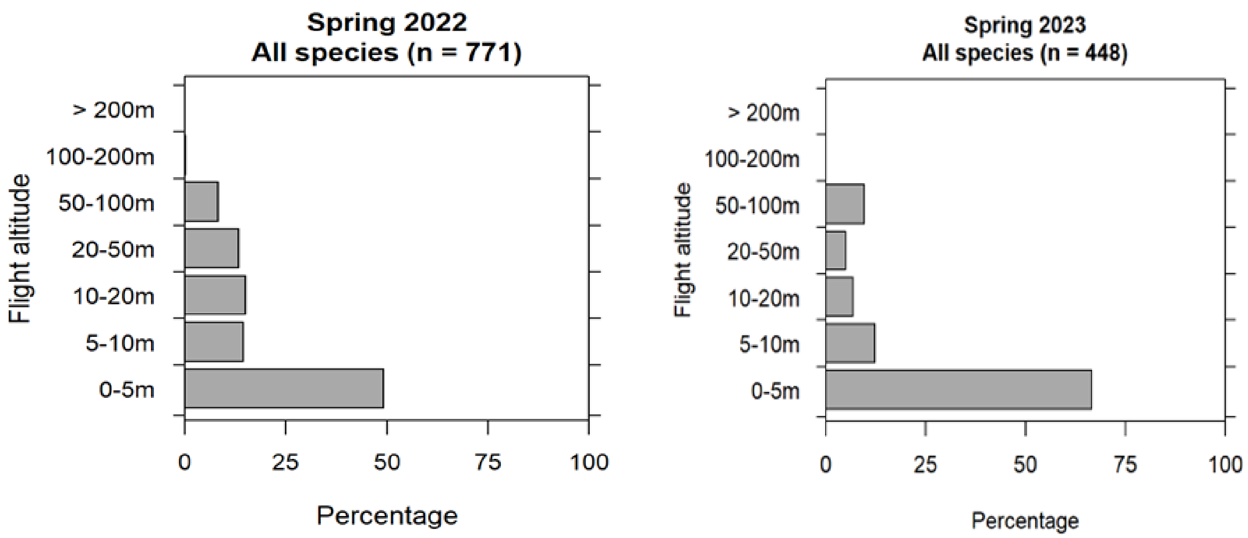


Figure 26. Flight altitude distribution of all visually observed birds during visual observations in spring 2022 and 2023 from vessel-based surveys.

Vertical radar data for flight altitude at the offshore location was available only for spring 2022 and spring 2023. Diurnal and nocturnal flight altitude distribution from vertical radar in spring 2022 were not very different from each other. In both cases, most of the signals (~35 %) were observed in the first 100 m above the water surface. In nocturnal migration, there was an increase in the proportion of signals observed in the very last altitude range (900 – 1000 m), indicating that probably during night many more birds fly at a higher altitude, whereas during diurnal migration in spring 2022 all other altitude ranges showed less than 10 % of signals (Figure 27).

In spring 2023, the flight altitude distribution of vertical radar signals was more different (Figure 28). During daytime, about 60 % of the signals were observed in the most lower altitude range (0 – 100 m), whereas less than 10 % of signals were observed in all other altitude ranges, respectively. During nights, the proportion of signals within the lowest flight altitude range was just above 25 % and the rest of the altitude ranges showed around 10 % of the proportion of signals. Compared to daylight migration, nocturnal migration appears to make more use of higher altitudes as well (Figure 29).

Result from land-based radar locations also showed a higher percentage of nocturnal migrants flying at higher altitudes compared to diurnal migration, particularly in autumn. However, compared to the offshore location, flight height distributions from Bornholm and Rügen generally showed that high altitudes at the onshore locations were frequented substantially more often than offshore (see also figures on flight altitude from onshore locations in the Appendix, Section 2.8).

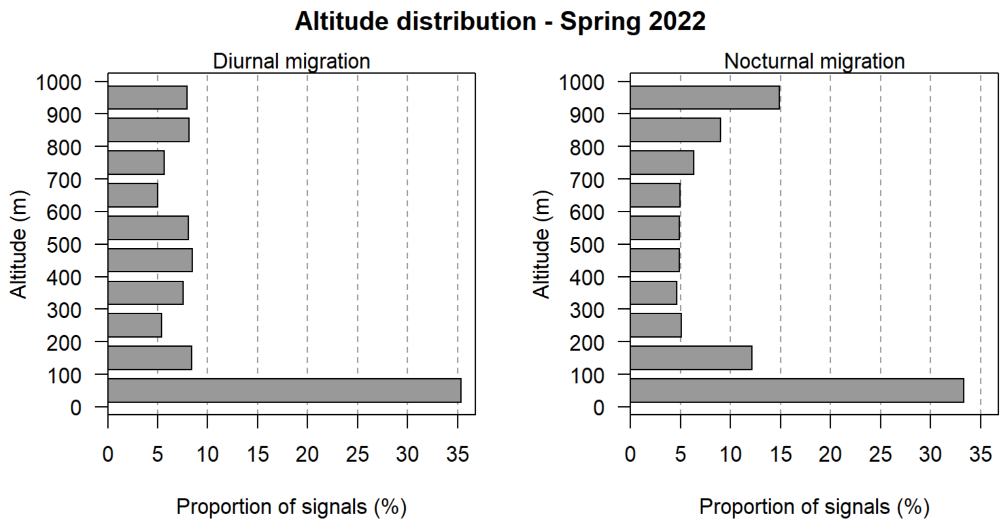


Figure 27. Flight altitude distribution, vertical radar data at the offshore location in spring 2022. Depicted is the relative appearance of signals up to 1,000 m height in 100 m increments. The panels on the left side show the altitude distribution of birds during the daylight phase, right panels during the night. The combined sample size is 1,432 radar screen shots.

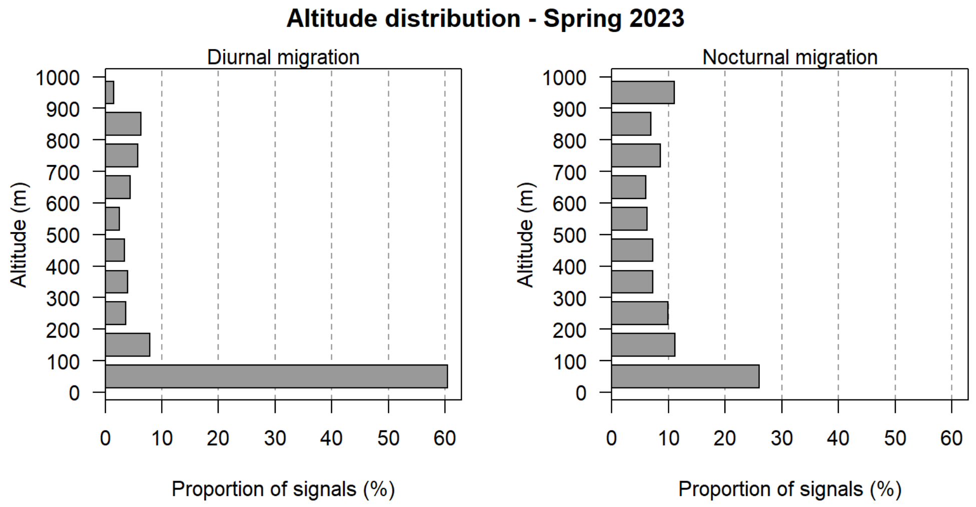


Figure 28. Flight altitude distribution, vertical radar data at the offshore location in spring 2023. Depicted is the relative appearance of signals up to 1,000 m height in 100 m increments. The panels on the left side show the altitude distribution of birds during the daylight phase, right panels during the night. The combined sample size is 1,466 radar screen shots.

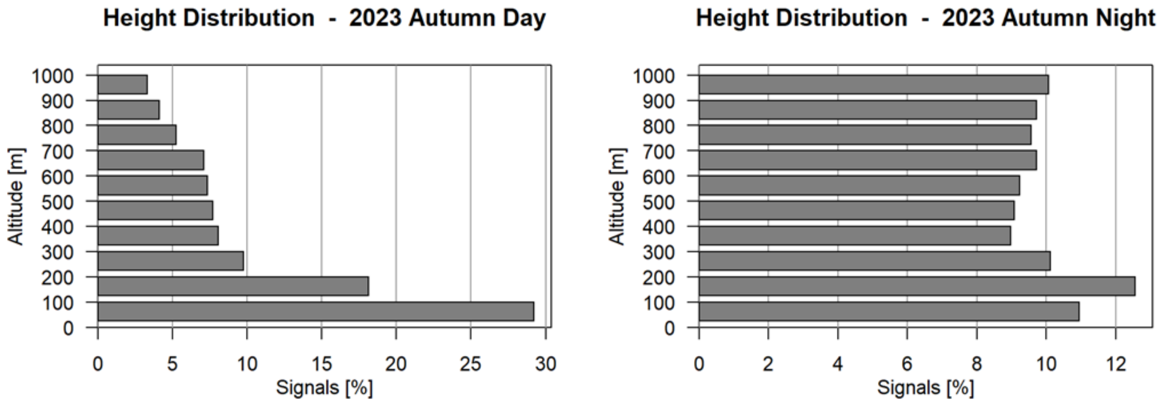


Figure 29. Flight altitude distribution, vertical radar data at Nexø in autumn 2023. Depicted is the relative appearance of signals up to 1,000 m height in 100 m increments. The panel on the left side show the altitude distribution of birds during the daylight phase, right panels during the night. The combined sample size is 27,275 radar screen shots.

Furthermore, the altitude distribution of bird migration during different seasons is also reflected by the MTRs recorded by the weather radars (Figure 30 and Figure 31).

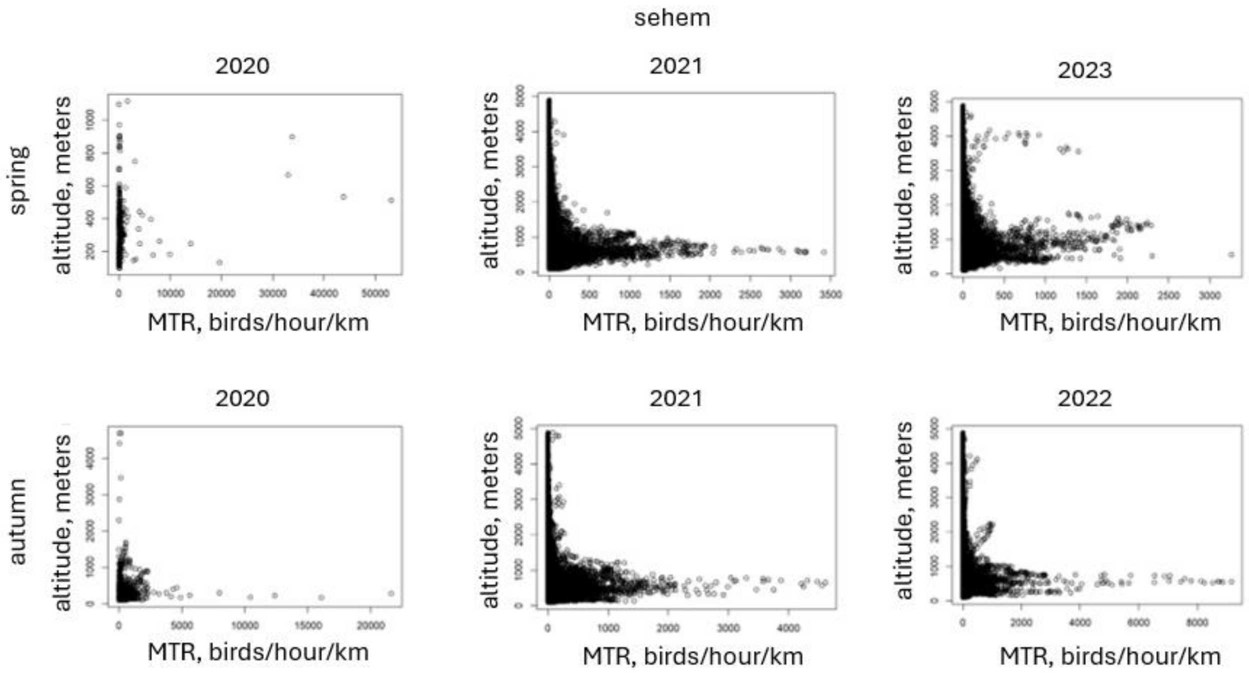


Figure 30. Altitude distribution of bird detections of all original working cycles (every 5 or 15 minutes) for weather radar station sehem, Gotland.

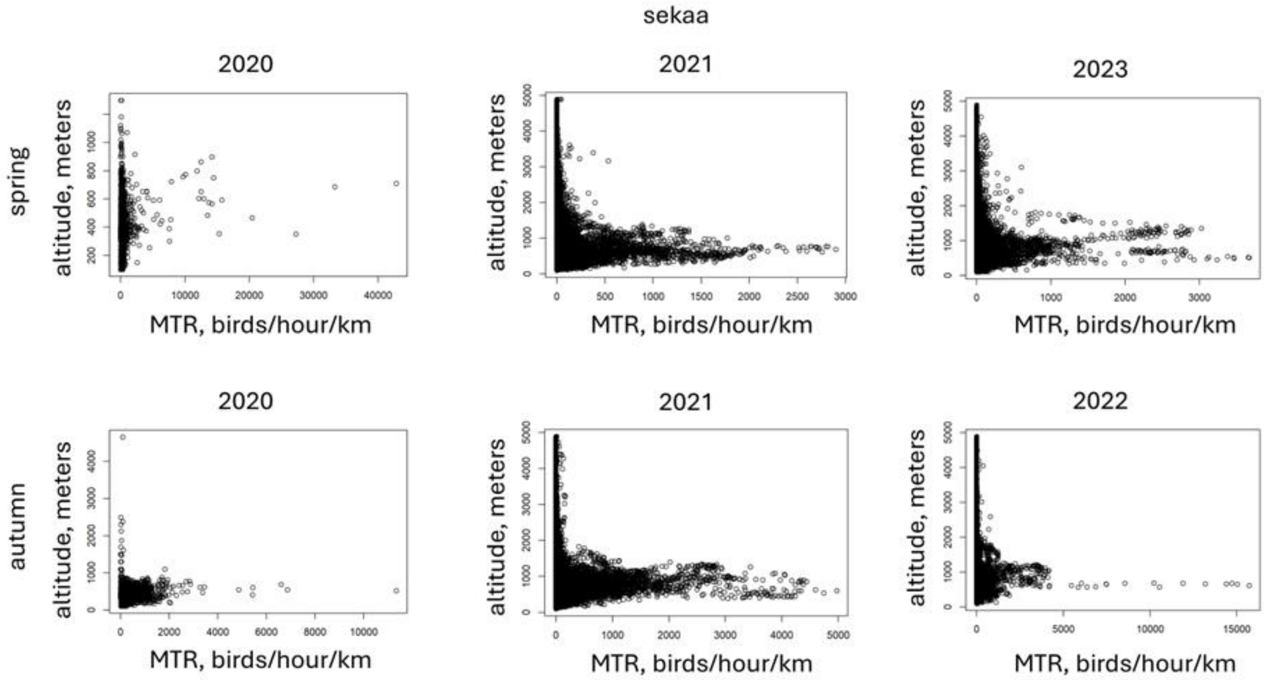


Figure 31. Altitude distribution of bird detections of all original working cycles (every 5 or 15 minutes) for weather radar station sekaa, Karlskrone.

RELEVANT SPECIES GROUPS

In the following section, the migration patterns of the most relevant species groups encountered in the pre-investigation area are described in more detail. For a graphical presentation of additional detailed results, please consult the respective figures in the Appendix, Section 2.8.

DIVERS

In this report, red-throated divers (*Gavia stellata*), black-throated divers (*Gavia arctica*) and unidentified divers (*Gavia spec*.) are treated collectively as divers (Gavidae). In total, 310 divers were observed from the islands of Bornholm and Rügen, whereas 57 individuals were sighted during the vessel-based surveys (Table 15).
Land-based and vessel-based recordings of migration intensity are comparable (0.03-0.96 ind./h).

Divers flew often at low altitudes; however, they were not rarely seen flying between 20 and 50 m of altitude. In spring, they were observed flying at relatively higher altitudes than in autumn, irrespective of the location. Their flying direction varied with respect to the season, year and location. In spring, they were seen flying to the NE (vessel-based surveys), E (Rügen, vessel-based surveys), to the SE (Rønne), and to the NW (Rønne, vessel-based surveys). In autumn, similar differences were seen with divers flying to the SW (vessel-based surveys), SE (Rønne), S (Nexø) and in many other directions (Rønne). For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 15. Migration intensity of divers at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	3	0.03	0.03	0.4
Bornholm, Rønne	Spring	2022	17	19	0.27	0.14	2
Bornholm, Rønne	Autumn	2022	20	71	0.48	0.23	4.39
Bornholm, Rønne	Spring	2023	20	11	0.08	0.03	0.36
Bornholm, Rønne	Autumn	2023	13	15	0.2	0.09	1
Bornholm, Nexø	Autumn	2022	18	62	0.81	0.22	3.25
Bornholm, Nexø	Autumn	2023	16	11	0.11	0.05	0.8
Rügen	Spring	2022	20	118	0.84	0.54	10.9
Vessel-based surveys							
Offshore	Autumn	2021	4	16	0.82	0.17	1.33
Offshore	Spring	2022	4	29	0.96	0.65	2.8
Offshore	Autumn	2022	4	1	0.05	0.05	0.18
Offshore	Spring	2023	4	11	0.36	0.18	0.88

GREAT CORMORANT

Migrating great cormorants (*Phalacrocorax carbo*) were observed at all four locations and during all seasons, however in larger numbers more in spring than in autumn (Table 16). At Rønne, for example, the mean migration intensity in autumn varied between 3-14 ind./h, whereas in spring, the mean intensity varied between 23-35 ind./h. On Rügen and on the vessel, mean spring densities were much lower (roughly a tenth in magnitude).

Table 16. Migration intensity of cormorants at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	289	3.12	2.39	30.34
Bornholm, Rønne	Spring	2022	17	3,647	35.04	12.11	187.38
Bornholm, Rønne	Autumn	2022	20	1,936	14.24	5.99	117.08
Bornholm, Rønne	Spring	2023	20	3,187	23.31	11.94	241.93
Bornholm, Rønne	Autumn	2023	13	1,152	13.65	7.4	97.33
Bornholm, Nexø	Autumn	2022	18	4,265	49.81	17.27	296
Bornholm, Nexø	Autumn	2023	16	1,534	14.46	3.94	52.86
Rügen	Spring	2022	20	405	2.9	0.88	12.86
Rügen	Spring	2023	20	912	6.04	2.45	35.86
Vessel-based surveys							
Offshore	Autumn	2021	4	12	0.6	0.21	0.95
Offshore	Spring	2022	4	164	5.4	3.91	17.07
Offshore	Autumn	2022	4	11	0.49	0.23	1.14
Offshore	Spring	2023	4	67	2.26	1.42	6.48

During land-based surveys, the observed flight altitude of great cormorants was higher (>20 m), whereas it was lower (<50 m) during vessel-based surveys. In autumn, cormorants migrate to the south or – to a smaller degree – to the southwest, whereas in spring, they migrate to the north, northeast or east depending on the study site. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

In the following figures, Figure 32 and Figure 33, visualisations of individual tracks are presented for great cormorants (n = 292) in spring and autumn, separately.

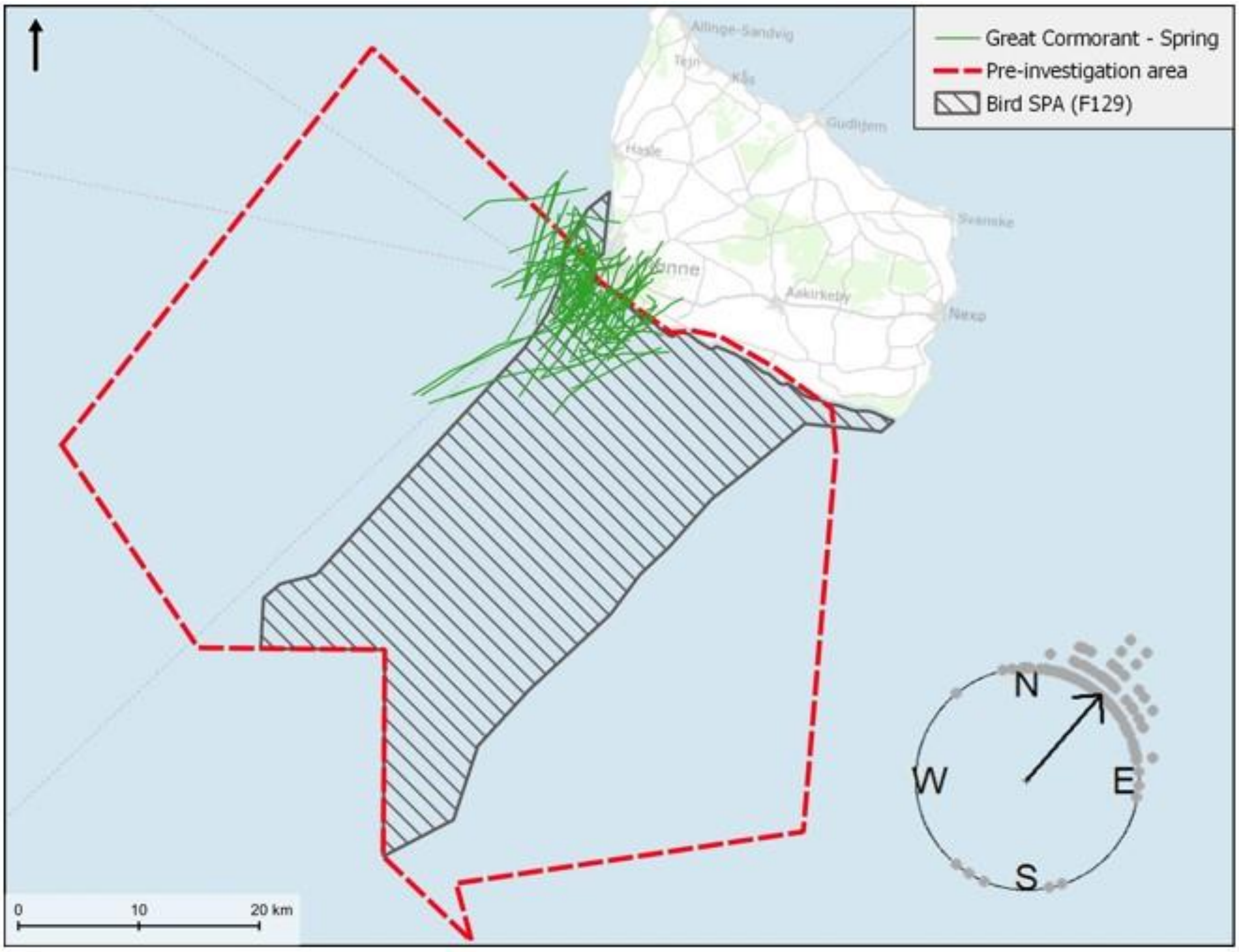


Figure 32. Visualization of produced great cormorant tracks (n = 104), during spring, summed for the years 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 104) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 41.0 degrees). Each track may represent an individual or a flock. The number of birds appears from Table 14.

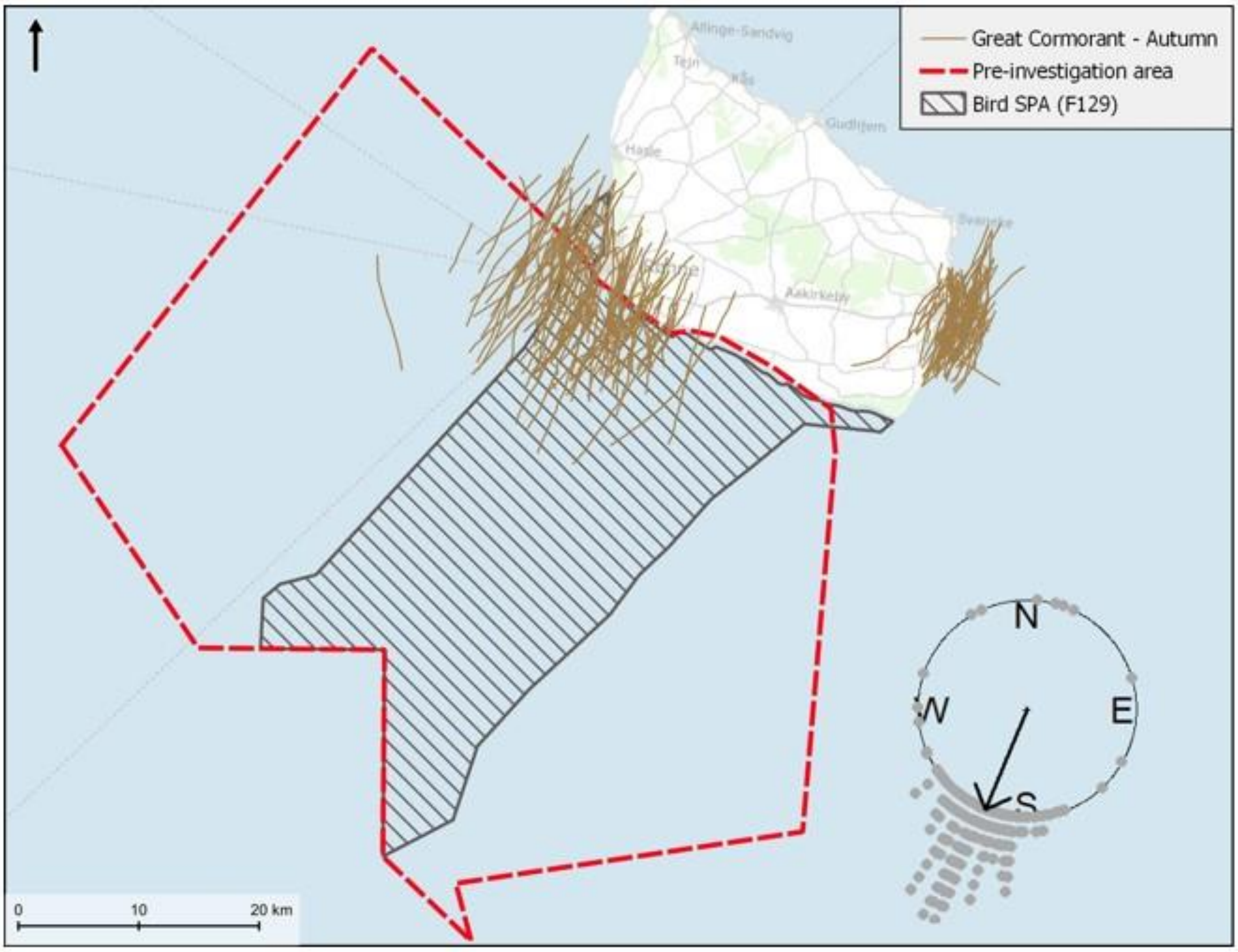


Figure 33. Visualization of produced great cormorant tracks (n = 188), during autumn, summed for the years 2021, 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 188) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 202.5 degrees). Each track may represent an individual or a flock. The number of birds appears from Table 14.

GEESE

Over 70,000 geese were recorded at all sites and during all migration seasons, however, apparently with a high variation from year to year (Table 17). The land-based studies recorded mean migration intensities of 7-137 ind./h, whereas the vessel-based surveys recorded 0-23 ind./h. The distribution of flight altitude shows again the divergence of land-based (predominantly >100 m) versus vessel-based surveys (0-5 m above sea level). The orientation during autumn migration is southwest (from south to west), and during spring migration towards northeast (from north to east). For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 17. Migration intensity of geese at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	11,403	117.49	52.49	635.2
Bornholm, Rønne	Spring	2022	17	5,338	61.04	35.9	478.72
Bornholm, Rønne	Autumn	2022	20	8,808	63.8	38.1	744
Bornholm, Rønne	Spring	2023	20	15,112	125.88	57.87	775.43
Bornholm, Rønne	Autumn	2023	13	1,024	13.2	7.38	92.31
Bornholm, Nexø	Autumn	2022	18	16,684	137.66	76.83	1,071.59
Bornholm, Nexø	Autumn	2023	16	878	9.09	5.25	81.83
Rügen	Spring	2022	20	806	7.39	3.42	58.59
Rügen	Spring	2023	20	11,155	78.94	52.26	1,046.43
Vessel-based surveys							
Offshore	Autumn	2021	4	495	23.71	13.65	60.19
Offshore	Spring	2022	4	60	1.76	1.5	6.24
Offshore	Autumn	2022	4	167	6.76	5.89	24.32
Offshore	Spring	2023	4	7	0.22	0.22	0.88

In the following (Figure 34 to Figure 37), visualisations of individual tracks are presented for *Branta* geese (n = 149) and for *Anser* geese (n = 157) in spring and autumn, respectively.

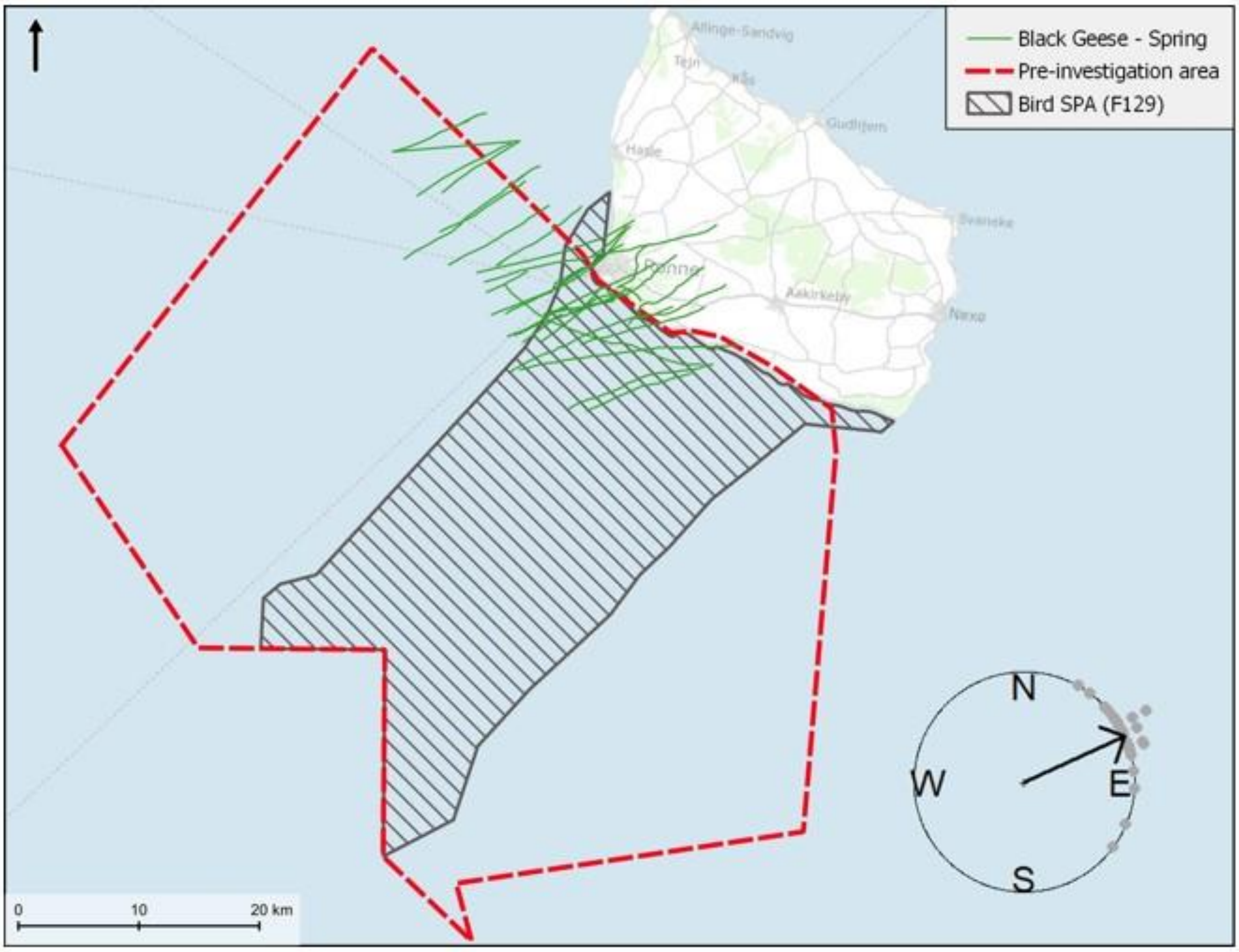


Figure 34. Visualization of produced black geese (*Branta*) tracks (n= 28), during spring, summed for the years 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 28) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 65.7 degrees). Each track may represent an individual or a flock. The number of geese appears from Table 17.

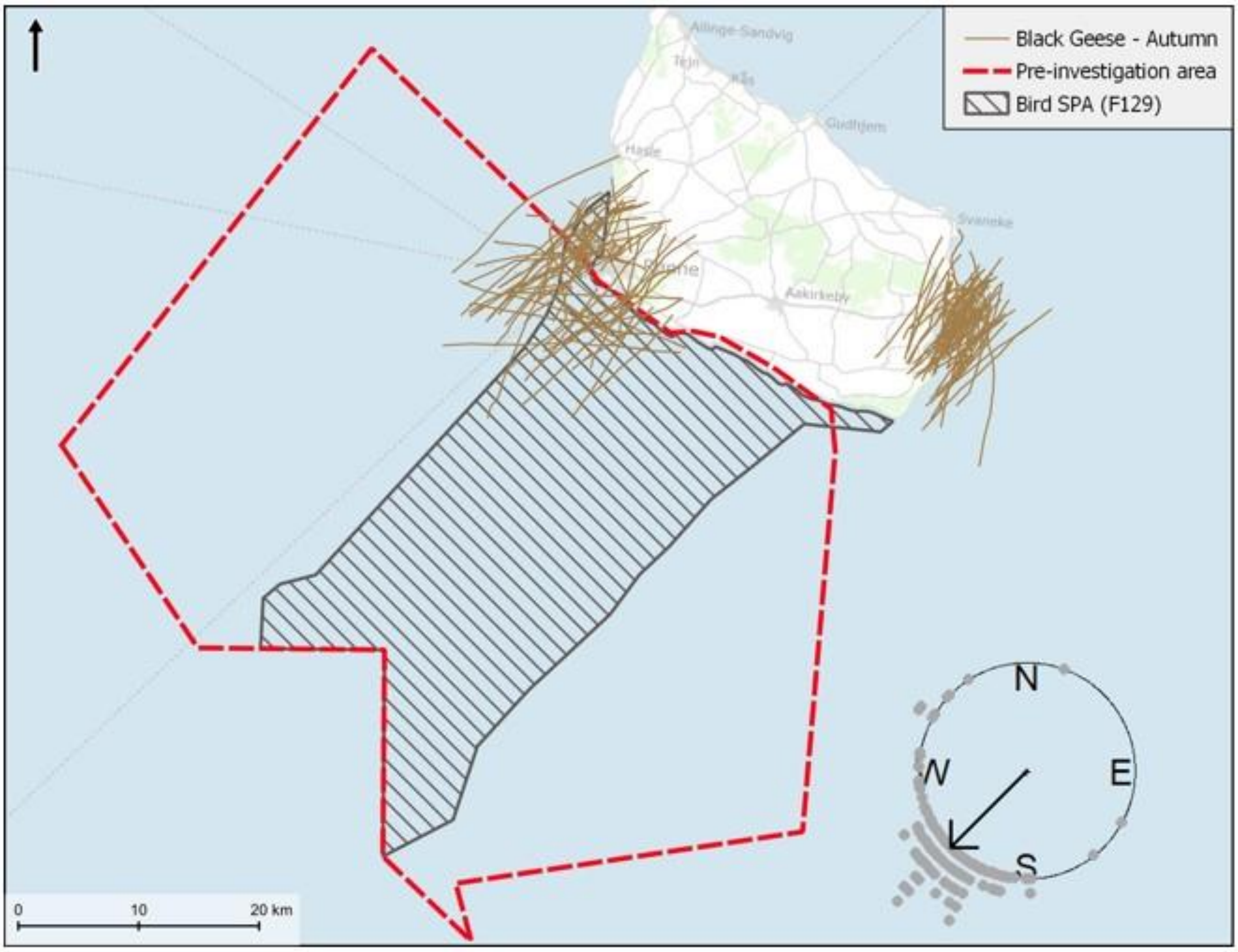


Figure 35. Visualization of produced black geese (*Branta*) tracks (n = 121), during autumn, summed for the years 2021, 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 121) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 225.0 degrees). Each track may represent an individual or a flock. The number of geese appears from Table 17.

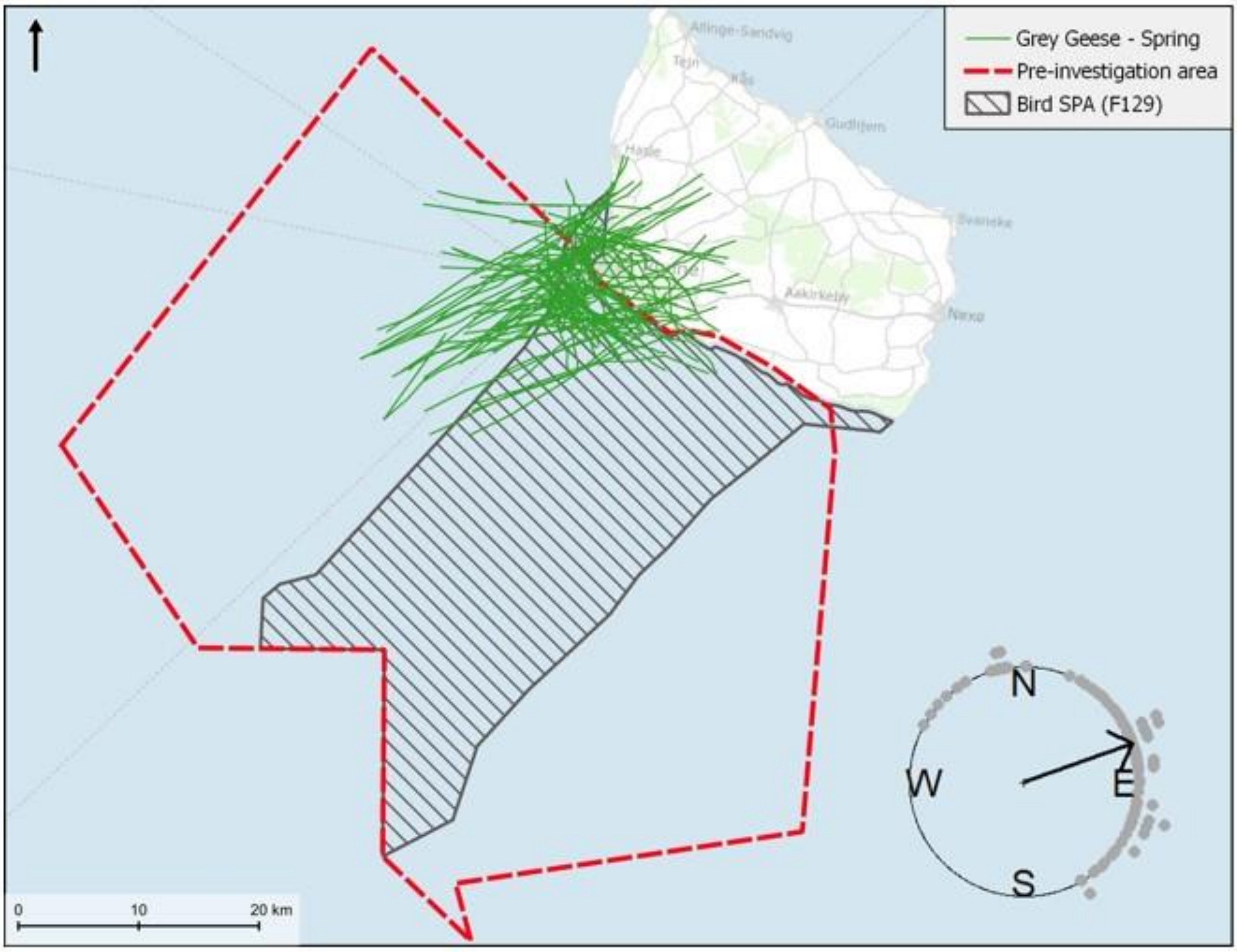


Figure 36. Visualization of produced grey geese (*Anser*) tracks (n = 90), during spring, summed for the years 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 90) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 70.6 degrees). Each track may represent an individual or a flock. The number of geese appears from Table 17.

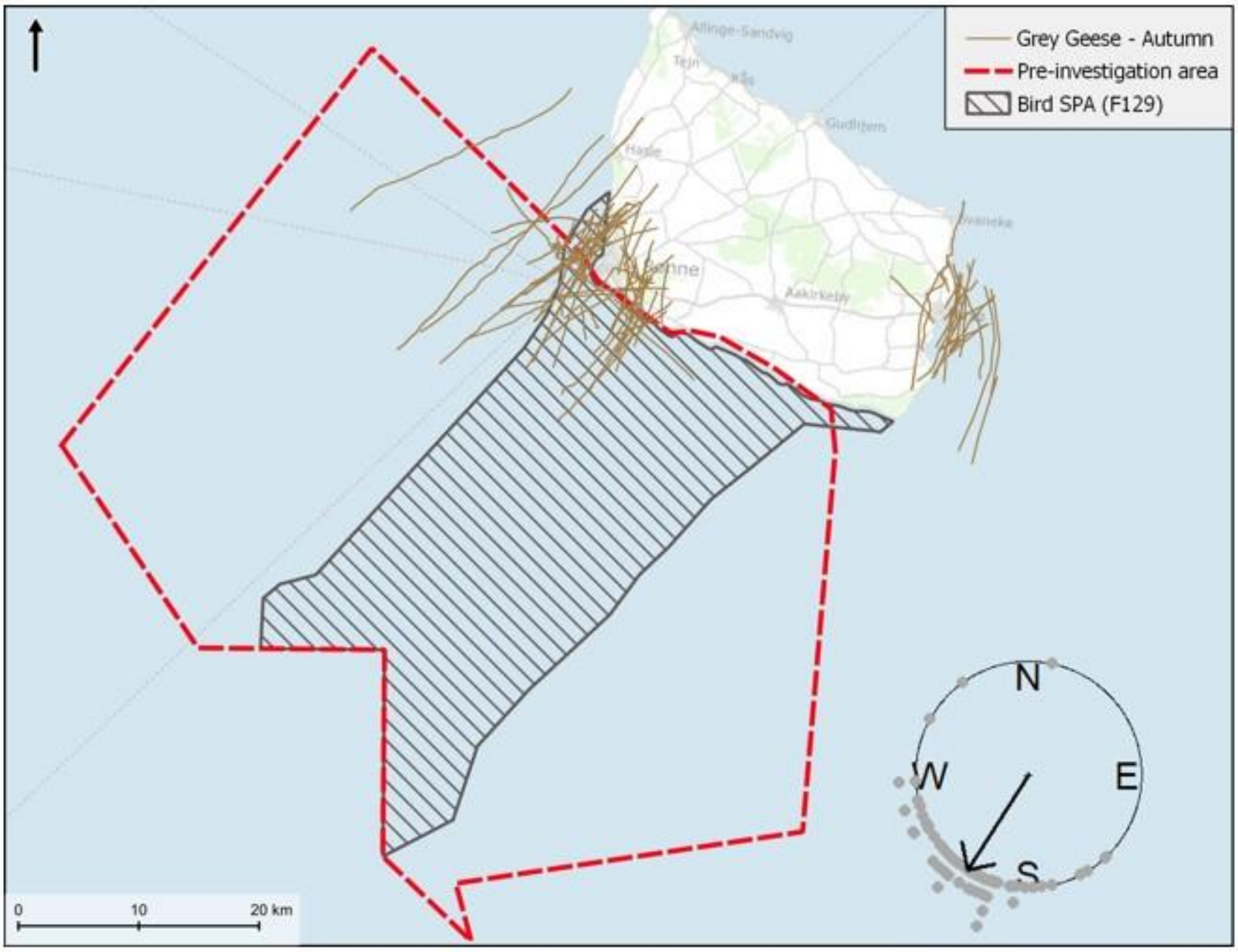


Figure 37. Visualization of produced grey geese (*Anser*) tracks (n= 67), during autumn, summed for the years 2021, 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 67) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 212.7 degrees). Each track may represent an individual or a flock. The number of geese appears from Table 17.

DUCKS

Ducks were recorded by the thousands (Table 18), mostly sea ducks such as common scoter, with mean migration intensities of up to 107 ind./h in land-based studies, whereas vessel-based studies recorded only 5-16 ind./h. During migration, ducks were recorded everywhere to fly predominantly also at lower altitudes (<100 m). During migration, ducks appear to disperse over a larger area, in autumn between northwest and south and in spring between north and southeast. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 18. Migration intensity of ducks at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	3,233	34.66	16.44	180
Bornholm, Rønne	Spring	2022	17	558	8.1	3.88	60.25
Bornholm, Rønne	Autumn	2022	20	11,412	74.65	67.22	1,349.81
Bornholm, Rønne	Spring	2023	20	1,780	13.38	5.4	68.71
Bornholm, Rønne	Autumn	2023	13	359	4.48	2.37	29.38
Bornholm, Nexø	Autumn	2022	18	8,754	107.11	31.8	553
Bornholm, Nexø	Autumn	2023	16	2,838	29.67	11.25	189.71
Rügen	Spring	2022	20	3,501	26.79	7.27	121.78
Rügen	Spring	2023	20	35	0.24	0.08	1.12
Vessel-based surveys							
Offshore	Autumn	2021	4	148	7.73	2.3	12.42
Offshore	Spring	2022	4	304	10.03	6.59	29.2
Offshore	Autumn	2022	4	395	16.08	6.93	28.48
Offshore	Spring	2023	4	159	5.37	1.24	8.28

BIRDS OF PREY

Large numbers of migrating birds of prey were observed only on Rügen with 4-6 individuals passing through per hour (Table 19).

Offshore and on Bornholm, the migration intensity was below 0.7 ind./h. Most land-based observations recorded migrating birds of prey at an altitude of 20-100 m, whereas most vessel-based observations recorded altitudes of 0-20 m. In autumn, birds of prey were heading in southeastern to southwestern directions and in spring in northerly to eastern direction. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 19. Migration intensity of birds of prey at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	45	0.47	0.15	1.73
Bornholm, Rønne	Spring	2022	17	59	0.62	0.17	2.62
Bornholm, Rønne	Autumn	2022	20	37	0.25	0.07	1.03
Bornholm, Rønne	Spring	2023	20	25	0.18	0.05	0.59
Bornholm, Rønne	Autumn	2023	13	25	0.33	0.1	1.4
Bornholm, Nexø	Autumn	2022	18	272	3.4	0.82	10.25
Bornholm, Nexø	Autumn	2023	16	40	0.4	0.17	2.4
Rügen	Spring	2022	20	858	6.29	1.56	24.53
Rügen	Spring	2023	20	648	4.54	0.93	16.97
Vessel-based surveys							
Offshore	Autumn	2021	4	10	0.48	0.25	1.14
Offshore	Spring	2022	4	8	0.26	0.12	0.53
Offshore	Autumn	2022	4	1	0.05	0.05	0.19
Offshore	Spring	2023	4	5	0.17	0.13	0.55

CRANES

Land-based observations recorded mean migration intensities of common cranes between 1-81 ind./h, mostly however, between 7-35 ind./h, whereas the few offshore observations resulted in a mean migration intensity of 1 ind./h Table 20. Flight altitudes >50 m was mostly recorded, on Bornholm frequently >200 m. In the autumn, cranes were migrating southeast to southwest, whereas in spring they were migrating north to northeast. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 20. Migration intensity of cranes at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	7,225	81.5	70.15	912.59
Bornholm, Rønne	Spring	2022	17	1,579	15.82	8.65	117.08
Bornholm, Rønne	Autumn	2022	20	360	2.49	1.12	20.29
Bornholm, Rønne	Spring	2023	20	1,080	7.66	4.13	66.29
Bornholm, Rønne	Autumn	2023	13	121	1.84	1.76	23
Bornholm, Nexø	Autumn	2022	18	3,880	35.56	22.77	371.33
Bornholm, Nexø	Autumn	2023	16	750	7.81	7.81	125
Rügen	Spring	2022	20	2,218	21.84	15.48	311.76
Rügen	Spring	2023	20	4,696	32.71	8.36	93
Vessel-based surveys							
Offshore	Autumn	2021	4	0	0	0	0
Offshore	Spring	2022	4	38	1.27	1.27	5.07
Offshore	Autumn	2022	4	0	0	0	0
Offshore	Spring	2023	4	0	0	0	0

In the following Figure 38 and Figure 39 visualisations of individual tracks are presented for common cranes (n = 193) in spring and autumn.

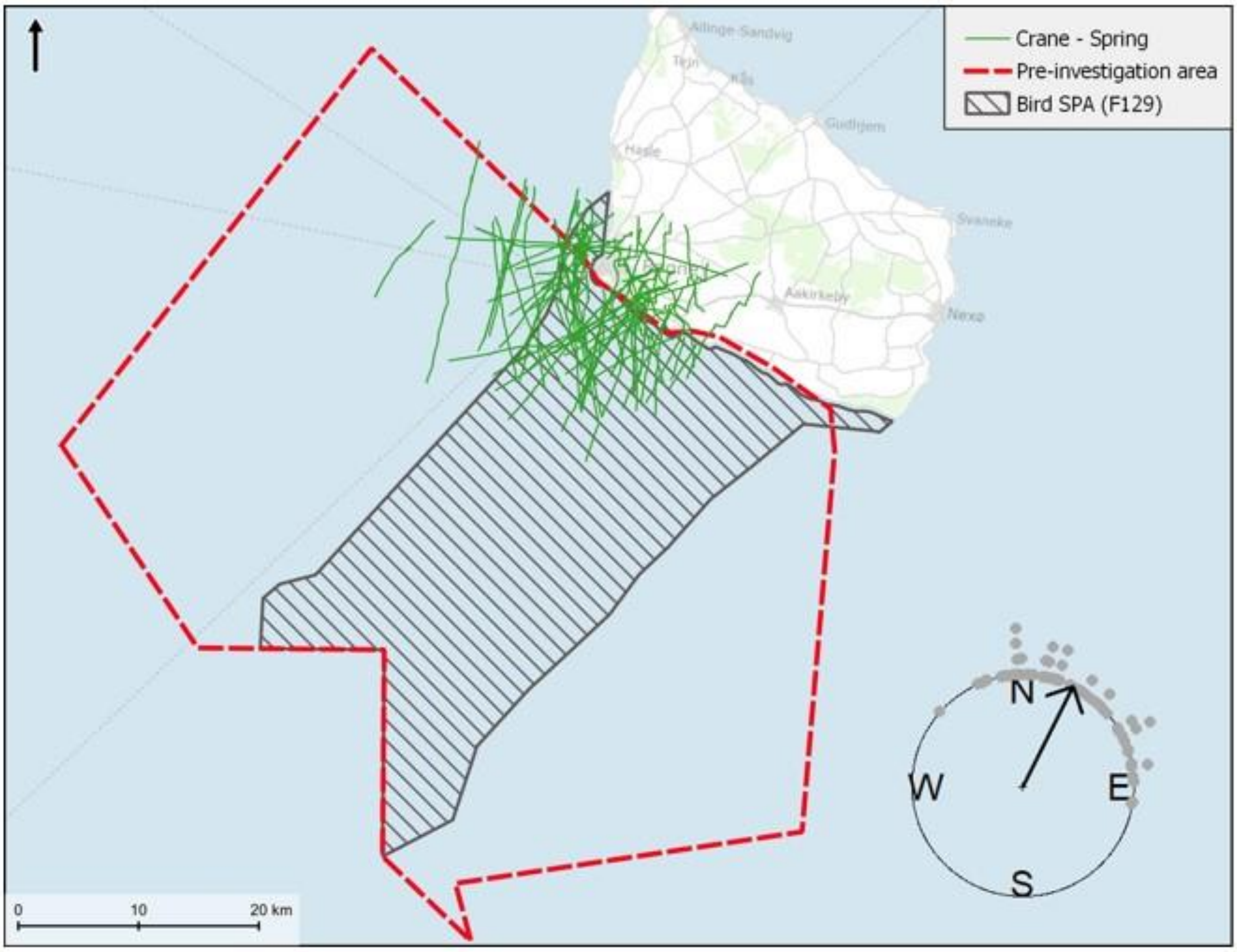


Figure 38. Visualization of produced common crane tracks (n= 68), during spring, summed for the years 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 68) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 26.9 degrees). Each track may represent an individual or a flock. The number of birds appears from Table 20.

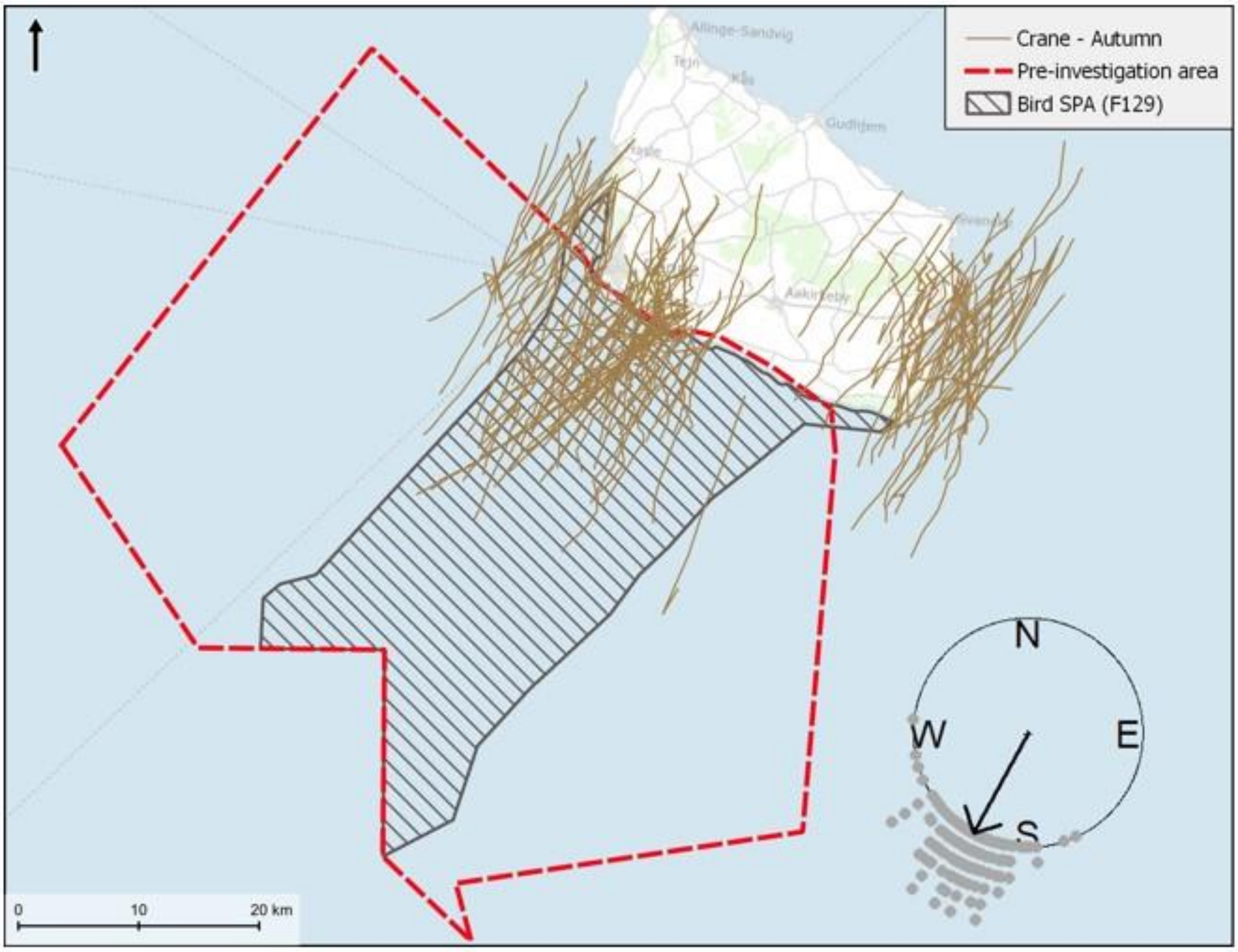


Figure 39. Visualization of produced common crane tracks (n= 125), during autumn, summed for the years 2021, 2022 and 2023. The circular plot shows the smoothed migration direction on a 360-degree axis. Each grey dot (n = 125) represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 208.6 degrees). Each track may represent an individual or a flock. The number of birds appears from Table 20.

GULLS

Larger numbers of gulls were only recorded during spring migration (0.3-2.9 ind./h). Most other recordings were an order of magnitude smaller, except for the offshore values with up to 3.7 ind./h. Migration intensity of gulls was generally much higher in spring than in autumn (Table 21). Gulls were mostly observed flying in altitudes between 0 and 20 m. During spring, they were also recorded in altitudes up to 50 m. The recorded flight directions varied mostly between SE and E in spring and SE to SW in autumn. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 21 Migration intensity of gull species at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value

Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	3	0.03	0.02	0.27
Bornholm, Rønne	Spring	2022	17	41	0.3	0.15	2.71
Bornholm, Rønne	Autumn	2022	20	17	0.1	0.08	1.28
Bornholm, Rønne	Spring	2023	20	361	2.7	1.93	38.81
Bornholm, Rønne	Autumn	2023	13	10	0.13	0.08	0.92
Bornholm, Nexø	Autumn	2022	18	19	0.26	0.12	2.25
Bornholm, Nexø	Autumn	2023	16	11	0.13	0.11	1.82
Rügen	Spring	2022	20	345	2.86	0.98	20.69
Rügen	Spring	2023	20	250	1.81	1.02	20
Vessel-based surveys							
Offshore	Autumn	2021	4	69	3.72	1.42	6.67
Offshore	Spring	2022	4	34	1.01	0.39	1.76
Offshore	Autumn	2022	4	0	0	0	**0**
Offshore	Spring	2023	4	26	0.87	0.29	1.38

TERNS

A total of 96 terns were observed during their migration during the visual observations, 45 in spring and 51 in autumn. The majority of these terns were either common terns (*Sterna hirundo*) or Arctic terns (*Sterna paradisaea*) or sandwich terns (*Thalasseus sandvicensis*). Except for an elevated migration intensity of 0.27 ind./h at Rügen in spring, all intensities of 0.05-0.2 ind./h were recorded in autumn, both land-based and offshore (Table 22). During spring, the observed flight altitudes were mainly below 10 m. Except for spring 2022, when the majority of individuals was recorded in altitudes between 10 and 20 m. During autumn, individuals were observed in heights ranging between 0 and 50 m. Flight directions were mainly directed towards SE in spring and ranged between SE and NW in autumn. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 22. Migration intensity of terns at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	0	0	0	0
Bornholm, Rønne	Spring	2022	17	5	0.06	0.05	0.75
Bornholm, Rønne	Autumn	2022	20	15	0.1	0.07	1.29
Bornholm, Rønne	Spring	2023	20	2	0.01	0.01	0.28
Bornholm, Rønne	Autumn	2023	13	4	0.05	0.04	0.48
Bornholm, Nexø	Autumn	2022	18	11	0.13	0.07	1.18
Bornholm, Nexø	Autumn	2023	16	16	0.15	0.08	1.14
Rügen	Spring	2022	20	36	0.27	0.22	4.3
Rügen	Spring	2023	20	0	0	0	**0**
Vessel-based surveys							
Offshore	Autumn	2021	4	0	0	0	0
Offshore	Spring	2022	4	0	0	0	**0**
Offshore	Autumn	2022	4	5	0.2	0.2	0.8
Offshore	Spring	2023	4	2	0.07	0.07	0.28

AUKS

Common guillemots (*Uria aalge*) or razorbills (*Alca torda*) were the two auk species recorded in the pre-investigation area. Land-based survey recorded average migration intensities of 0-0.2 ind./h, whereas the offshore surveys recorded densities of 0.7-3.8 ind./h. There is no clear difference in the average migration densities between spring and autumn migration (Table 23). Recorded flight altitudes were mainly below 5 mboth during spring and autumn. No clear pattern in terms of flight direction was detected neither during spring nor autumn. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 23. Migration intensity of auks at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	12	0.13	0.1	1.24
Bornholm, Rønne	Spring	2022	17	16	0.22	0.15	2.5
Bornholm, Rønne	Autumn	2022	20	25	0.19	0.13	2.46
Bornholm, Rønne	Spring	2023	20	0	0	0	0
Bornholm, Rønne	Autumn	2023	13	8	0.11	0.09	1.09
Bornholm, Nexø	Autumn	2022	18	1	0.01	0.01	0.25
Bornholm, Nexø	Autumn	2023	16	14	0.14	0.07	0.8
Rügen	Spring	2022	20	6	0.04	0.03	0.55
Rügen	Spring	2023	20	0	0	0	0
Vessel-based surveys							
Offshore	Autumn	2021	4	78	3.83	1.04	5.9
Offshore	Spring	2022	4	57	1.9	1.06	3.87
Offshore	Autumn	2022	4	17	0.76	0.26	1.27
Offshore	Spring	2023	4	59	1.97	0.39	2.9

SONGBIRDS

Large numbers of passerines fly across the Baltic Sea and thus also pass the pre-investigation area, especially during their autumn migration (when they constitute more than 95 % of all migrating birds, cf. Report BSH, 2020). Migration intensity concentrates on certain days of the whole migration period (75 % of all passerines were observed during 17-33 % of the migration days in the study). These results obtained from visual observations were also confirmed by using radar echoes. Regarding flight altitudes, almost half of the radar echoes (registered up to an altitude of 1,000 m) were recorded in the lowest 200 m of altitude, e.g., between the sea surface and an altitude of 200 m.

Land-based surveys recorded mean migration intensities of 2-57 ind./h, whereas the offshore-based surveys revealed considerably lower mean migration intensities (1-14 ind./h; Table 24).

Most songbirds were migrating offshore just above sea-level (0-5 m) or at altitudes between 5-50 m near land. Only one survey (Rønne, autumn 2023) showed an unusual altitudinal preference of >200 m by migrating songbirds. During autumn migration, songbirds flew in southerly, southwestern, and western (and occasionally even in eastern) directions, whereas during spring migration, they were flying in northerly, northeast, and eastern directions depending on the study site. For further figures regarding flight altitudes and directions see Appendix, Section 2.8.

Table 24. Migration intensity of songbirds at the different locations. Indicated are the total number of visually observed individuals, the maximum (daily value) of migration intensity (ind./h) and the total number of survey days.

Location	Season	Year	Number of survey days	Number of individuals	Migration intensity (ind./h)		
					Mean	Standard Error	Maximum daily value
Land-based surveys							
Bornholm, Rønne	Autumn	2021	13	4,472	45.85	27.59	365.6
Bornholm, Rønne	Spring	2022	17	412	5.44	2.98	49
Bornholm, Rønne	Autumn	2022	20	339	2.35	0.71	13.73
Bornholm, Rønne	Spring	2023	20	350	2.8	0.95	15.26
Bornholm, Rønne	Autumn	2023	13	4,103	49.19	41.59	547.23
Bornholm, Nexø	Autumn	2022	18	1,124	12.05	4.01	55.38
Bornholm, Nexø	Autumn	2023	16	1,509	15.09	8.27	130.56
Rügen	Spring	2022	20	6,893	57.95	31.37	512.77
Rügen	Spring	2023	20	2,919	20.92	10.81	196.86
Vessel-based surveys							
Offshore	Autumn	2021	4	299	14.45	6.8	28.38
Offshore	Spring	2022	4	62	1.94	0.43	2.93
Offshore	Autumn	2022	4	93	3.81	3.04	12.8
Offshore	Spring	2023	4	53	1.75	0.21	2.25

LASER RANGEFINDER STUDIES

Laser rangefinder measurements were recorded in spring 2022, when horizontal radar data was not available. These studies helped determine the direction of flight as well as the relative flight altitude of different species and species groups of relevance. Therefore, laser rangefinder studies were only employed to verify horizontal radar studies and are reported here separately. The analysis of laser rangefinder results from Rügen was particularly thorough, because the radar system was not operational at commencement of the study. Graphs and tables shown below summarize the results.

SPECIES AND NUMBERS OBSERVED

Table **25** shows all species that have been measured with laser rangefinder, the dates at which they occurred, and the number of individuals and flocks (tracks) observed. The following figures (Figure 40 to Figure 44) show histograms of the number of individuals and flocks for the most common species and species groups per dates of measurement in spring 2022.

Table 25. Species and species groups for which laser range measurements were taken between March and May 2022 at Rügen. Number of individuals and flocks (or tracks) and dates at which the species occurred are shown as well. The last row indicates the total number of species, individuals, dates and tracks with laser rangefinder measurements.

Species	Scientific name	Species groups	Number of		
			dates	individuals	tracks
Red- throated diver	*Gavia stellata*	Divers	1	2	1
Black-throated diver	*Gavia arctica*	Divers	1	10	1

Species	Scientific name	Species groups	Number of		
			dates	individuals	tracks
Unidentified diver	*Gavia spp*	Divers	1	6	1
Grey heron	*Ardea cinerea*	Herons	3	12	4
Mute swan	*Cygnus olor*	Swans	3	11	4
Greylag goose	*Anser anser*	Geese	7	118	12
Canada goose	*Branta canadensis*	Geese	1	80	2
Barnacle goose	*Branta leucopsis*	Geese	5	27	5
Unidentified goose	*Anser spp, Branta spp*	Geese	1	170	1
Common shelduck	*Tadorna tadorna*	Ducks	1	2	1
Eurasian wigeon	*Mareca penelope*	Ducks	1	19	3
Common teal	*Anas crecca*	Ducks	1	2	1
Mallard	*Anas platyrhynchos*	Ducks	3	12	5
Common eider	*Somateria mollisima*	Ducks	7	53	10
Long-tailed duck	*Clangula hyemalis*	Ducks	6	19	8
Common scoter	*Melanitta nigra*	Ducks	14	801	73
Velvet scoter	*Melanitta fusca*	Ducks	2	8	2
Common goldeneye	*Bucephala clangula*	Ducks	1	3	1
Red-breasted merganser	*Mergus serrator*	Ducks	3	18	4
Goosander	*Mergus merganser*	Ducks	3	4	3
Unidentified merganser	*Mergus sp.*	Ducks	1	19	2
Unidentified duck	*Anatidae*	Ducks	1	40	1
European honey buzzard	*Pernis apivorus*	Birds of prey	3	65	11
Black kite	*Milvus migrans*	Birds of prey	1	1	1
Red kite	*Milvus milvus*	Birds of prey	11	141	41

Species	Scientific name	Species groups	Number of		
			dates	individuals	tracks
White-tailed sea eagle	*Haliaeetus albicilla*	Birds of prey	7	8	8
Western marsh harrier	*Circus aeruginosus*	Birds of prey	7	10	8
Hen harrier	*Circus cyaneus*	Birds of prey	5	8	7
Eurasian sparrowhawk	*Accipiter nisus*	Birds of prey	14	47	43
Eurasian buzzard	*Buteo buteo*	Birds of prey	8	17	10
Osprey	*Pandion haliaetus*	Birds of prey	5	8	7
Eurasian kestrel	*Falco tinnunculus*	Birds of prey	2	2	2
Merlin	*Falco columbarius*	Birds of prey	1	1	1
Peregrine falcon	*Falco peregrinus*	Birds of prey	1	1	1
Common crane	*Grus grus*	Cranes	14	1,795	72
Eurasian curlew	*Numenius arquata*	Waders	2	18	2
Razorbill	*Alca torda*	Auks	1	1	1
Total:	*33 species*		19 dates	3,559 birds	360 tracks

Data are available from a total of 19 dates between 16th of March and 12th of May on which laser rangefinder measurements were taken. During these dates, different species were measured, all the identified species are shown in Table 25.

In total two species of divers, one species of heron, one swan species, several geese, duck and birds of prey species, as well as common crane, were measured when observed with the rangefinder and followed during their trajectory of flight as long as the observations allowed. Since the focus was placed on common cranes and birds of prey, more tracks were available for these groups. Other commonly measured species groups presented below were geese and ducks.

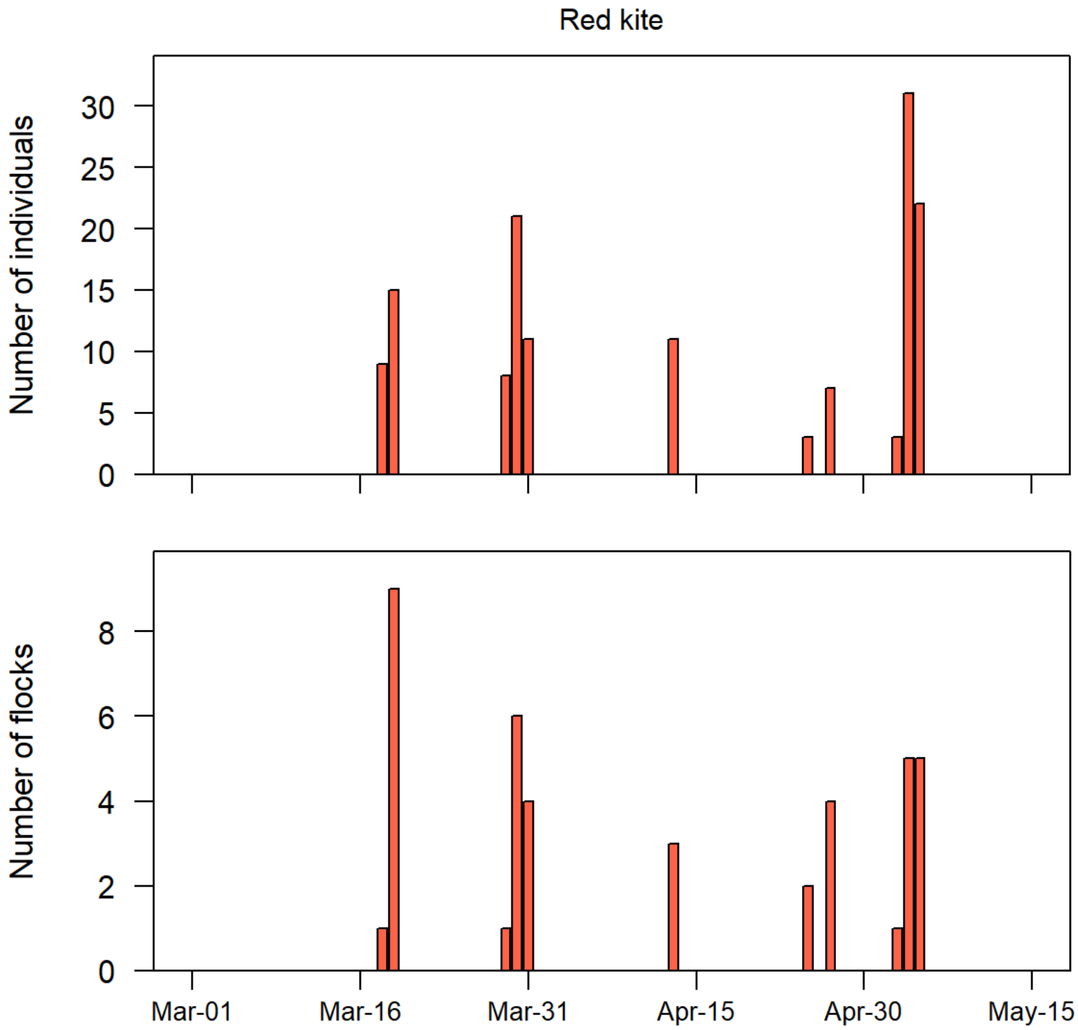


Figure 40. Number of individuals and flocks of red kites for which measurements with laser rangefinder were made at different dates at Rügen during spring 2022. Note the different scale for flocks (tracks) and individuals.

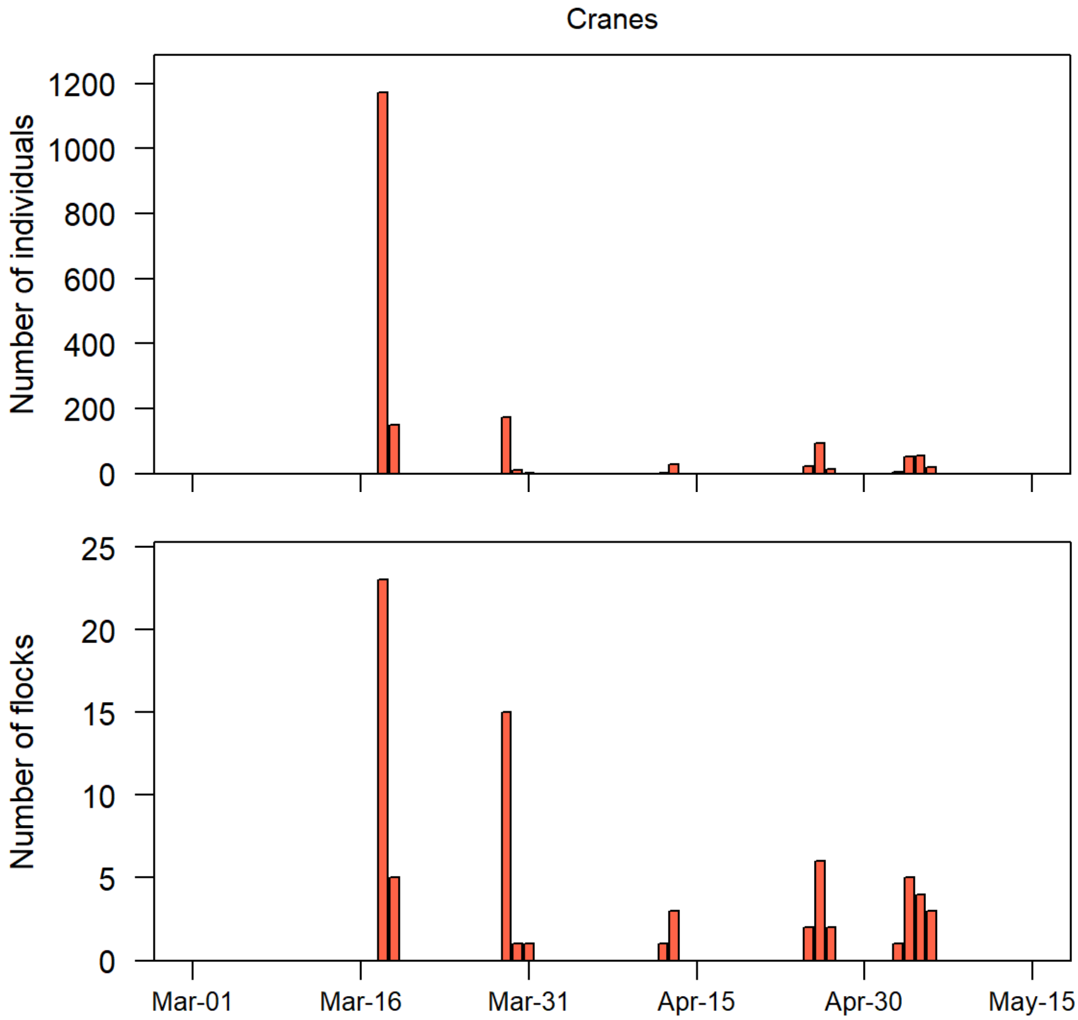


Figure 41. Number of individuals and flocks of common cranes for which measurements with laser rangefinder were made at different dates at Rügen during spring 2022.

Common cranes were more frequently observed in March, especially on 18th of March 2022 there were several flocks measured which accounted for more than the half of all observed individuals (> 1000 individuals) during the whole season (Figure 41).

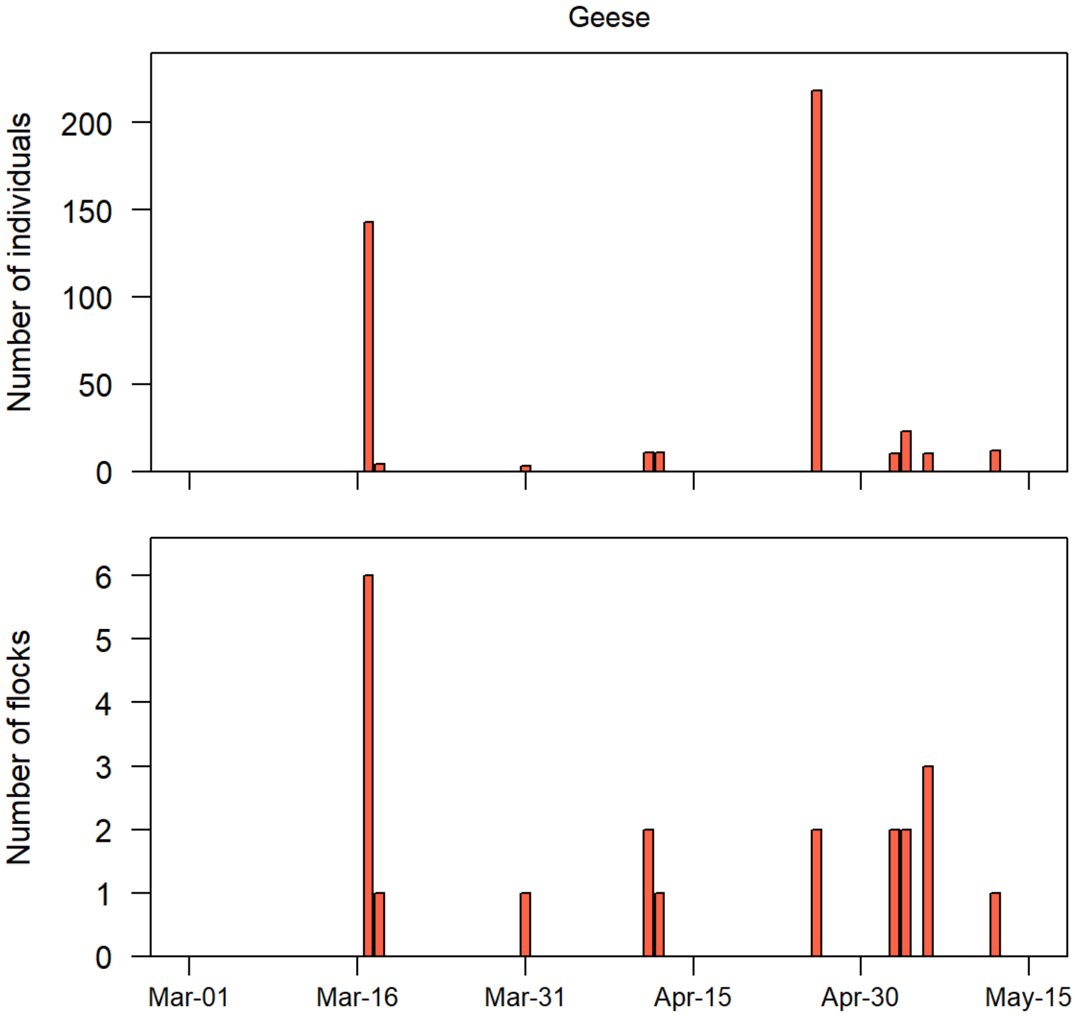


Figure 42. Number of individuals and flocks of geese for which measurements with laser rangefinder were made at different dates at Rügen during spring 2022.

Geese were observed throughout all the season, but their number of individuals varied strongly depending also on the species. Most geese were observed on 17th of March, and on 26th of April 2022. On the 26th of April more than 200 individuals of geese were counted (Figure 42).

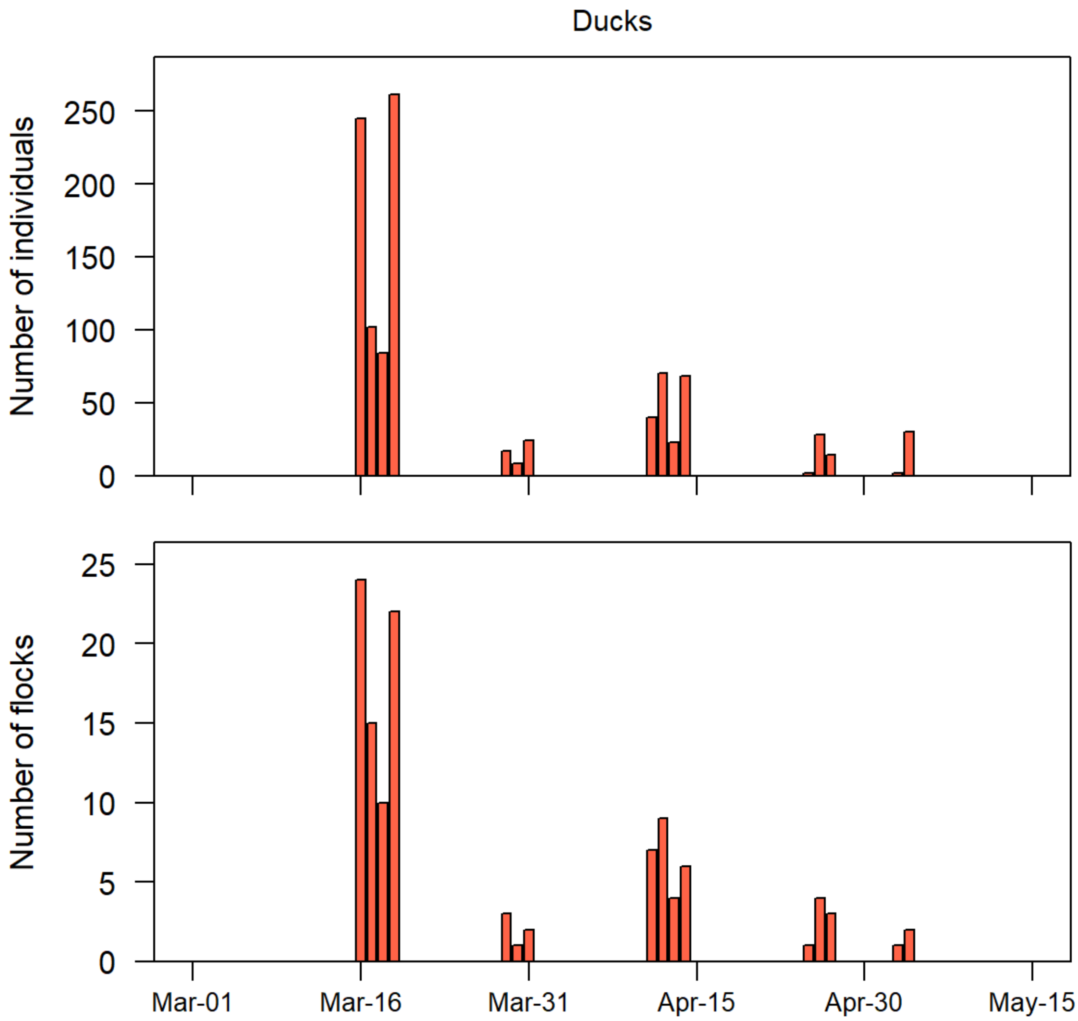


Figure 43. Number of individuals and flocks of ducks for which measurements with laser rangefinder were made at different dates at Rügen during spring 2022.

Ducks were also more frequent in March, but the number of individuals observed was more or less proportional to the number of flocks (tracks) followed. 16th of March and 19th of March were the dates with the largest number of ducks measured (~250 individuals each day, Figure 43).

The different species of birds of prey (12 species) were observed during all spring 2022, except for the very first date of measurement and the last day (12th of May). Often birds of prey are observed flying alone and so the number of flocks often are the same as the number of individuals observed (Figure 44). Most individuals of birds of prey were observed on the 4th of May, and this was due to a large number of European honey buzzards (62 individuals in 8 tracks) and red kites (32 individuals of 5 tracks) measured during that day.

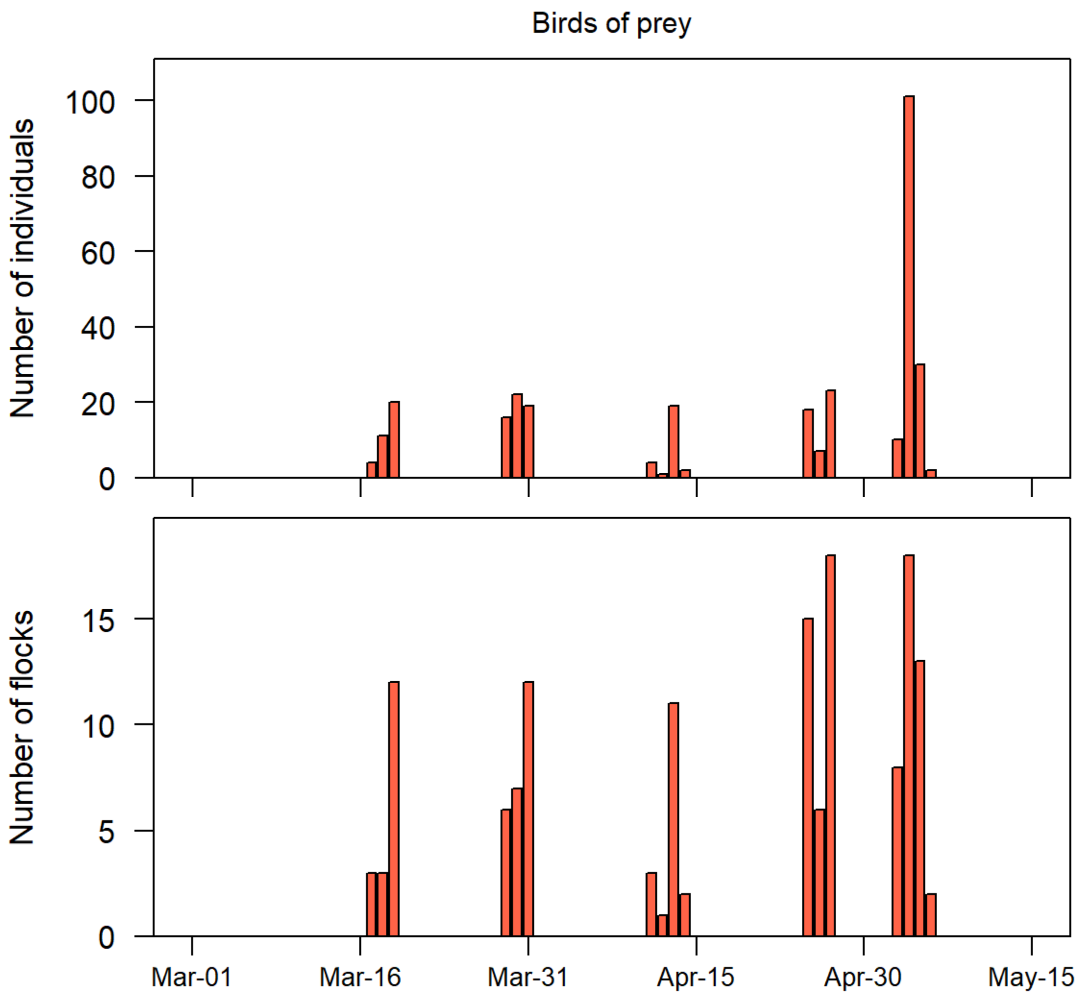


Figure 44. Number of individuals and flocks of birds of prey for which measurements with laser rangefinder were made at different dates at Rügen during spring 2022.

FLIGHT DIRECTIONS

The following figures summarize the directions of the measurements done with laser rangefinder. Each point in Figure 45 and Figure 46 is the average (mean with circular statistics) angle of direction for all angles calculated between two consecutive laser rangefinder measurements of each track. Figures are shown only for the most abundant species and species groups: geese, ducks, birds of prey, red kite, and common crane.

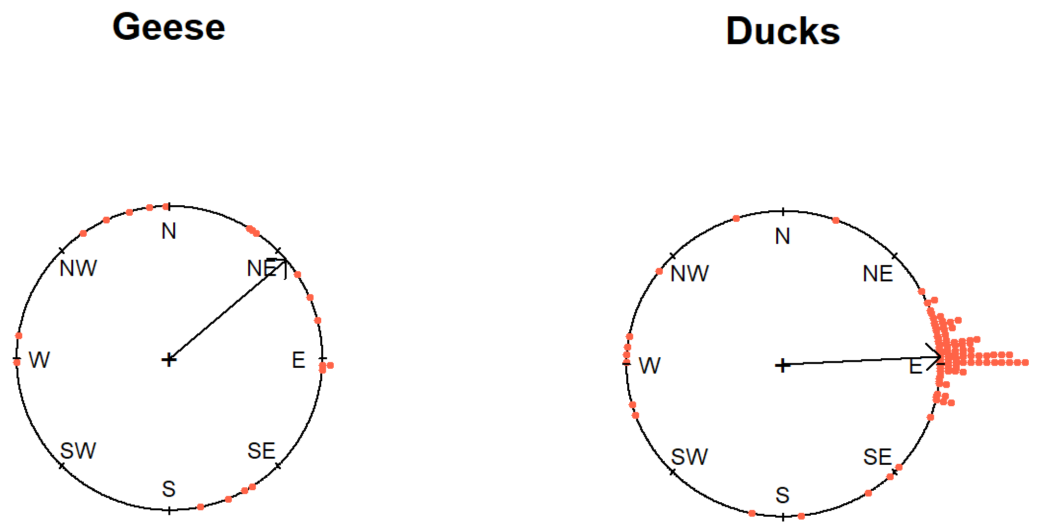


Figure 45. Directions of flight of laser rangefinder for all species of geese (left) and ducks (right) together at Rügen in spring 2022. Each gray point represents the average of every angle of direction (between 0 and 359°) measured between two consecutive rangefinder measurements in each track. All tracks of all species are represented together. Angles of direction are stacked on top of each other so that those most commonly occurring are easily distinguished. The black arrow represents the mean value of all angles (mean calculated for circular statistics). E (East) at 0°, N (North) at 90°, W (West) at 180° and S (South) at 270°.

The different species of geese were observed flying in different directions (Figure 45). Nonetheless, many measurements indicate an easterly direction of flight. However, there were also part of the tracks pointing at north-westerly or southeasterly directions, although the mean direction of flight indicates a NE direction (Table 26 to Table 29).

A different situation is observed for ducks. Irrespective from the species, they all appear to fly consistently towards the east (Figure 45).

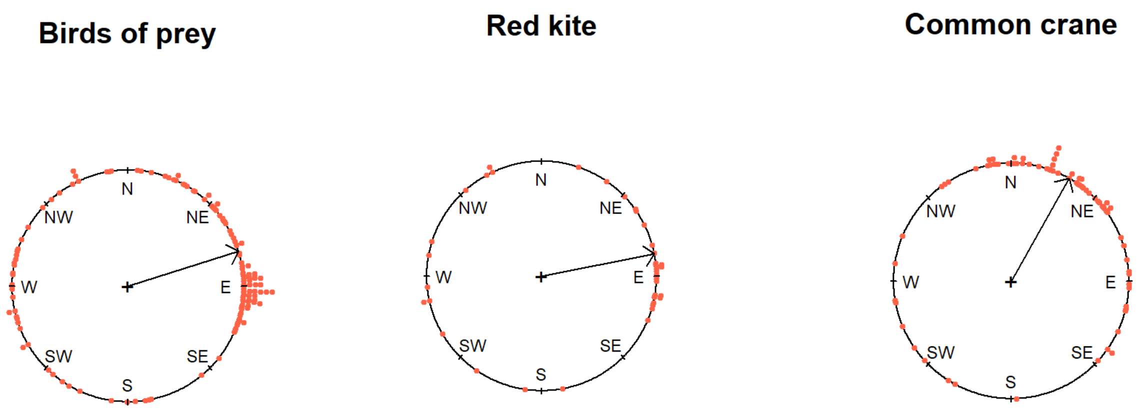


Figure 46. Directions of flight of average laser rangefinder measurements for all tracks of all species of birds of prey together (left) for red kite (middle) and for cranes (right). For details see description in Figure 45.

Birds of prey were also observed flying towards all directions, including the west, but the great majority of tracks and measurements done indicate an eastern direction of flight which coincides in this case with the mean direction of flight (Figure 46).

Common cranes were the species for which most data from rangefinder exist, and the data is consistent. The flight direction of most cranes measured in spring 2022 was NNE, (Figure 46).

FLIGHT ALTITUDES

Laser rangefinder studies also provide information about the altitudes at which birds most often fly. Table 26 and Table 27 summarize the flight altitudes for all species and species groups. Figures with altitude distribution are shown for the most commonly occurring species and species groups Figure 47 to Figure 49.

Table 26. Summary statistics for flight direction (in degrees) and flight altitudes for the species measured with laser rangefinder in spring 2022 at Rügen. Note that circular statistics have been applied for flight direction (degrees). The angles directions are measured in degrees and are counted from 0 to 360 in a counter clock direction (0 starts at E, 90 is N, 180 is W and 270 is S). Note that altitudes may be negative (especially for ducks and low-flying species due to uncertainties in the measurements).

Species	Flight direction (°)			Altitude (m)		
	Mean	Median	Direction approx.	Mean ± SD	Median	Max
Red- throated diver	5.4	5.4	E	19.4 ± 0	19.4	23
Black-throated diver	0.9	0.9	E	30.4 ± 0	30.4	35
Unidentified diver	10.7	10.7	E	-9.8 ± 0	-9.8	-9
Grey heron	337.1	348.4	SEE	72.5 ± 46.5	85.5	116
Mute swan	319.5	312.4	SE	53.6 ± 17.3	53.9	73

Species	Flight direction (°)			Altitude (m)		
	Mean	Median	Direction approx.	Mean ± SD	Median	Max
Greylag goose	78.9	91	NE	61.5 ± 47.3	48.4	161
Canada goose	359	23.5	E	22.8 ± 18.2	29.3	46
Barnacle goose	325.6	302.3	SE	43.3 ± 12.8	38.7	78
Unidentified goose	355.8	355.8	E	-8.8 ± 0	-8.8	-6
Common shelduck	143	143	NW	58.7 ± 0	58.7	67
Eurasian wigeon	359.4	355.4	E	14.3 ± 20.7	12.7	71
Common teal	13	13	E	43.2 ± 0	43.2	47
Mallard	331.9	339.8	SEE	31.9 ± 27.3	43.2	85
Common eider	356	2.3	E	-5.4 ± 7.5	-8.6	12
Long-tailed duck	6.2	3.8	E	-7.8 ± 4.4	-9.8	4
Common scoter	4.3	4	E	-2.9 ± 15.5	-9.2	79
Velvet scoter	10.4	10.4	E	-4.9 ± 6.9	-4.9	0
Common goldeneye	3.2	3.2	E	-7.3 ± 0	-7.3	0
Red-breasted merganser	1.2	2.3	E	18.7 ± 25.8	17.7	87
Goosander	262.9	262.9	SW	13.1 ± 15.5	4.8	31
Unidentified merganser	47.8	47.8	NE	57.1 ± 35.1	57.1	92
Unidentified duck	-	-	-	-6 ± 0	-6.0	-6
European honey buzzard	219.8	233.2	SW	101.7 ± 36.8	111.5	200
Black kite	5.5	5.5	E	173.2 ± 0	173.2	189
Red kite	11	3.1	E	100.6 ± 78.7	79.3	796
White-tailed sea eagle	289.1	283.6	SE	57.8 ± 46.4	41.3	340
Western marsh harrier	108.6	146.8	NW	61.2 ± 43.5	50.1	154

Species	Flight direction (°)			Altitude (m)		
	Mean	Median	Direction approx.	Mean ± SD	Median	Max
Hen harrier	45.9	65.7	NE	27.8 ± 7.5	28.4	43
Eurasian sparrowhawk	22.5	9.5	NEE	47.7 ± 28.3	44.2	160
Eurasian buzzard	17.9	355	NEE	75.3 ± 59.8	68.7	185
Osprey	276.2	278.3	S	57.4 ± 40.7	47.0	176
Eurasian kestrel	41.6	41.6	NE	43 ± 7.5	43.0	55
Merlin	-	-	-	31 ± 0	31.0	31
Peregrine falcon	353.4	353.4	E	44 ± 0	44.0	55
Common crane	60.8	68	NE	148.2 ± 96.9	119.7	554
Eurasian curlew	14.5	14.5	E	65.2 ± 87.4	65.2	194
Razorbill	0.4	0.4	E	-3.5 ± 0	-3.5	-1

Table 27. Summary statistics for flight direction (in degrees) and flight altitudes for species groups measured with laser rangefinder in spring 2022 at Rügen.

Species groups	Flight direction (°)			Altitude (m)		
	Mean	Median	Direction approx.	Mean ± SD	Median	Max
Divers	5.7	5.4	E	13.3 ± 20.8	19.4	35
Herons	337.1	348.4	SEE	72.5 ± 46.5	85.5	116
Swans	319.5	312.4	SE	53.6 ± 17.3	53.9	73
Geese	40.3	44.3	NE	48.3 ± 40.8	38	161
Ducks	2.9	2.8	E	1.6 ± 20.1	-8.6	92
Birds of prey	17.3	4	E	70.9 ± 58	56.1	796
Cranes	60.8	68	NE	148.2 ± 96.9	119.7	554
Waders	14.5	14.5	E	65.2 ± 87.4	65.2	194
Auks	0.4	0.4	E	-3.5 ± NA	-3.5	-1

While ducks, auks and divers mainly conduct their flight at low altitudes (see Table 26 and Table 27), half of the geese were flying above 20 m of altitude and all cranes and most birds of prey flew at high altitudes (> 20 m), with cranes flying mainly at ranges between 50-200 m (see Figure 47 to Figure 49).

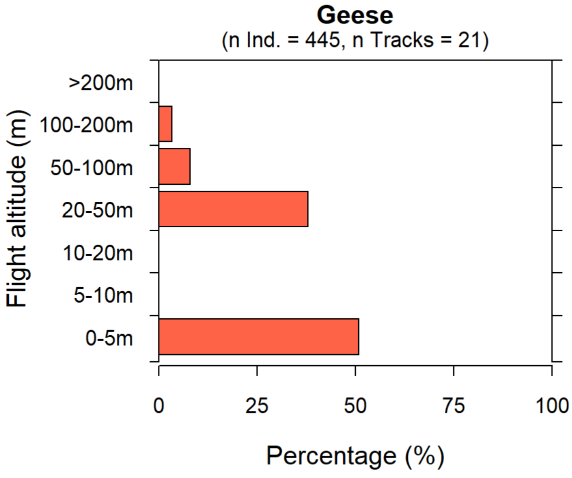


Figure 47. Altitude distribution of all species of geese measured with laser rangefinder at Rügen during spring 2022.

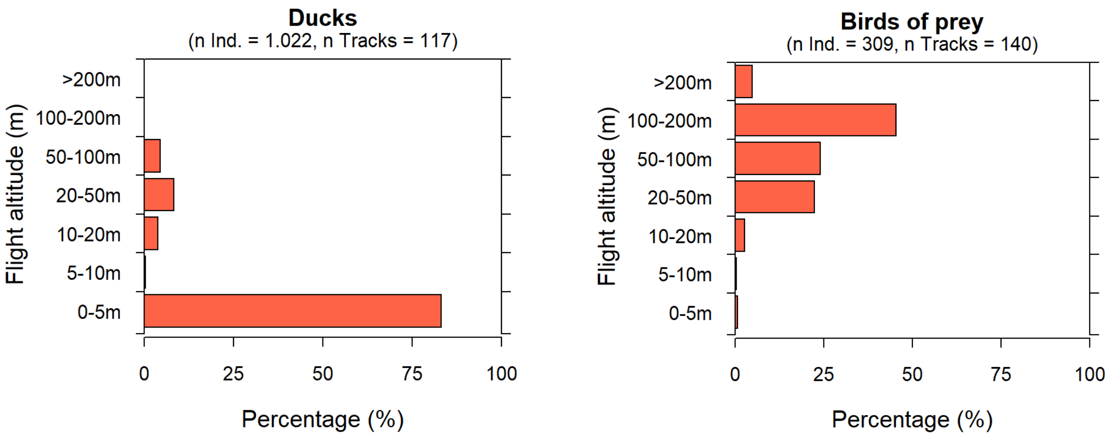


Figure 48. Altitude distribution of all individuals (n) of all species of ducks (left) and birds of prey (right) measured with laser rangefinder at Rügen during spring 2022.

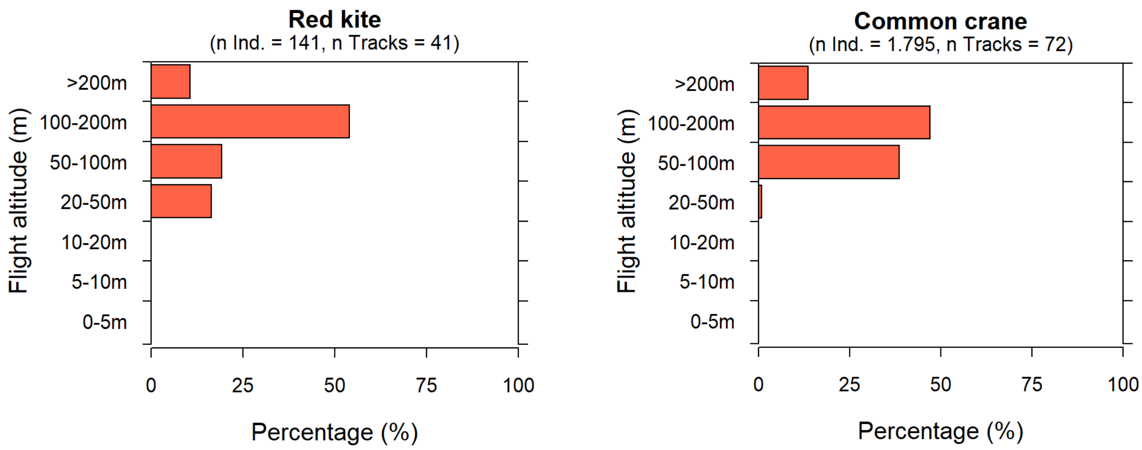


Figure 49. Proportion of individuals (n) of red kites (left) and common cranes (right) measured with laser rangefinder at Rügen during spring 2022.

5 CONCLUSIONS

5.1 LAND- AND VESSEL-BASED SURVEYS

The desktop study of existing data provided ample proof of the western Baltic Sea around the island of Bornholm as a hub of long-distance bird migration. According to the literature reviewed, a crossroad of songbirds migrating nocturnally in a broad front in a NE-SW direction exists, as well as a large number of seabirds migrating in E-W direction, and cranes and birds of prey migrating diurnally in N-S direction. Most species appear to use the same route in reverse direction during return migration. Apart from taxonomic preferences, their flight direction and altitude appear to be strongly weather-dependent.

The land- and vessel-based surveys conducted in 2021 to 2023 confirmed the existence of this general pattern within the pre-investigation area. The weather-radar, on the other hand, does not allow for that kind of fine detail on a small geographic scale as discussed in the following.

The species composition recorded during the visual observations of the land- and vessel-based surveys was dominated by a few predominant species groups and varied only a little between the four study sites and the five migration seasons: Waterbirds such as cormorants, geese, ducks, and auks dominated during autumn and spring migration and, in addition, gulls in autumn and waders in spring. Among the landbirds, the predominant species groups were cranes, pigeons, and songbirds.

Autumn migration intensity peaked in October, for the land-based observation sometime in early November and for the vessel-based observations sometime already in late September. Spring migration intensity peaked mostly in late March to April with vessel-based intensities a little later in April. In general, the migration intensity was regularly about 5-10 times higher near the islands of Bornholm and Rügen than offshore. This was true both for monthly means as well as on a day-by-day basis.

The flight direction during migration was toward north to east in spring and towards south to west in autumn – as was to be expected. Visual observations of the flight altitude provided a discrepancy between birds migrating near either of the two islands of Bornholm or Rügen versus offshore with the latter travelling rather low over the sea surface, and the nearshore birds travelling much higher. This well-known phenomenon is usually interpreted as an avoidance behaviour of higher wind speeds, i.e., an adaptation to conserve energy.

Furthermore, the migration patterns of the most relevant species groups (divers, cormorants, geese, ducks, birds of prey, cranes, waders, gulls, terns, auks, and songbirds) observed in the pre-investigation area are being described in more detail with the survey results as examples.

Beyond the confirmation of the general migration pattern for the pre-investigation areas, this study was able to fill essential knowledge gaps for the pre-investigation area. The increasing number of offshore wind farms under construction or in operation, e.g. in German waters, provides a growing challenge for migrating birds. Especially under inclement weather conditions (not studied here) such as low visibility or sudden head winds, nocturnal migrants descend to very low altitudes to either navigate by landmarks or to land until onward navigation is possible. For other parts of the study, additional offshore data would have been beneficial for reasons presented in this report.

5.2 MIGRATION PATTERNS DURING THE SEASON

In general, the plotted MTR for day and night periods for the two periods analysed (March to May and August to November) show that migration does not occur equally at all dates, but peaks at some dates, most probably coinciding with favourable weather conditions (Alerstam 1990). Weather conditions influence migration, as this may affect the energy costs of flights as well as visibility, thus affecting the survival of migrating birds (Alerstam 1990, Newton 2010). If the distribution of bird detections throughout the season is too homogenous, this can indicate that data are not realistic and should not be used.

According to the literature, most birds migrate at a height of up to 1.5 km above the ground, and few migrate above 3 km of altitude (Newton, 2010). Nonetheless, there are some species that are well known to frequently fly above these altitudes. Waders returning from Africa to Europe, for example, are known to ascend rapidly above 3 km of altitude to compensate for flying costs. Thrushes may reach high altitudes to find suitable winds (Newton 2010). Most birds fly below the clouds, although those that break the cloud layer may be able to escape difficult weather conditions (mist, rain, snow). Nevertheless, flying at high altitudes also comes with costs. While its advantages, besides reducing energy costs and reduction of wind turbulence, include avoidance of obstacles and reduced predation risk, the cost is the effort required for ascending, which is costly for heavy birds (Newton 2010). A study conducted in the Netherlands using bird migration data extracted from weather radar suggested that flying at high altitudes occurs mostly when wind conditions near the surface are unfavourable. In this sense, migrating birds, do not only fly at high altitudes to optimize wind support but are forced to find a balance between different adaptive pressures. However, they tend to concentrate at the lowest altitudes with acceptable, but not necessarily optimal wind conditions (Kemp et al. 2013).

The flight altitude distribution observed in the data analyzed show the expected pattern. Most migration took place within the first 2 km of altitude, although there was always a relatively small proportion of birds migrating at much higher altitudes.

Typically, migration occurs at the lowest few hundred meters above the ground (Bruderer et al. 2018, Nilsson et al. 2018) and different profiles should be inspected with care for the possible methodological errors. In some cases, altitude distribution of bird-like echoes is very different from the expected pattern, no conclusions should be drawn from these values. Based on this consideration, several seasons for all radars in this study were not further analysed.

Another potential source of errors related to the use of weather radars to study altitude of bird migration is the landscape limitations. Lowest elevations of the radar scans can be partly shadowed by landscape elements, thus leading to an underestimation of migration at the very lowest few hundred meters.

Nonetheless, it is generally possible to detect birds with the aid of weather radar data. Therefore, analysing weather radar data with regard to the occurrence of bird signals provides the opportunity to track bird migration events for an entire region within the radius of the radar's detection range. There is a weather radar station on Bornholm in the immediate vicinity of the pre-investigation area. Other radar stations are located along the coasts of Germany (Rostock [52.160214N/11.176144E]), Sweden (Karlskrona [56.295617N/15.610177E] and Hemse/Gotland [57.303437N/18.400188E]) and Denmark (Bornholm [55.112804N/14.887444E] and Stevns/Fyn [55.325614N/12.448202E]). For this reason, it was decided before the start of the pre-investigation to consider the data from these weather radar stations for visualising bird migration events to complement the bird radar investigations carried out locally on Rügen and Bornholm.

In total, radar data from three weather radar stations in the Baltic Sea region of Bornholm-Rügen-Skane were analysed for bird signals (however, only the two Swedish ones proved to be useful). For the analysis, only completely unfiltered weather radar data, i.e. raw data without any loss of information, are usable. The preliminary evaluation showed, however, that of the Rostock weather radar stations only provided processed radar data from which no further conclusions about bird migration could be drawn. The more distant Swedish stations Karlskrona and Hemse, on the other hand, could be analysed for bird signals and were used to approximate bird migration. The altitude distribution determined with the data from these stations showed that hardly any bird signals were recorded above approx. 1000 m above the ground. This underlines the significance of the bird radar surveys carried out locally on Rügen and Bornholm, which only detected bird migration up to an altitude of 1000 m. By concentrating the radar surveys on the first 1000 above ground, no altitude range relevant for bird migration was omitted.

Furthermore, the weather radar data recorded continuously from 2020 to 2022 showed that the migration periods in this region are between March and May and July and November. The highest migration rates are consistently observed at all weather radar stations in September and October and thus in autumn. This is also consistent with the radar surveys carried out locally.

Unfortunately, more detailed statements on local bird migration cannot be made from the weather radar data, as it was not possible to include the nearest and thus most relevant radar station in the analysis due to the loss of radar data from the weather radar on Bornholm.

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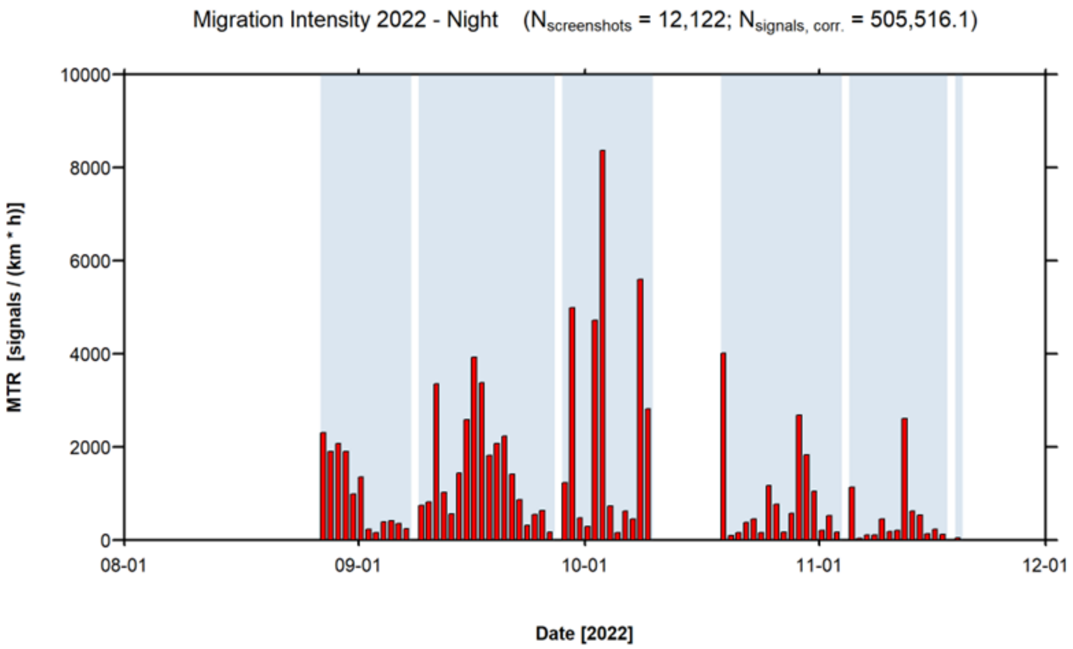
7 APPENDIX PART B MIGRATING BIRDS

7.1 OVERALL MIGRATION INTENSITY – VERTICAL RADAR



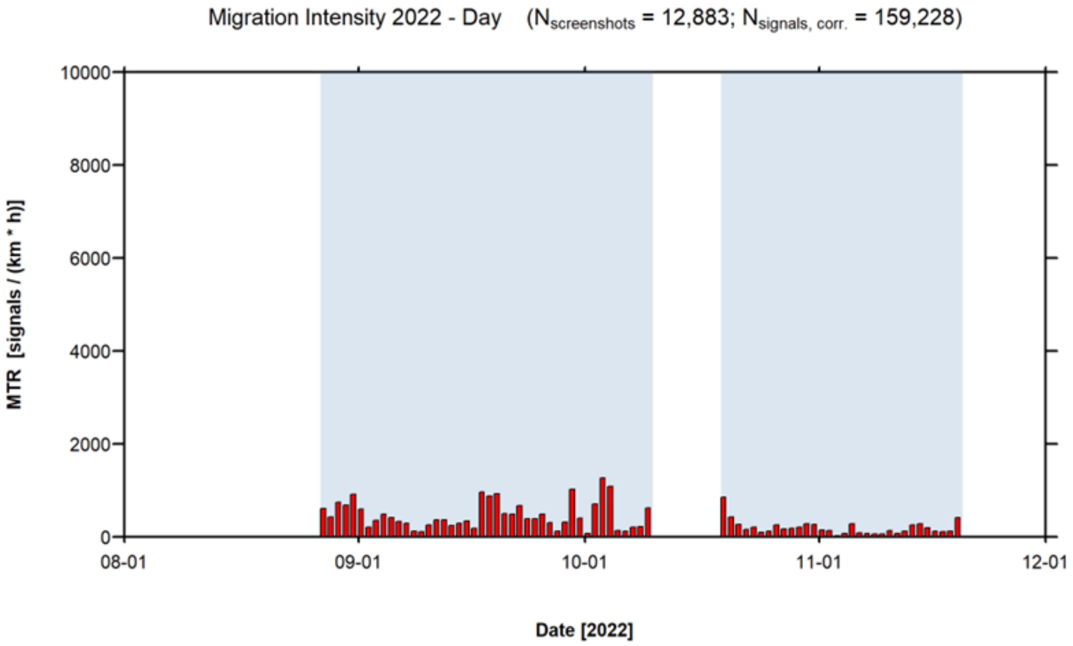
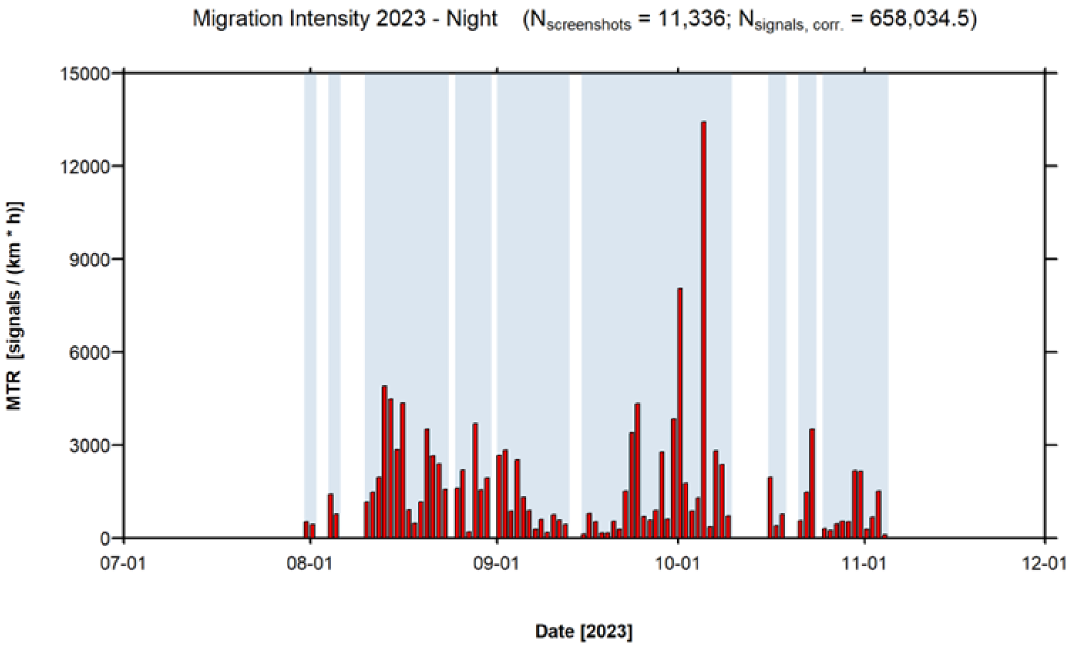


Figure 50. Nocturnal and diurnal migration intensities at Nexø in 2022 recorded by vertical radar.



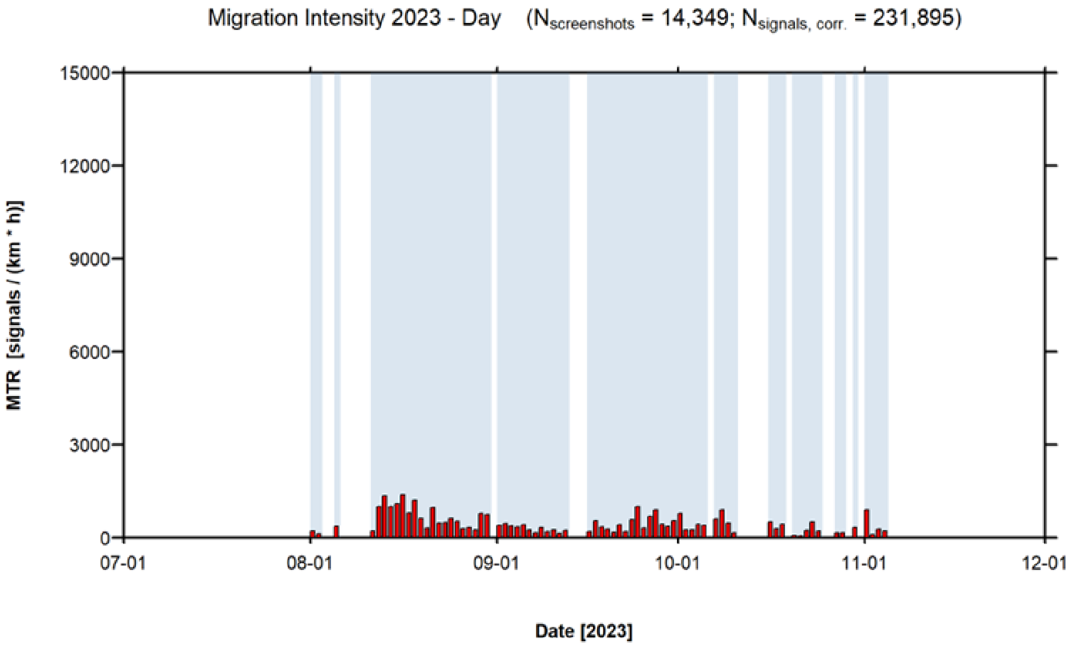
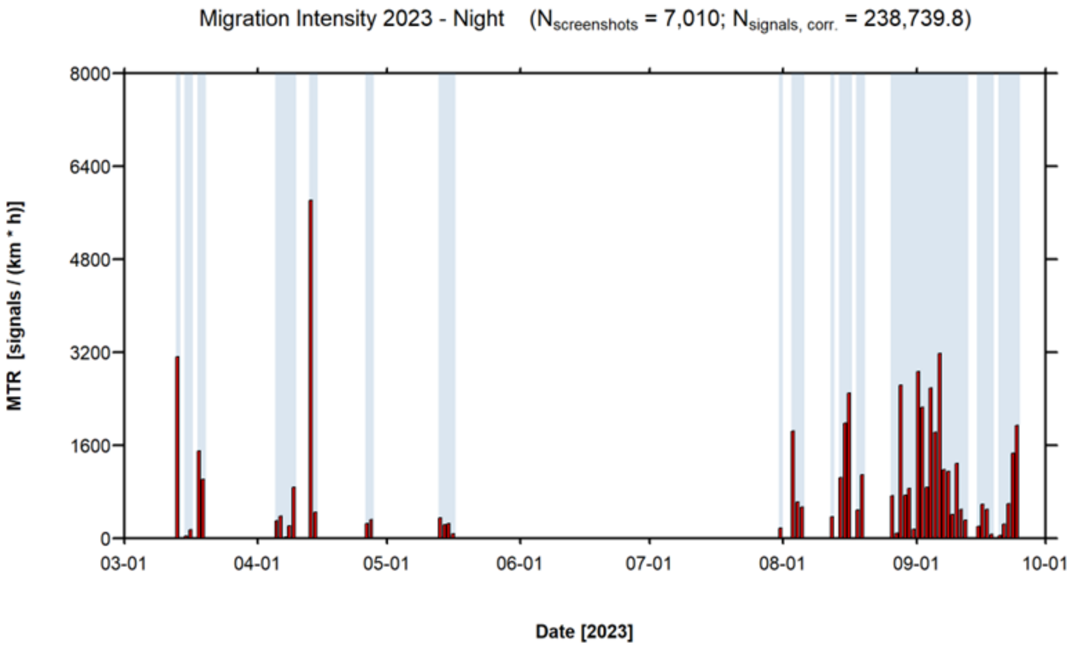


Figure 51. Nocturnal and diurnal migration intensities at Nexø in 2023 recorded by vertical radar.



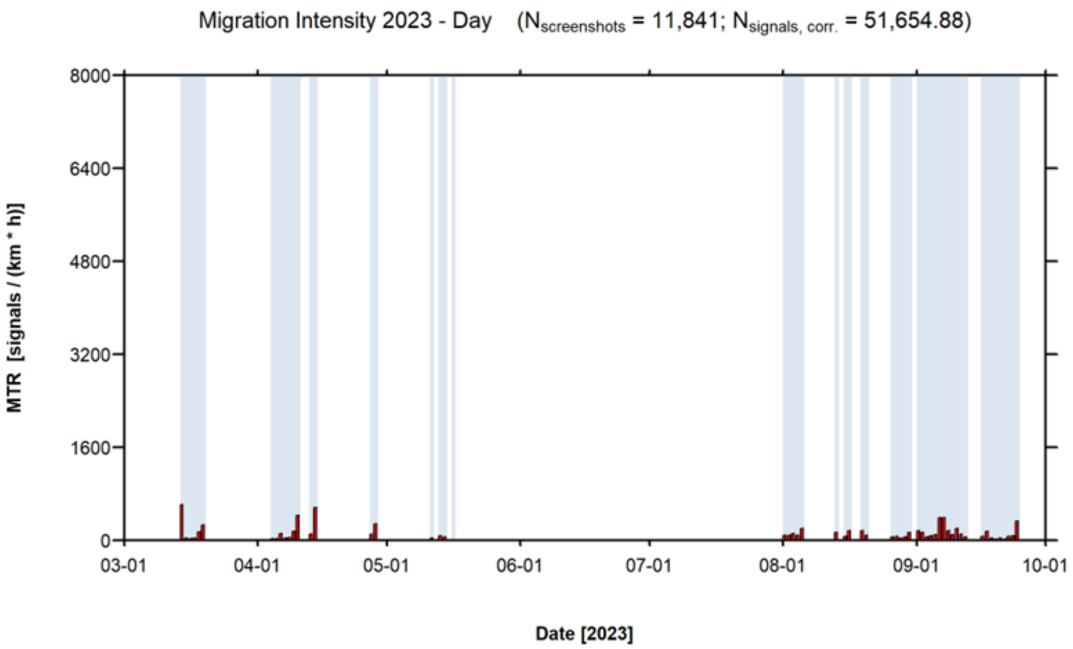
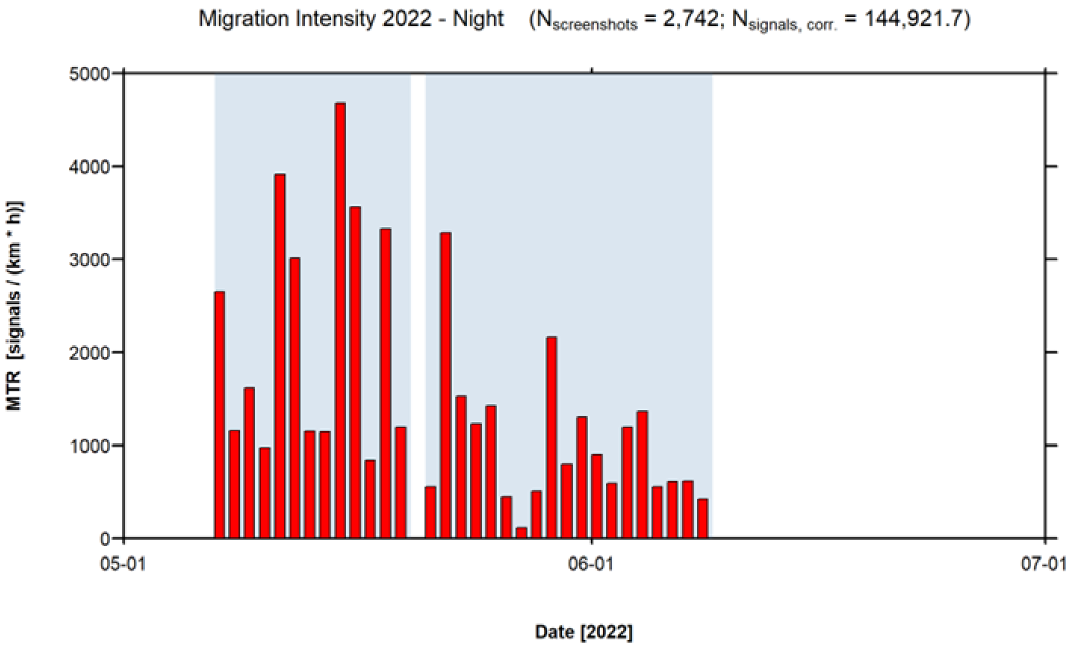


Figure 52. Nocturnal and diurnal migration intensities at Rønne in 2023 recorded by vertical radar.



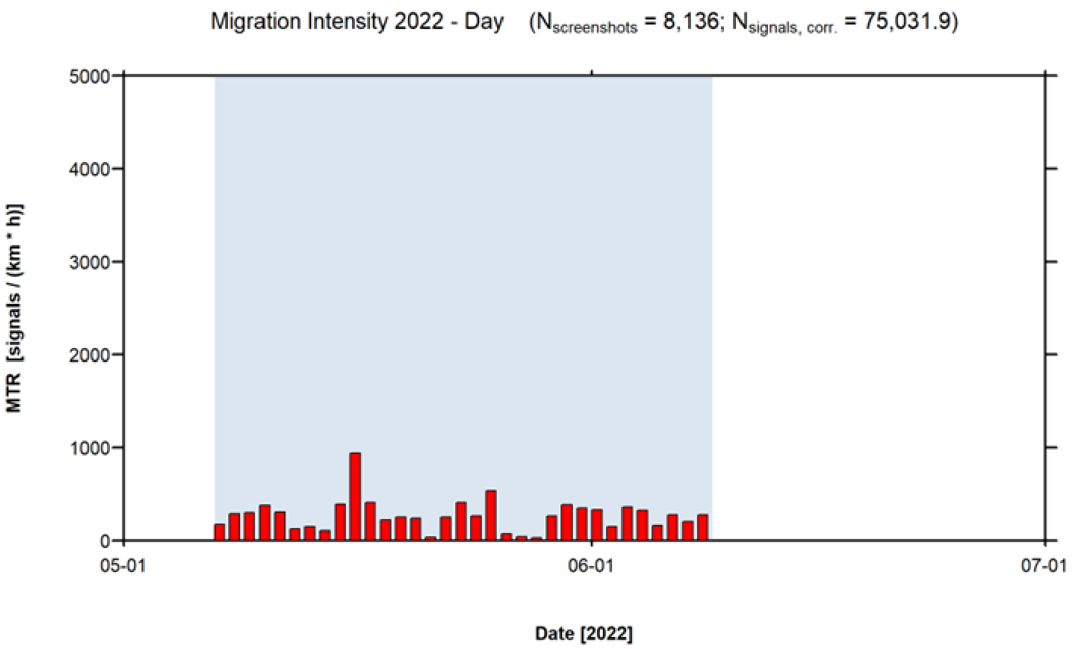
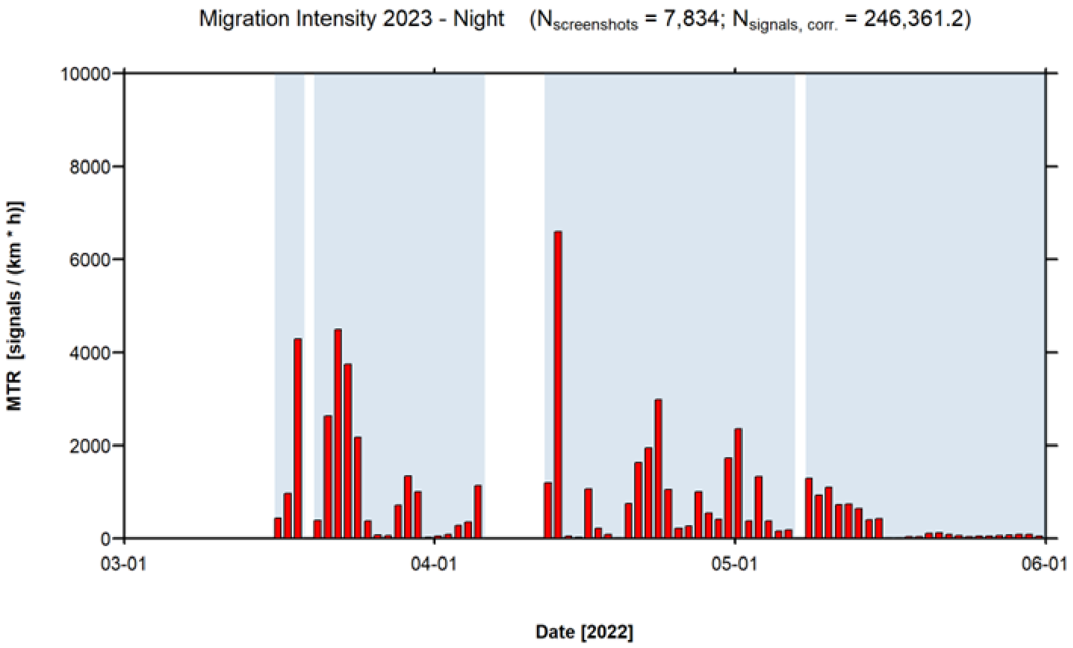


Figure 53. Nocturnal and diurnal migration intensities at Rügen in 2022 recorded by vertical radar.



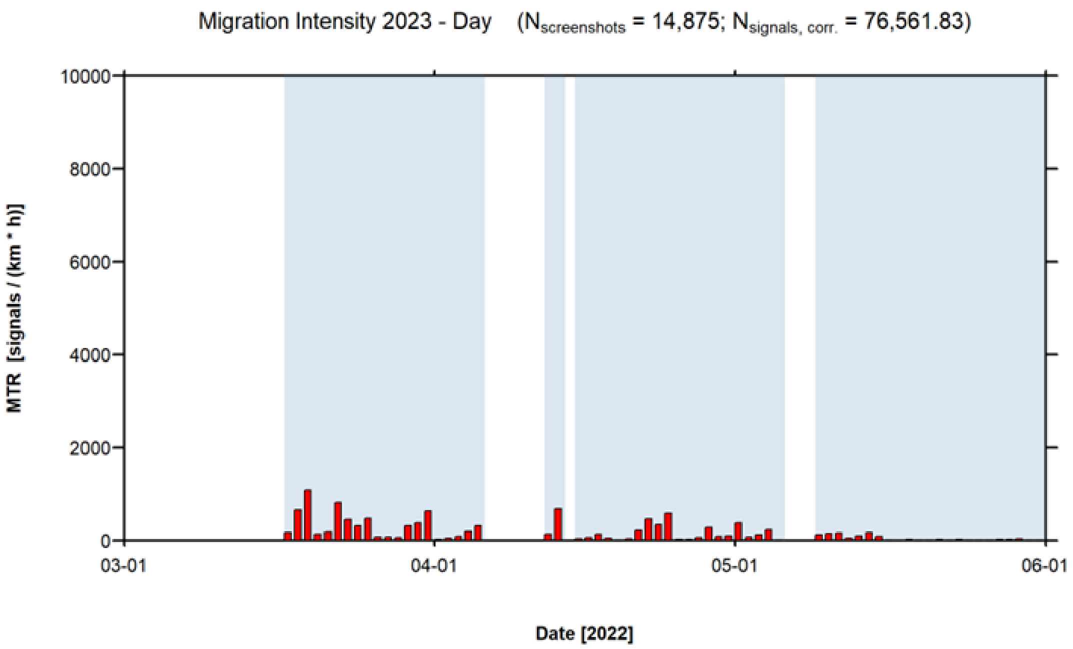


Figure 54. Nocturnal and diurnal migration intensities at Rügen in 2023 recorded by vertical radar.

7.2 24 H PHENOLOGY – VERTICAL RADAR

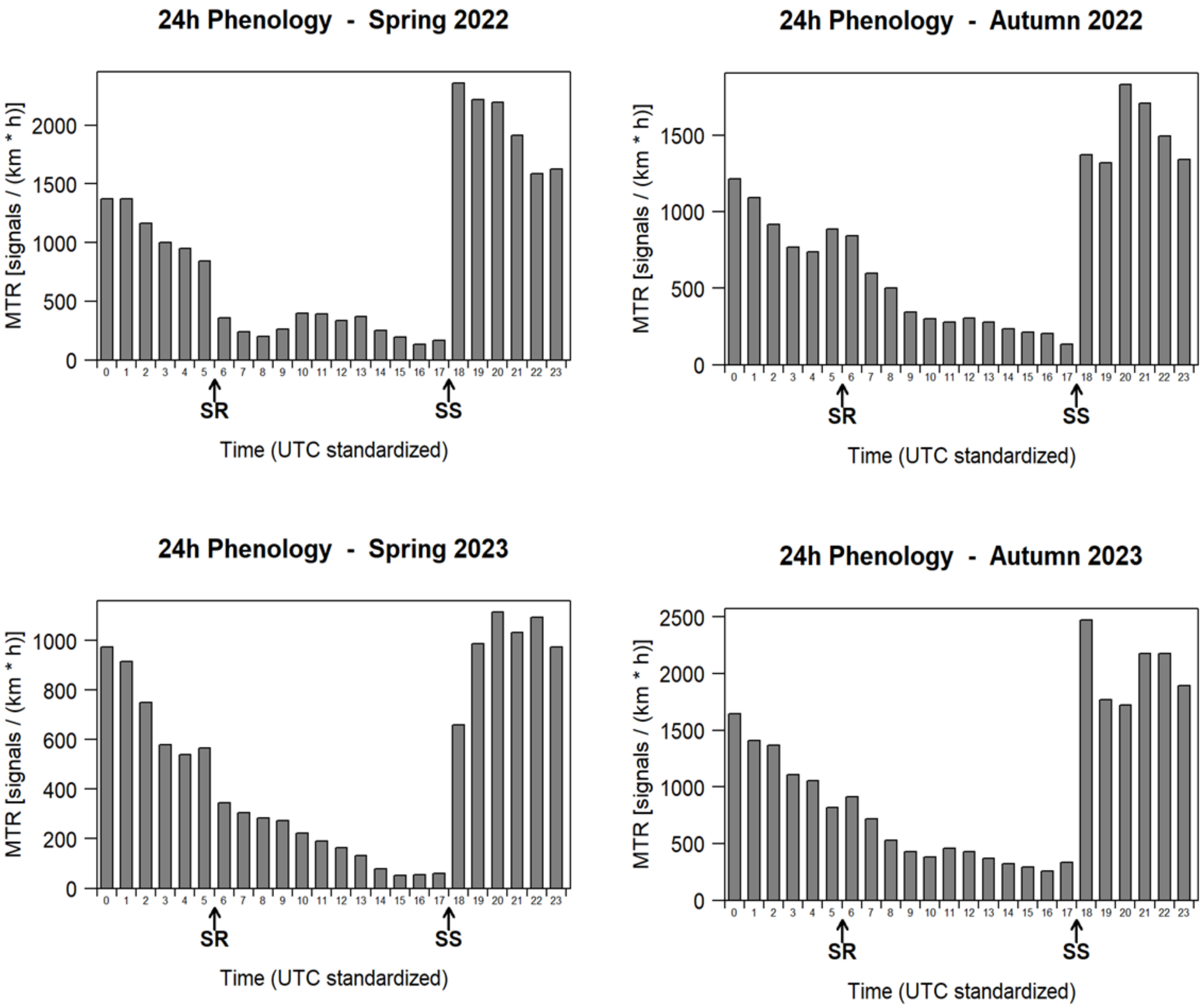


Figure 55. Pattern of 24 h migration intensity, vertical radar data from Rügen in spring (left) and Nexø in autumn (right). SR: Sunrise, SS: Sunset.

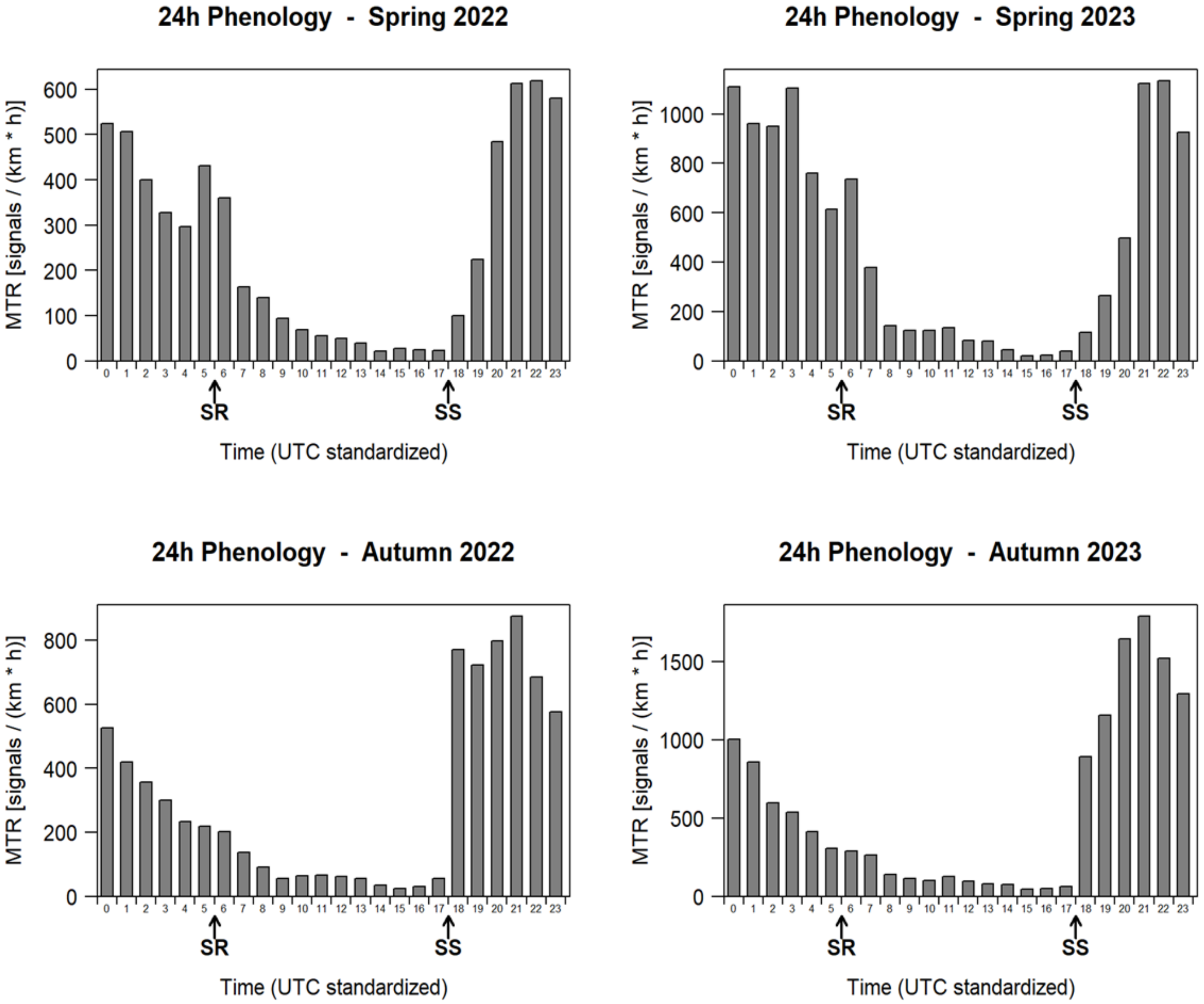


Figure 56. Pattern of 24 h migration intensity, vertical radar data from Rønne in 2022 (left) and 2023 (right). SR: Sunrise, SS: Sunset.

7.3 OVERALL HEIGHT DISTRIBUTION DURING DAY AND NIGHT

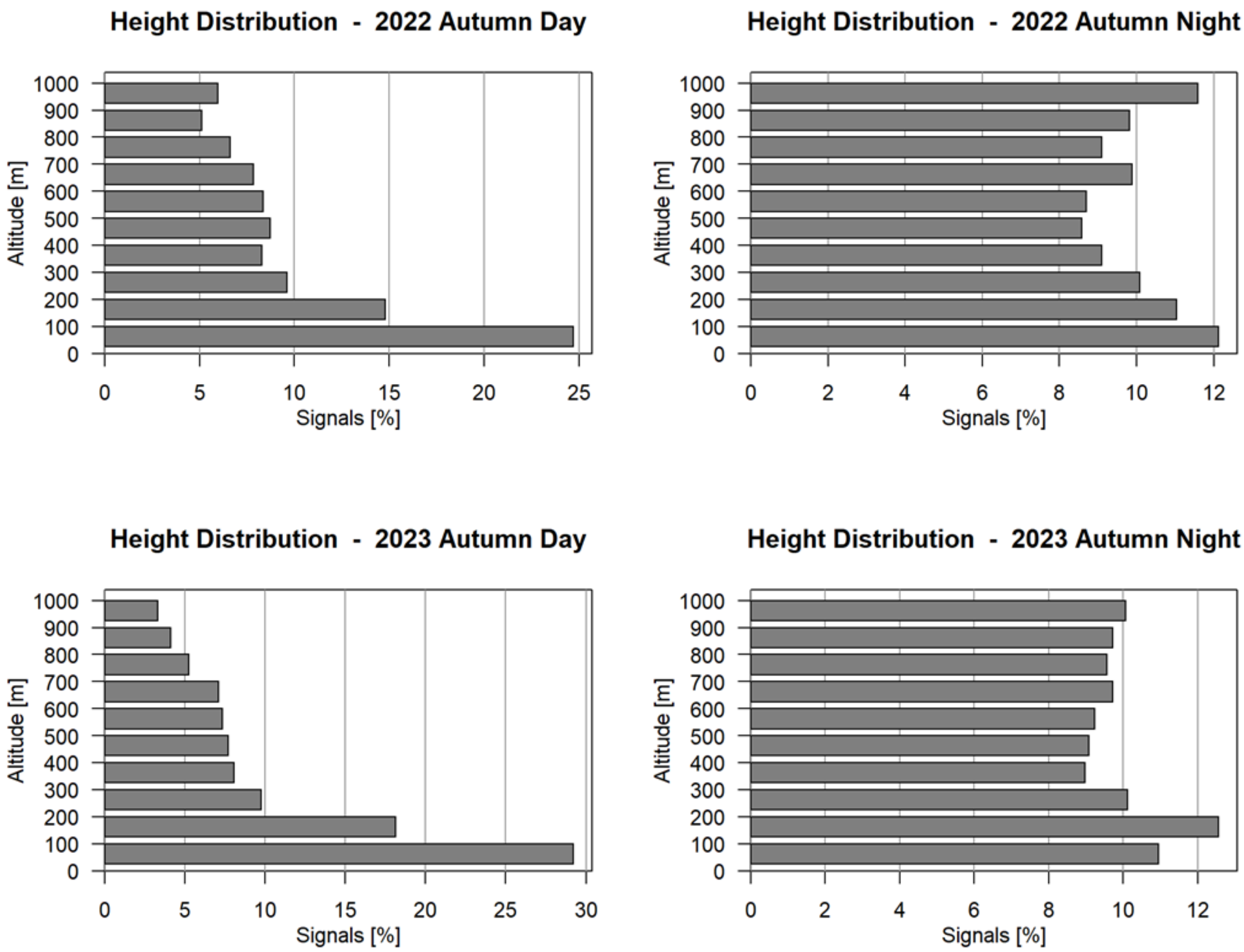


Figure 57. Altitudinal distribution of daytime (left) and nighttime (right) migrant bird signals at Nexø in autumn 2022 and 2023 recorded by vertical radar.

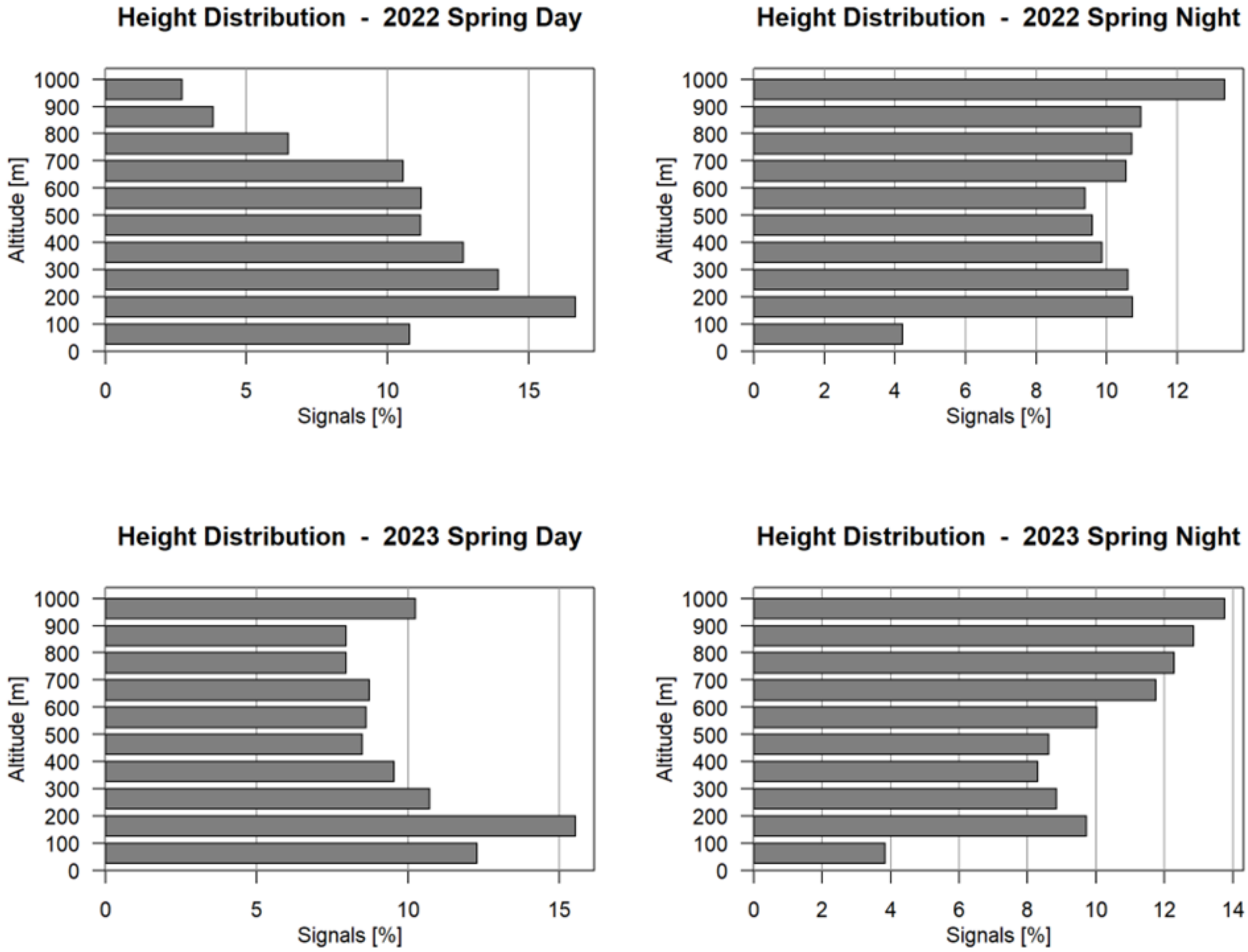


Figure 58. Altitudinal distribution of daytime (left) and nighttime (right) migrant bird signals at Rügen in spring 2022 and 2023 recorded by vertical radar.

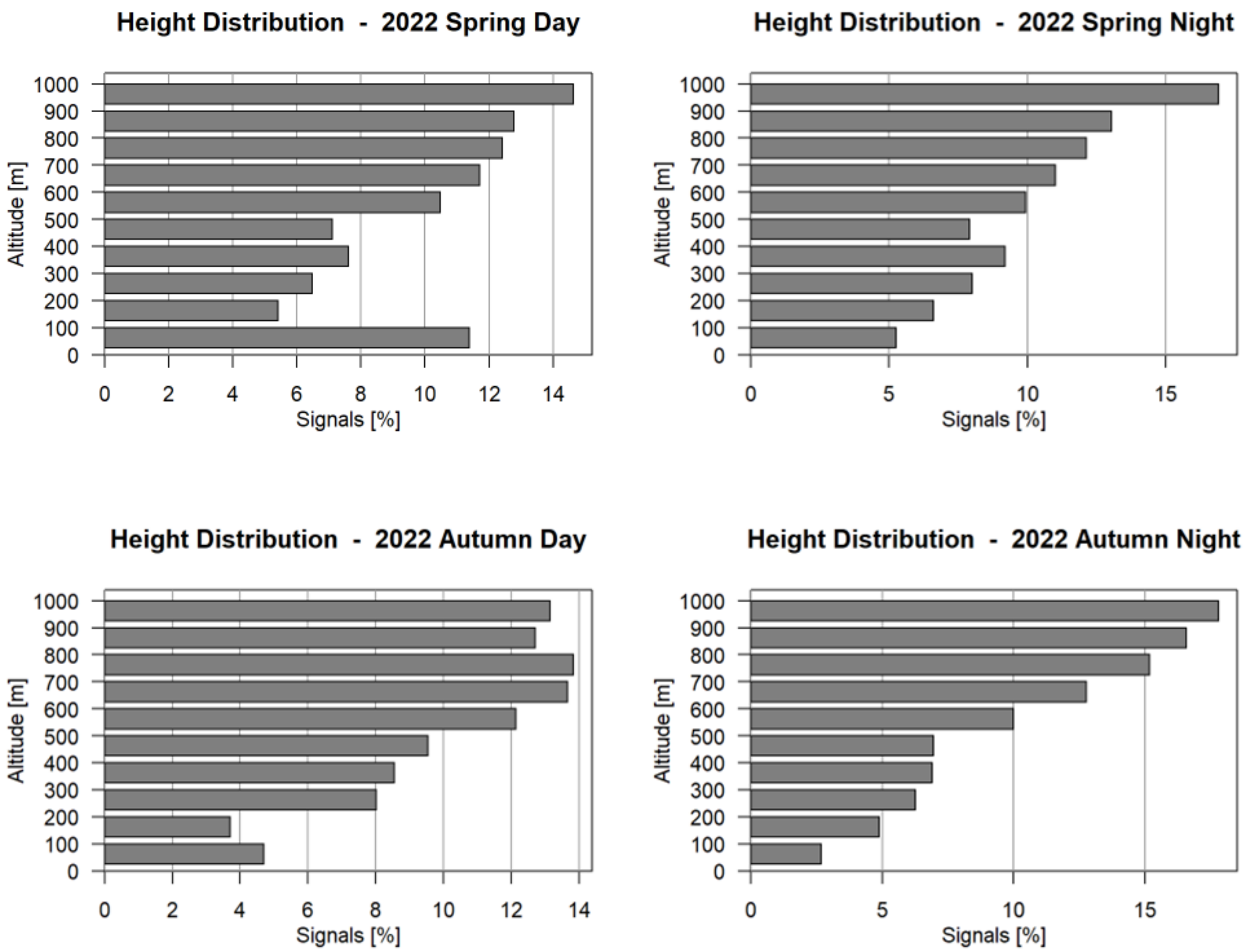


Figure 59. Altitudinal distribution of daytime (left) and nighttime (right) migrant bird signals at Rønne in spring and autumn 2022 recorded by vertical radar.

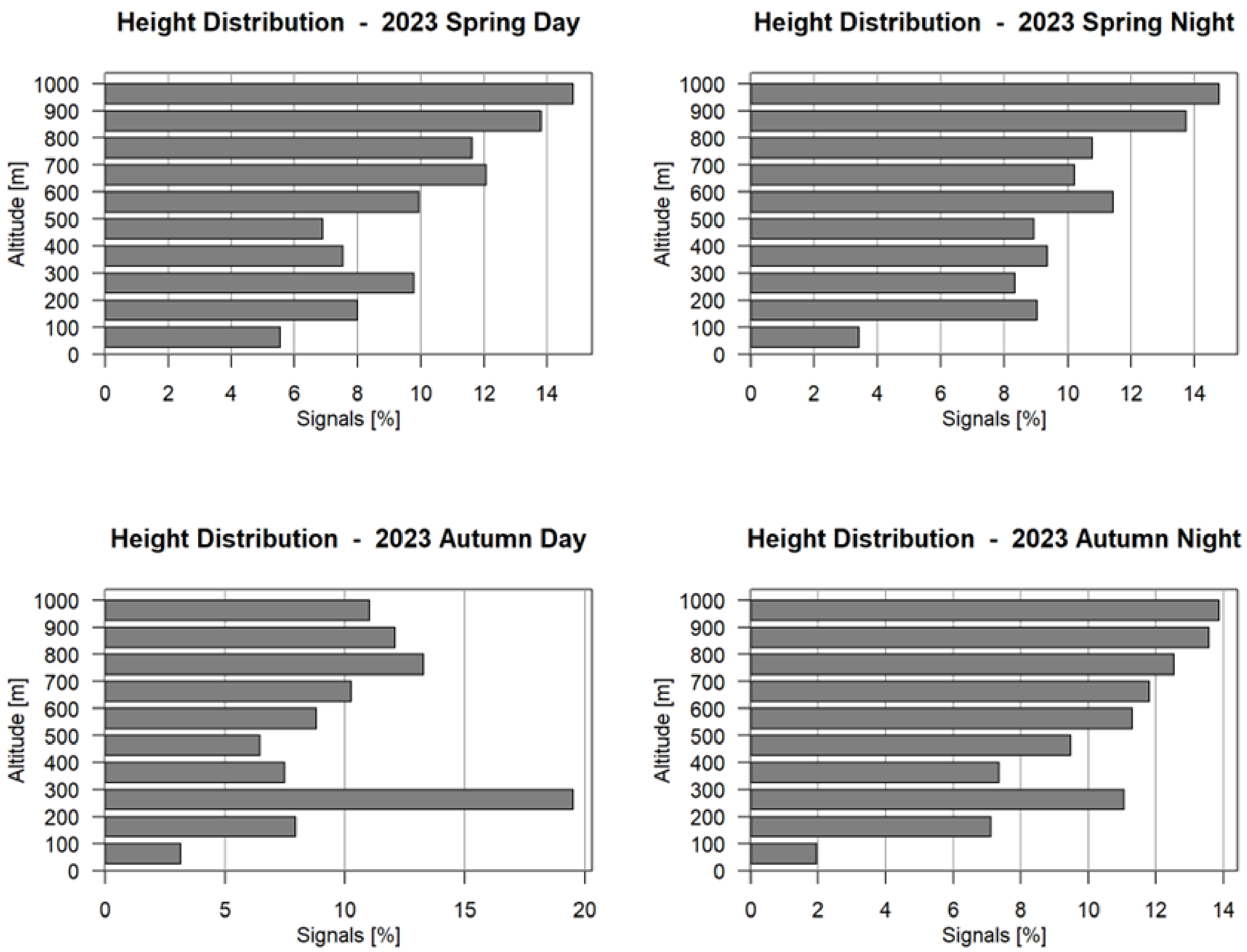


Figure 60. Altitudinal distribution of daytime (left) and nighttime (right) migrant bird signals at Rønne in spring and autumn 2023 recorded by vertical radar.

OVERALL DIURNAL MIGRATION INTENSITY

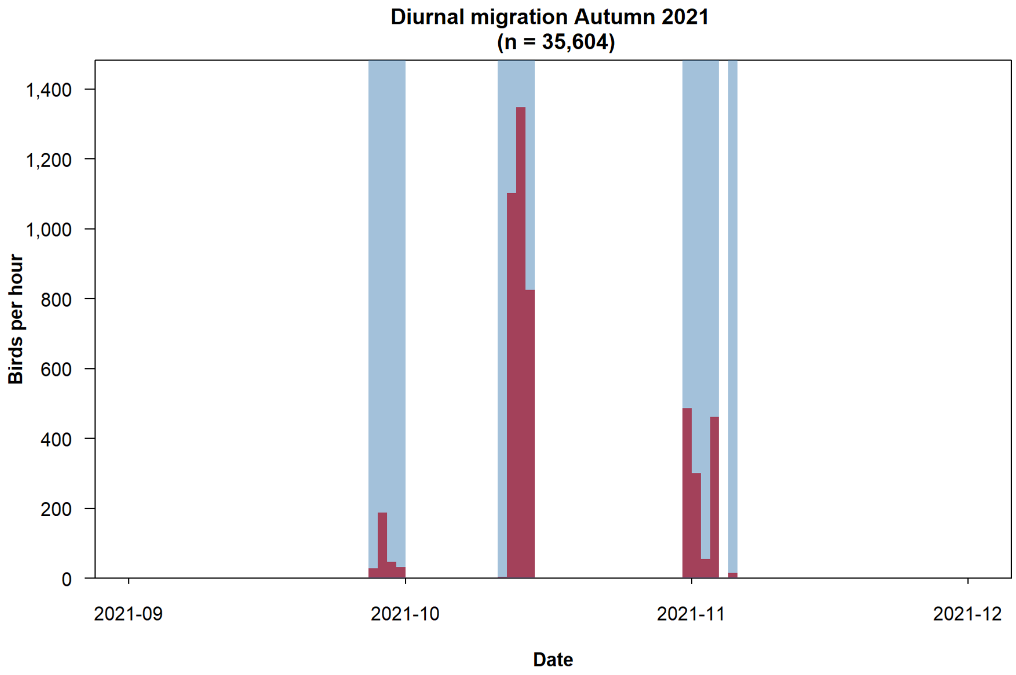


Figure 61. Diurnal migration intensity in autumn 2021 on Bornholm (Rønne), (visual observations, red bars). Light blue shades indicate the dates of the surveys.

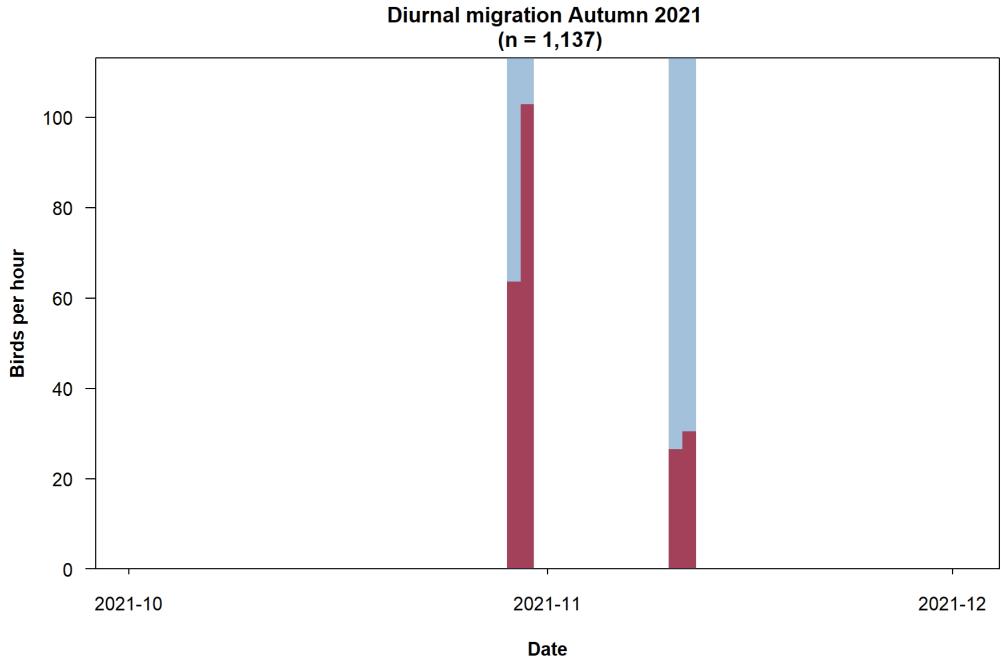


Figure 62. Diurnal migration intensity in autumn 2021 (visual observations, red bars) from vessel-based surveys. Light blue shades indicate the dates of the surveys.

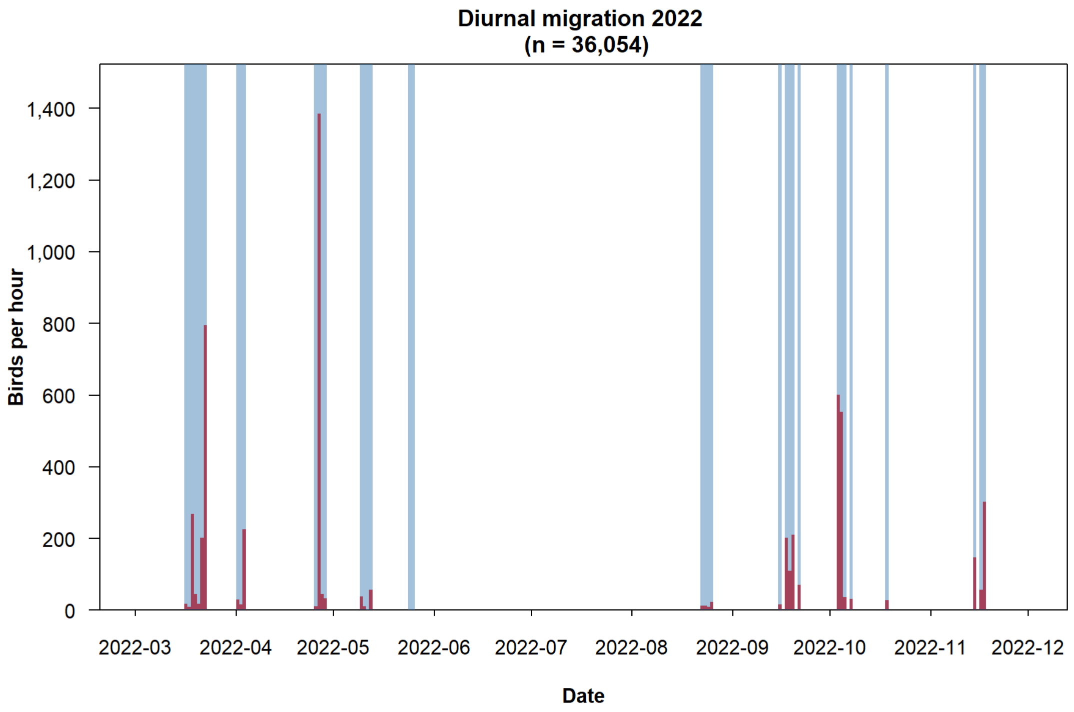


Figure 63. Diurnal migration intensity in spring and autumn 2022 on Bornholm (Rønne)(visual observations, red bars). Light blue shades indicate the dates of the surveys.

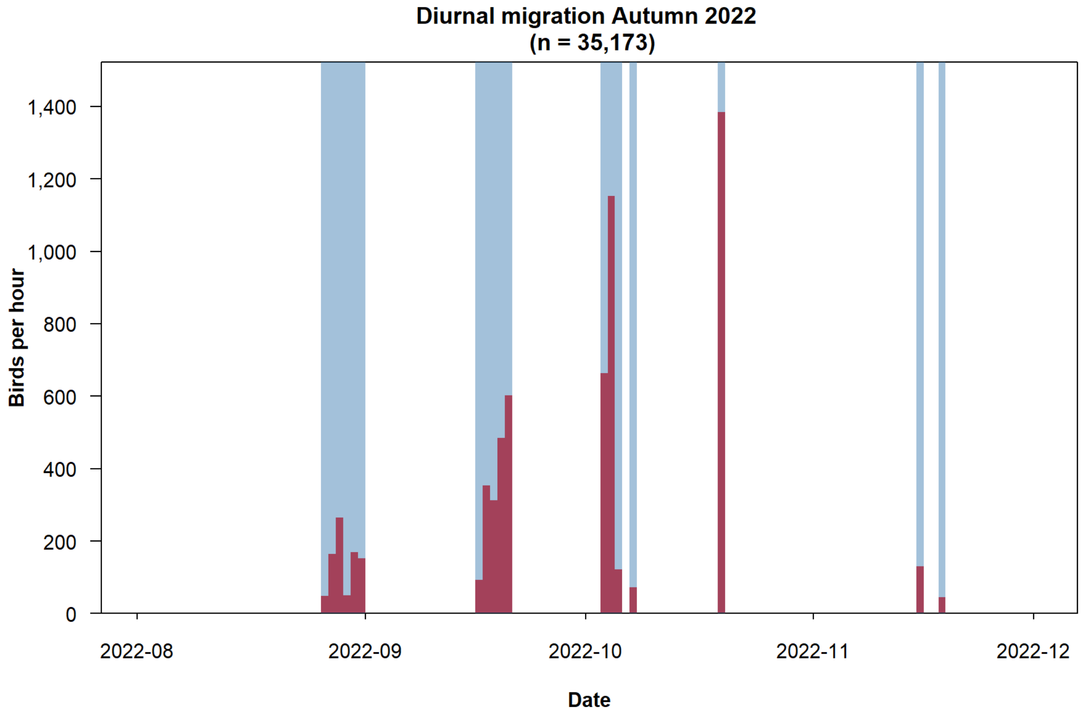


Figure 64. Diurnal migration intensity in autumn 2022 (visual observations, red bars) from Bornholm (Nexø). Light blue shades indicate the dates of the surveys.

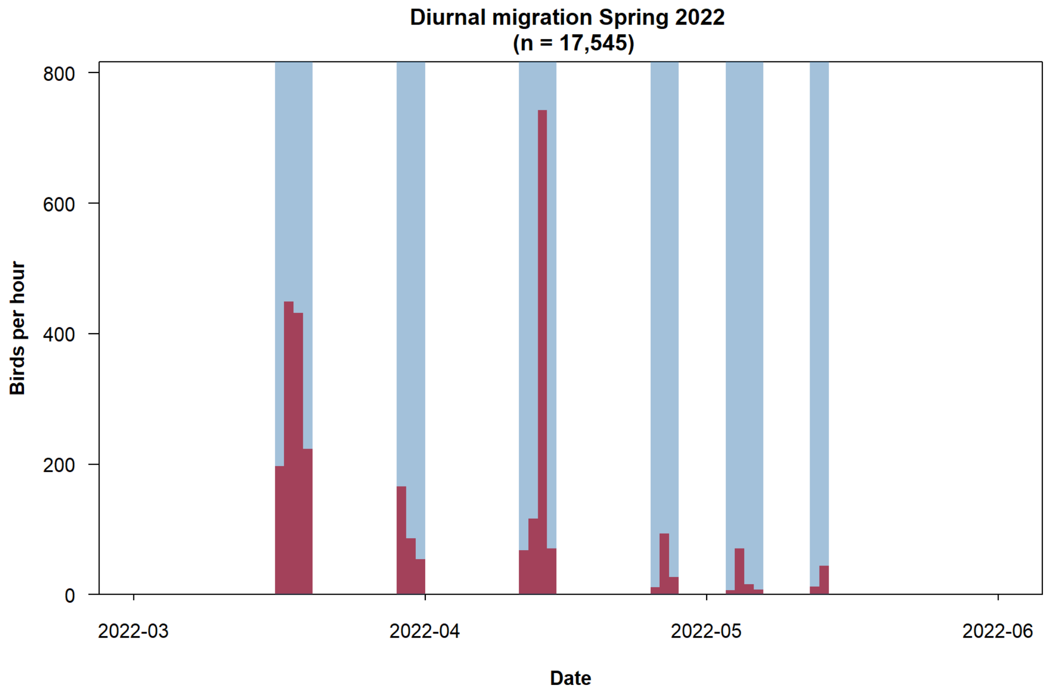


Figure 65. Diurnal migration intensity in spring 2022 on Rügen (visual observations, red bars). Light blue shades indicate the dates of the surveys.

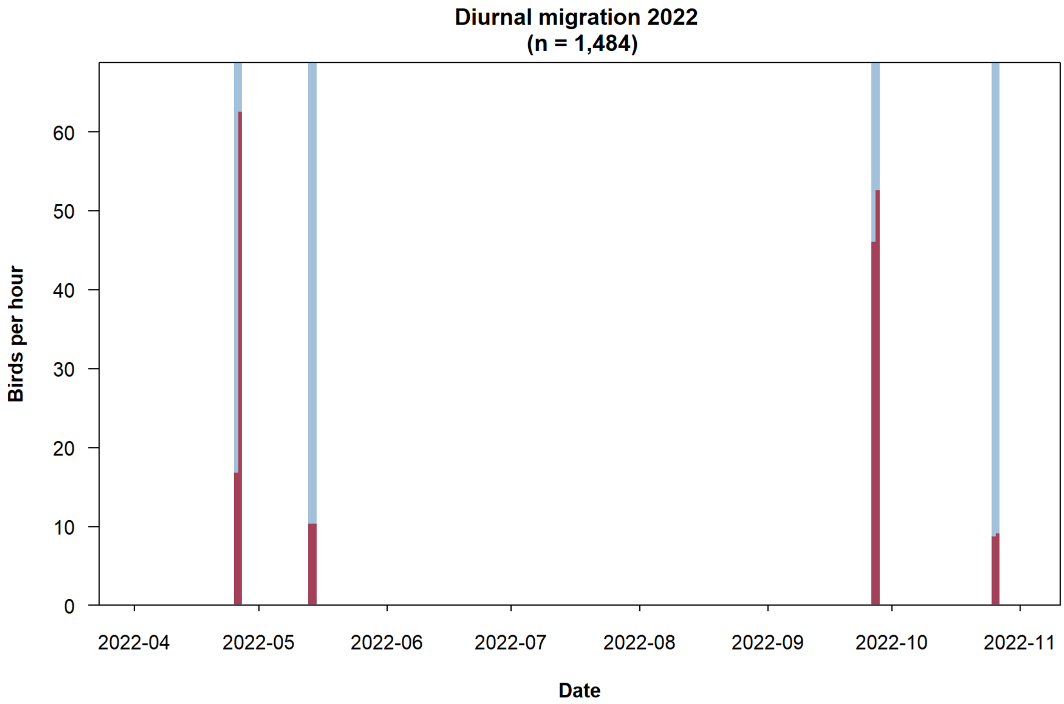


Figure 66. Diurnal migration intensity in spring and autumn 2022 (visual observations, red bars) from vessel-based surveys (offshore). Light blue shades indicate the dates of the surveys.

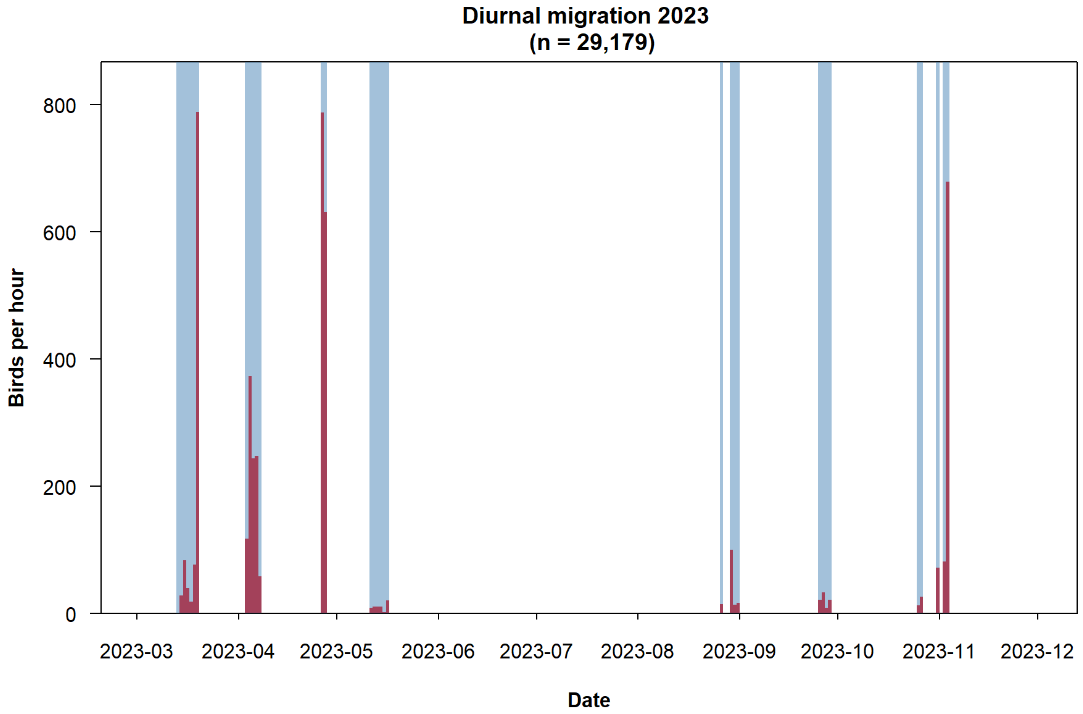


Figure 67. Diurnal migration intensity in spring and autumn 2023 on Bornholm (Rønne) (visual observations, red bars). Light blue shades indicate the dates of the surveys.

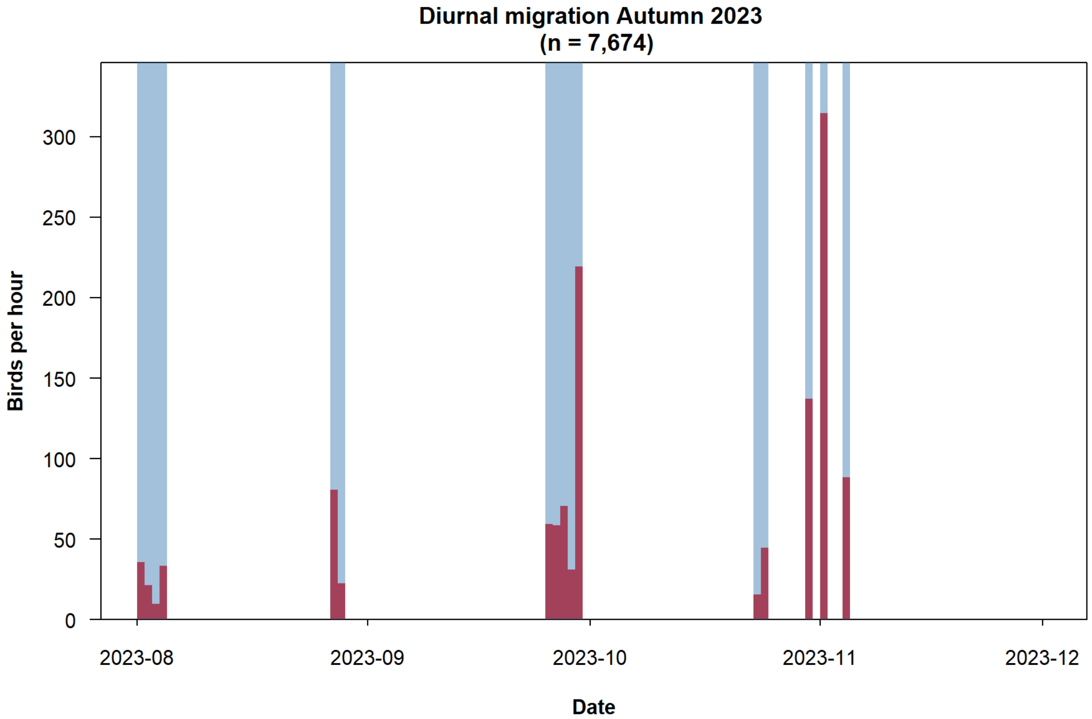


Figure 68. Diurnal migration intensity in autumn 2023 (visual observations, red bars) on Bornholm (Nexø). Light blue shades indicate the dates of the surveys.

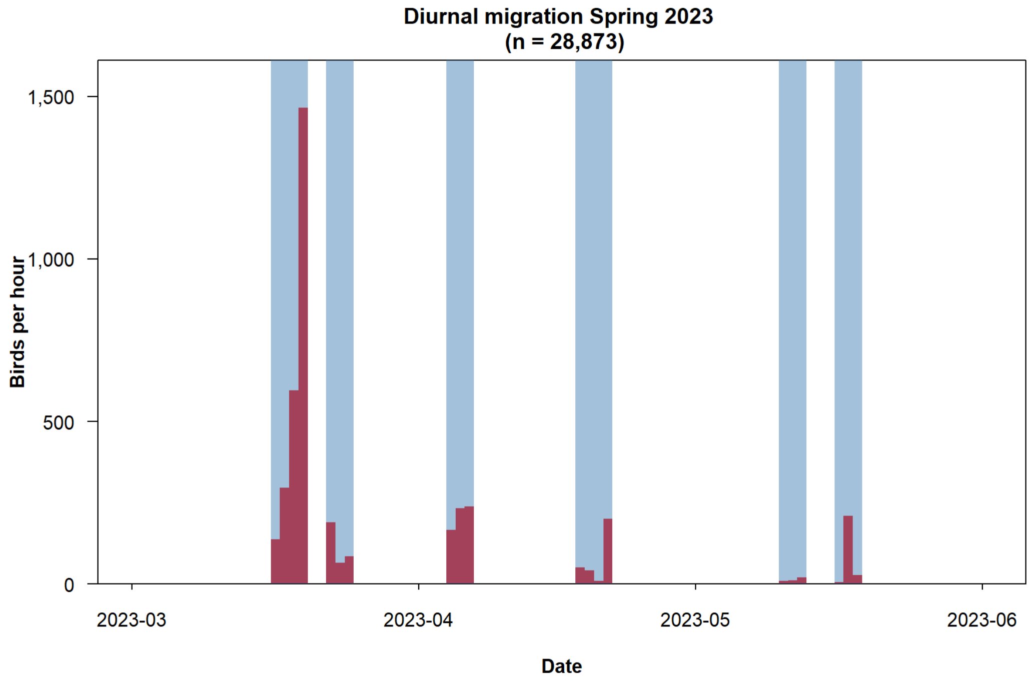


Figure 69. Diurnal migration intensity in spring 2023 on Rügen (visual observations, red bars). Light blue shades indicate the dates of the surveys.

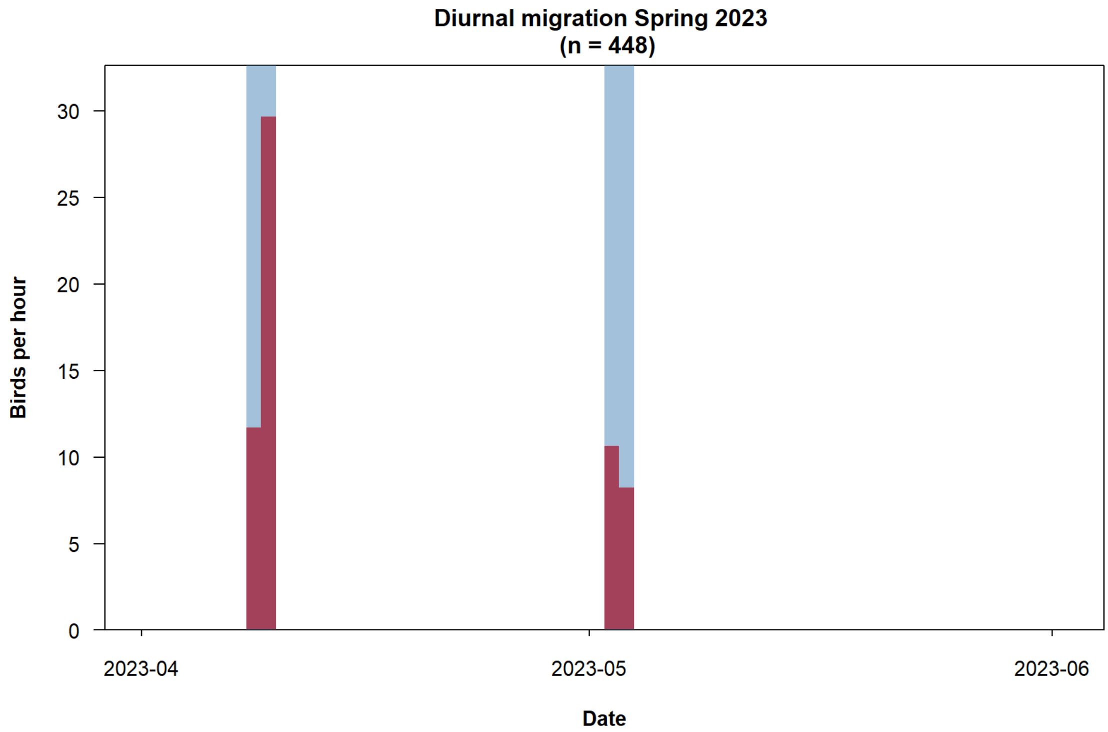


Figure 70. Diurnal migration intensity in spring 2023 (visual observations, red bars) from vessel-based surveys. Light blue shades indicate the dates of the surveys.

FLIGHT DIRECTIONS – ALL SPECIES

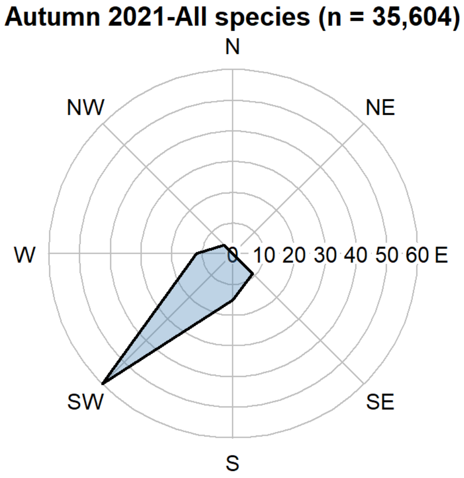


Figure 71. Flight directions of all observed birds during daytime in autumn 2021 on Bornholm, Rønne. Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

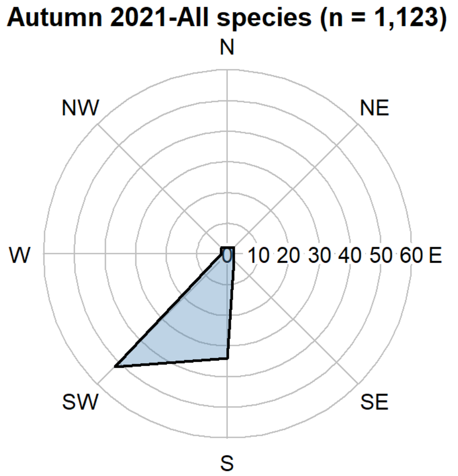


Figure 72. Flight directions of all observed birds during daytime in autumn 2021 from vessel-based surveys. Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

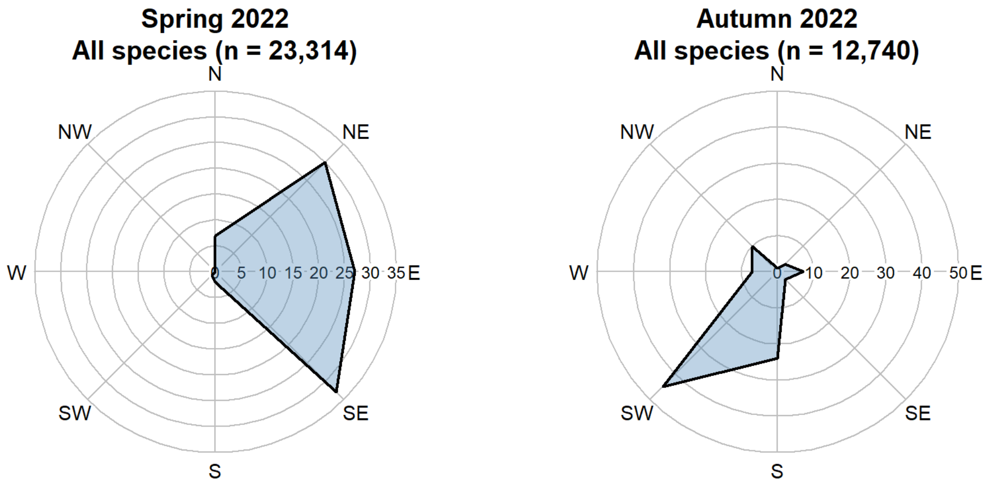


Figure 73. Flight directions of all observed birds during daytime in spring and autumn 2022 on Bornholm, Rønne. Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

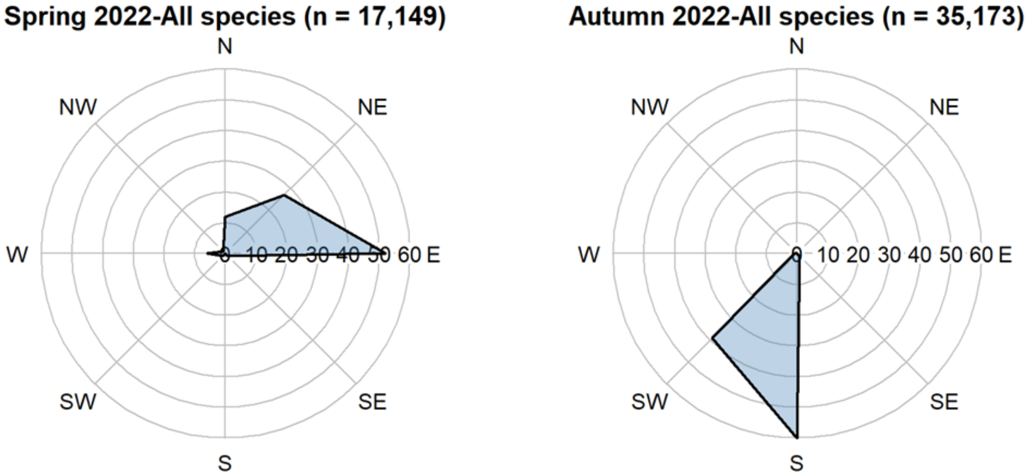


Figure 74. Flight directions of all observed birds during daytime in spring 2002 on Rügen (left panel) and autumn 2022 from Bornholm, Nexø (right panel). Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

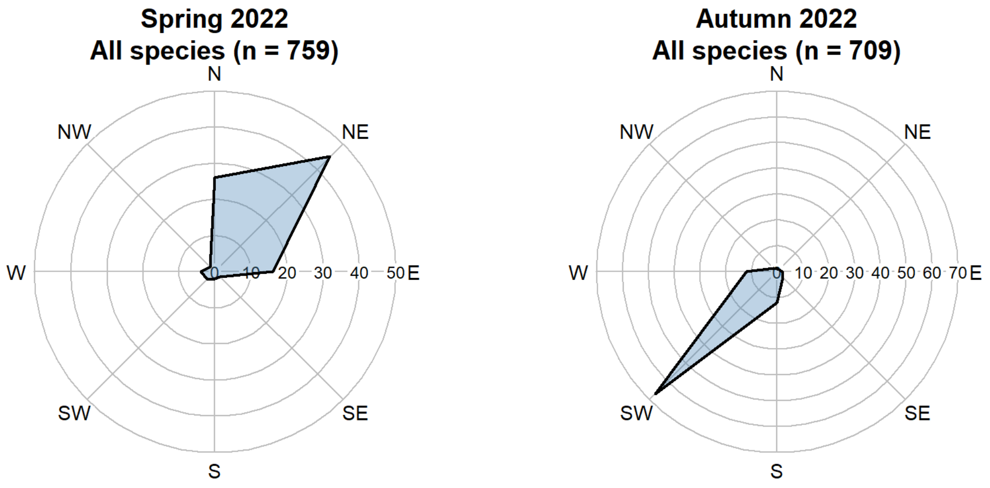


Figure 75. Flight directions of all observed birds during daytime in spring and autumn 2022 from vessel-based surveys. Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

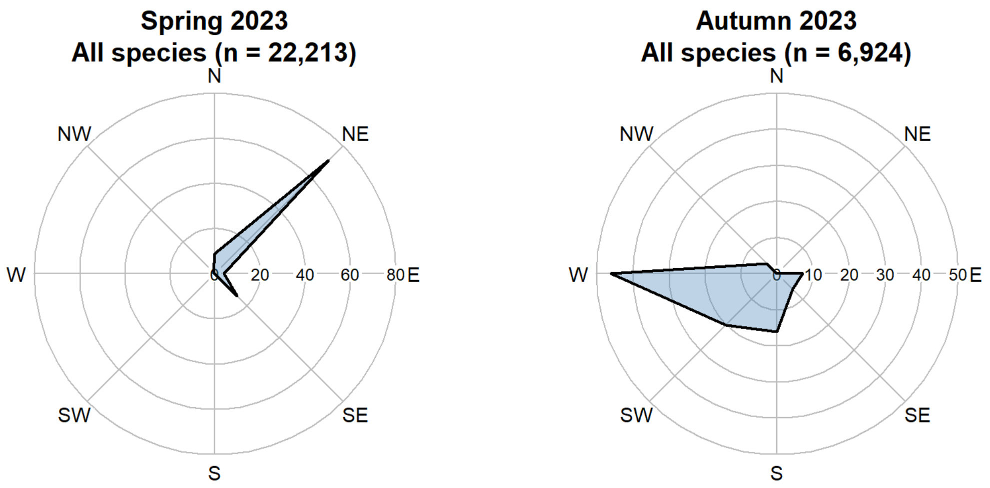


Figure 76. Flight directions of all observed birds during daytime in spring and autumn 2023 on Bornholm, Rønne. Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

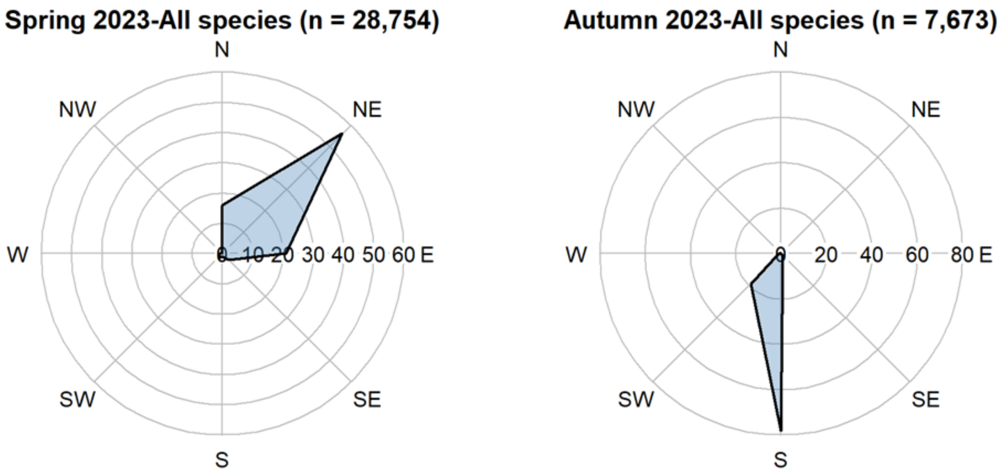


Figure 77. Flight directions of all observed birds during daytime in spring 2023 from Rügen (left panel) and autumn 2022 from Bornholm, Nexø (right panel). Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

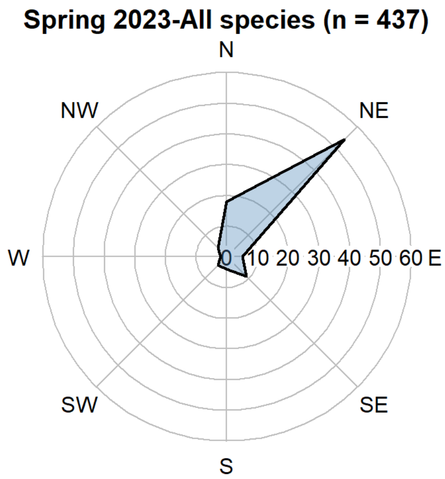


Figure 78. Flight directions of all observed birds during daytime spring 2023 from vessel-based surveys. Observers estimated the flying direction in 45° increments: N = North, NE = Northeast, E = East, SE = Southeast, S = South, SW = Southwest, W =West, NW = Northwest. Numbers on the axis represent percentages.

DIVERS

FLIGHT ALTITUDES

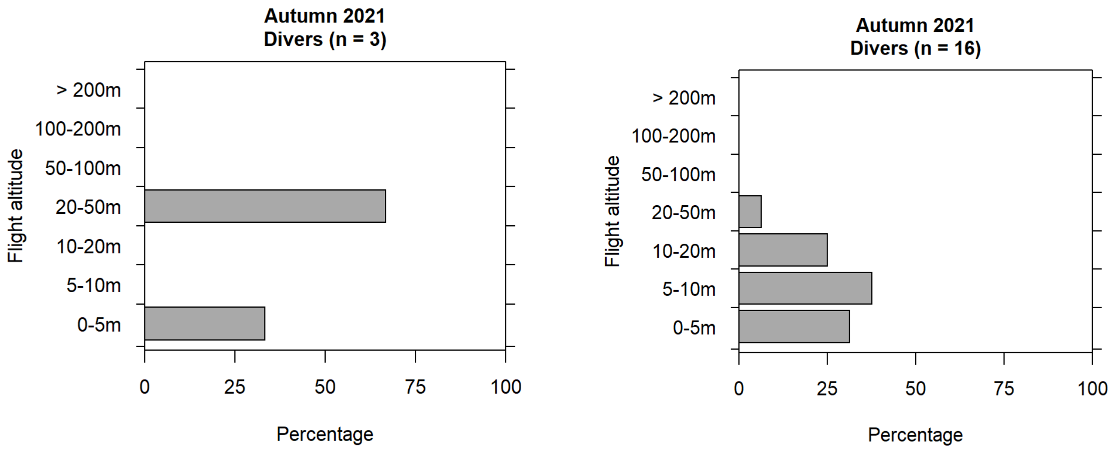


Figure 79. Flight altitude distribution of divers during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

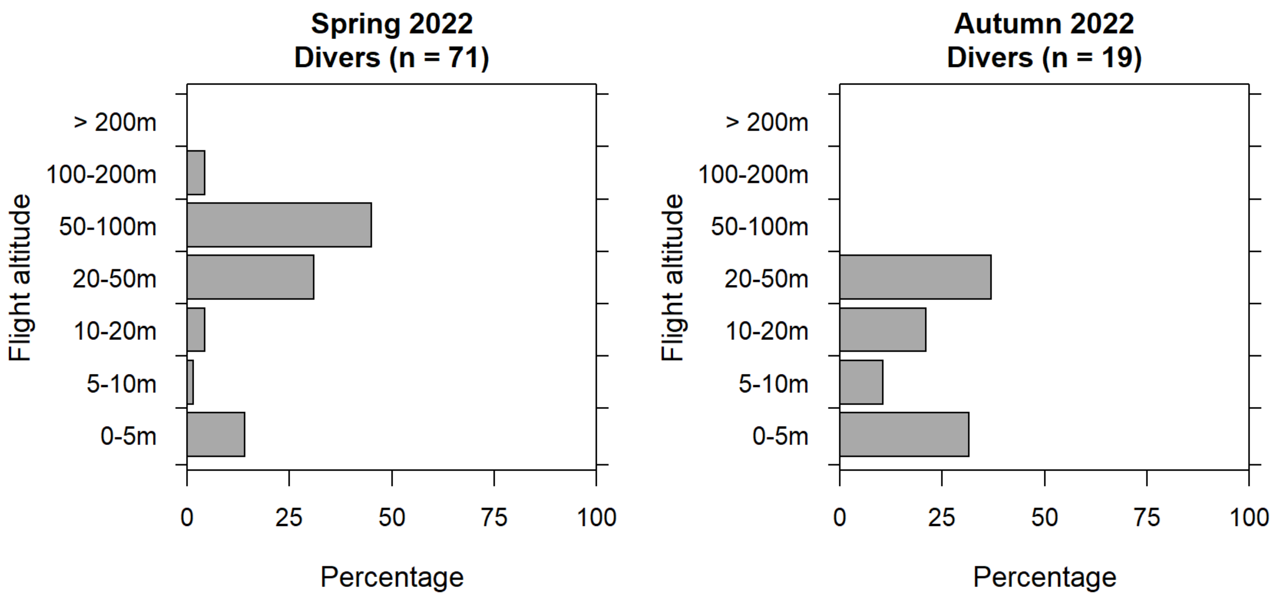


Figure 80. Flight altitude distribution of divers during visual observations in spring and autumn 2022 on Bornholm, Rønne.

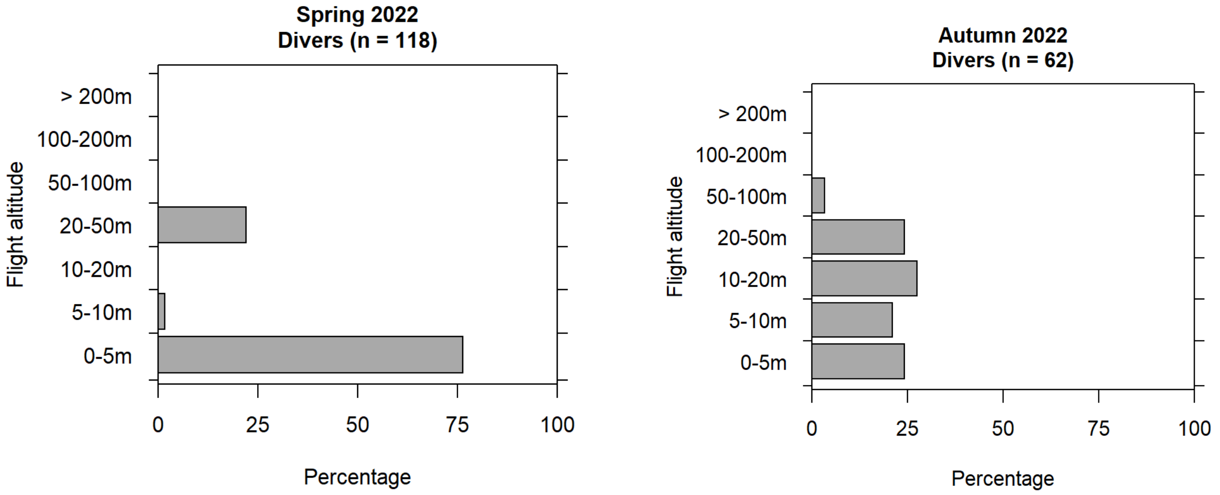


Figure 81. Flight altitude distribution of divers during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

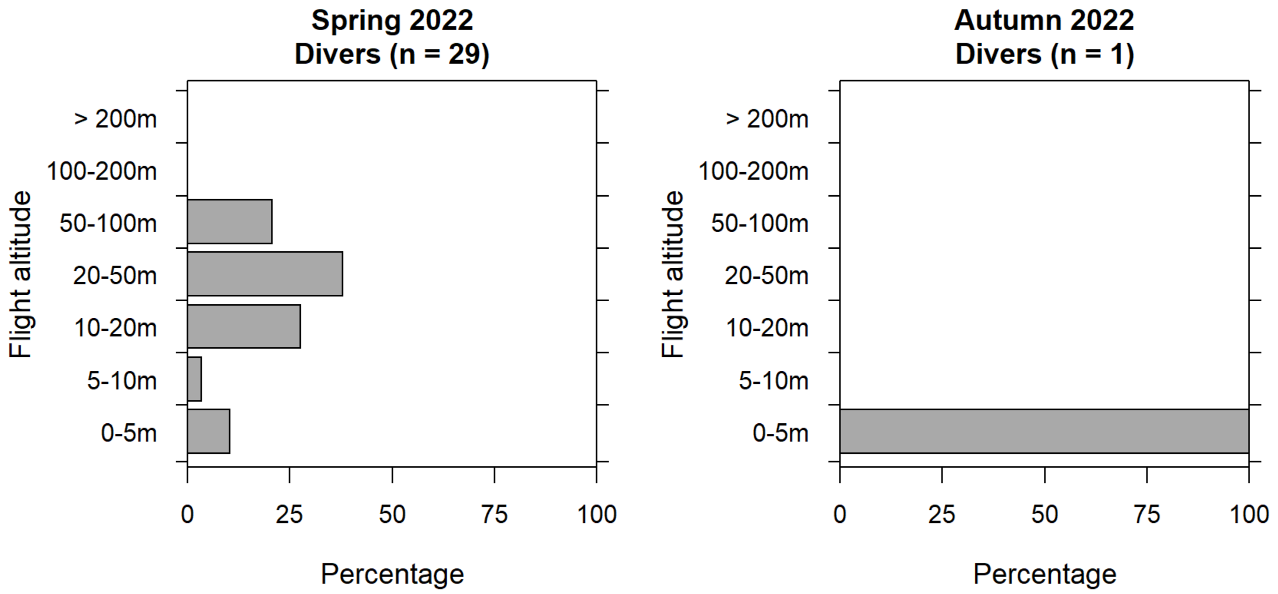


Figure 82. Flight altitude distribution of divers during visual observations in spring and autumn 2022 from vessel-based surveys.

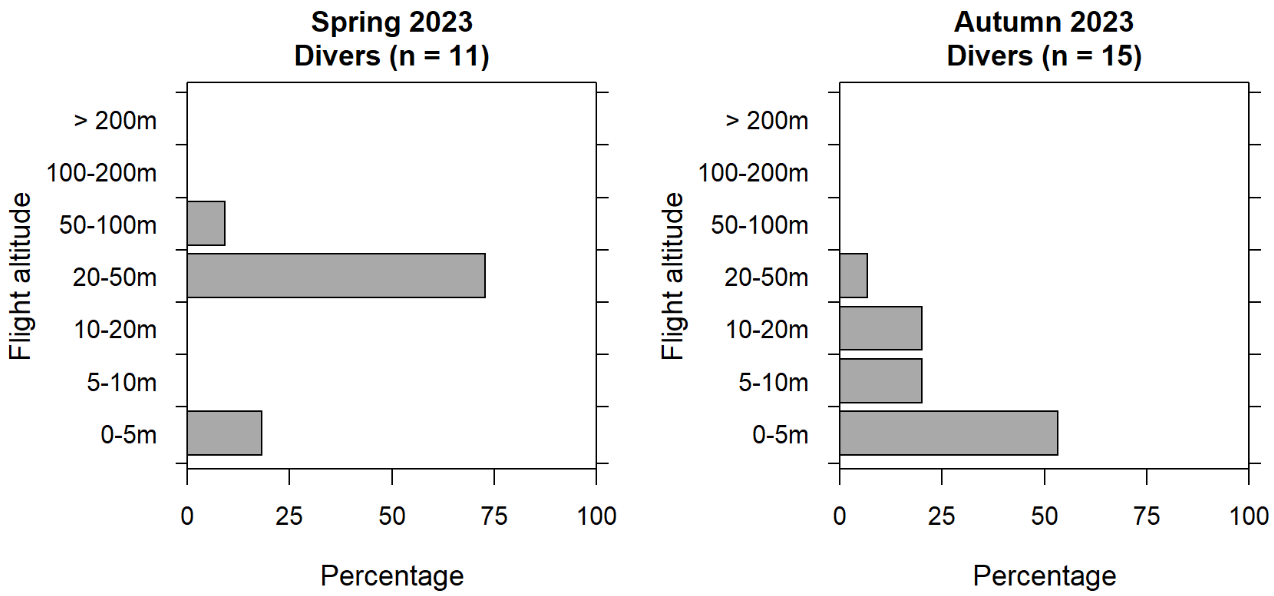


Figure 83. Flight altitude distribution of divers during visual observations in spring and autumn 2023 on Bornholm, Rønne.

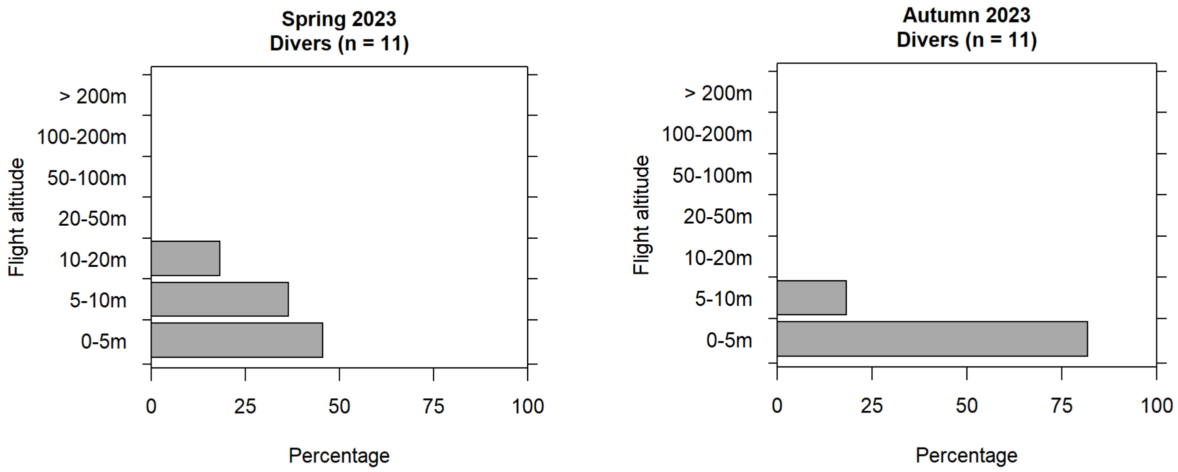


Figure 84. Flight altitude distribution of divers during visual observations in spring 2023 from vessel-based surveys (left) and in autumn 2023 on Bornholm, Nexø (right).

FLIGHT DIRECTIONS

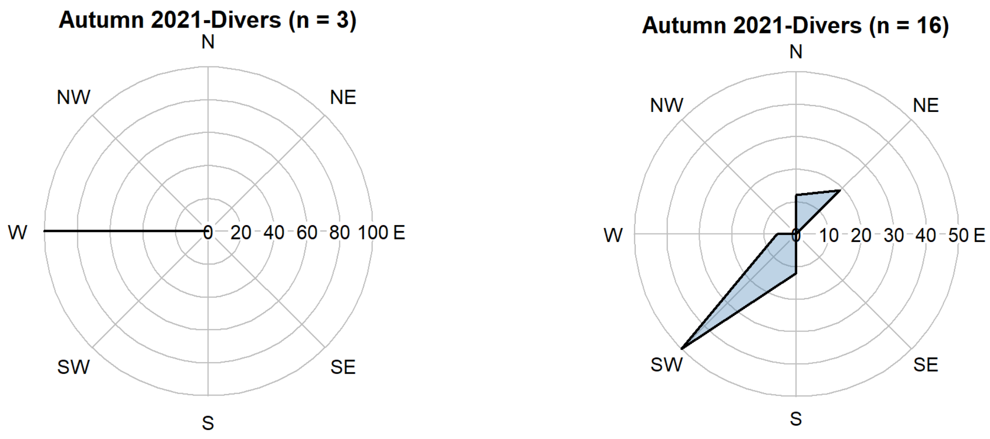


Figure 85. Flight directions of divers during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

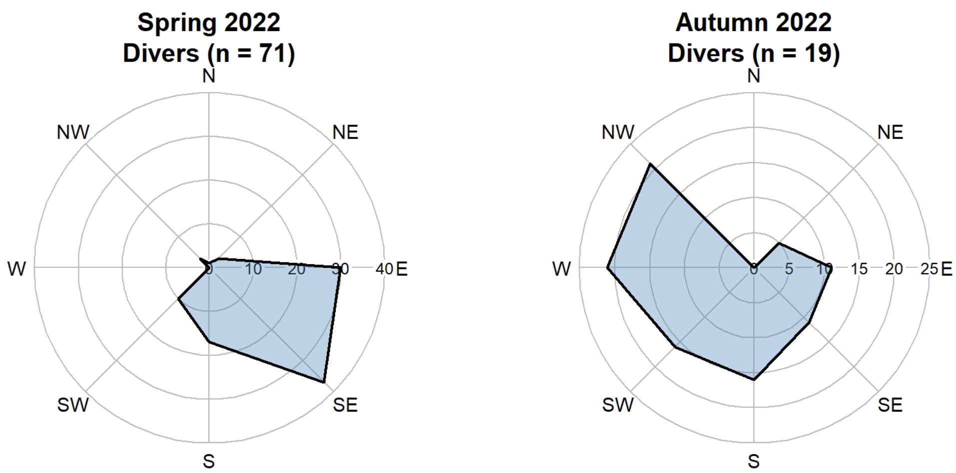


Figure 86. Flight directions of divers during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

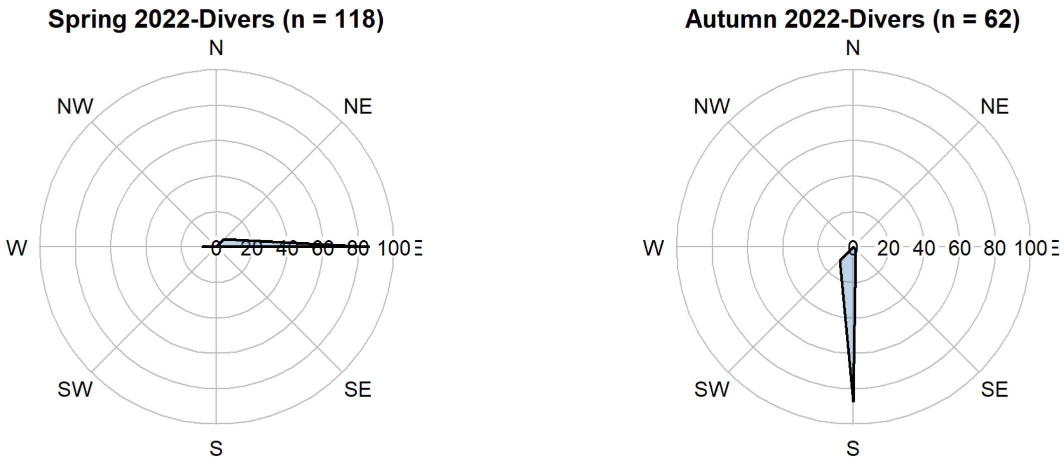


Figure 87. Flight directions of divers during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

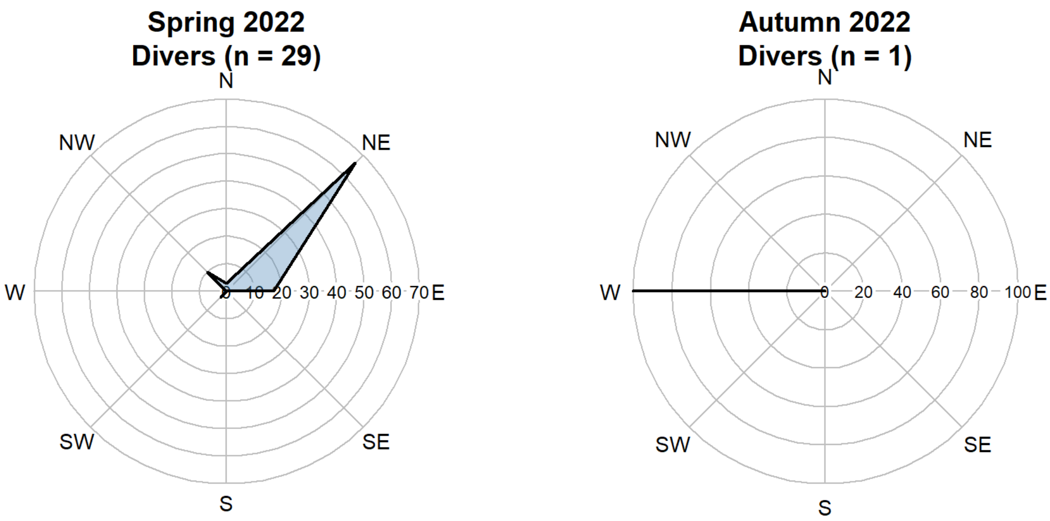


Figure 88. Flight directions of divers during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

CORMORANTS

FLIGHT ALTITUDES

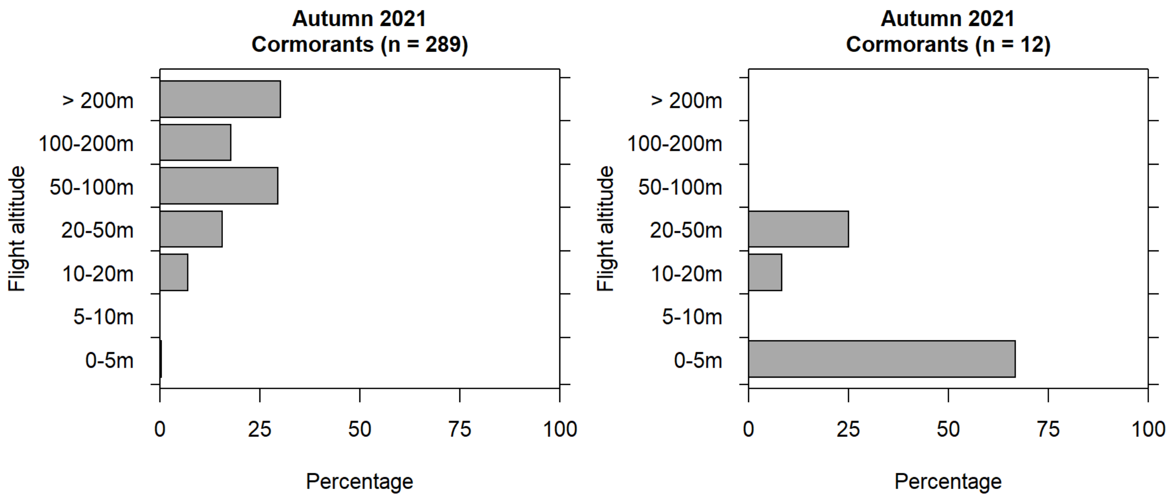


Figure 89. Flight altitude distribution of cormorants during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

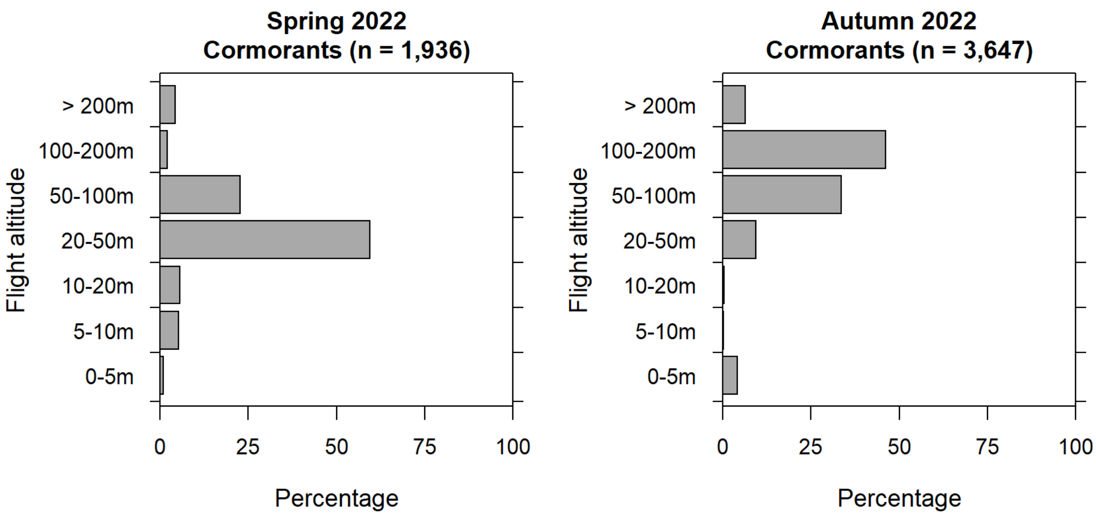


Figure 90. Flight altitude distribution of cormorants during visual observations in spring and autumn 2022 on Bornholm, Rønne.

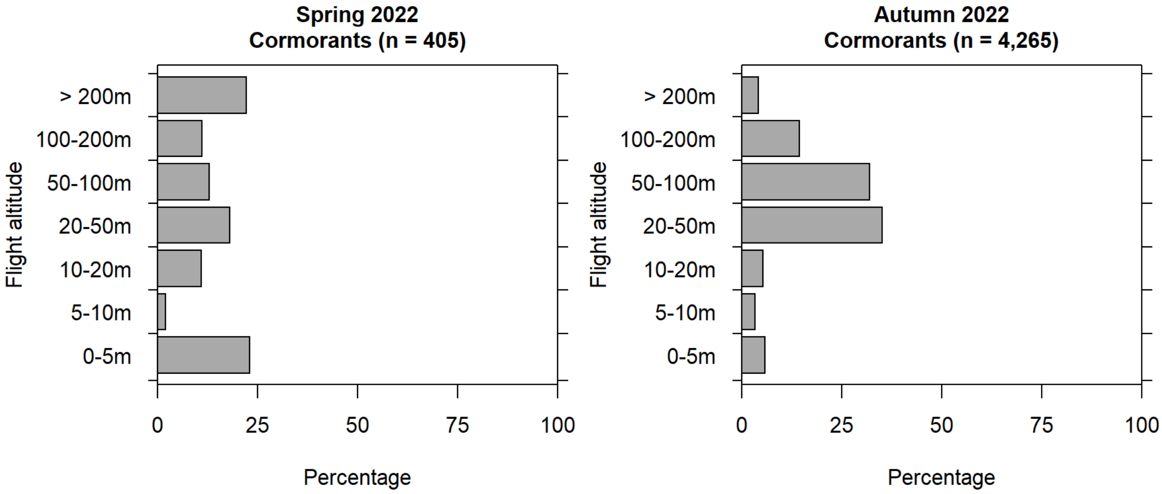


Figure 91. Flight altitude distribution of cormorants during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

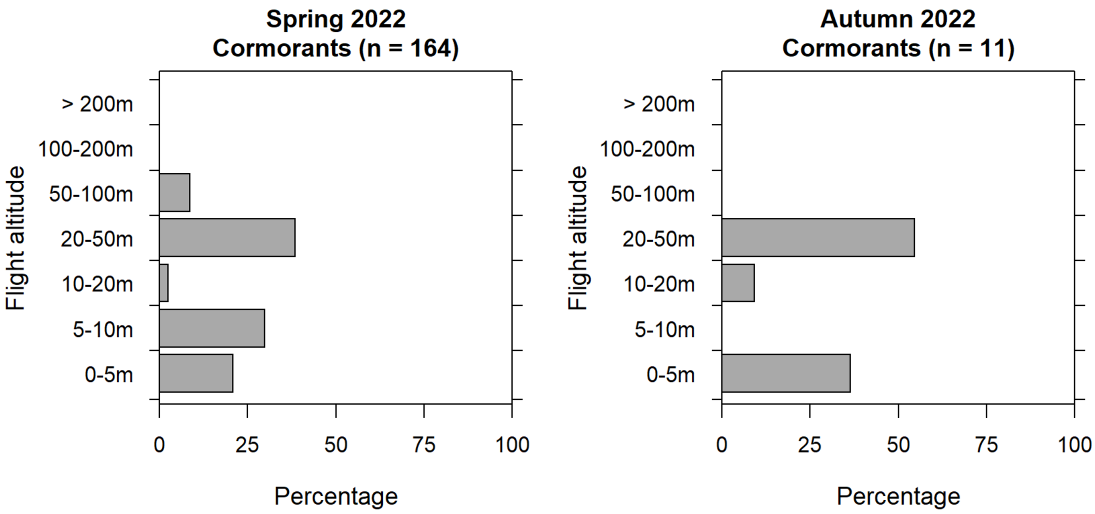


Figure 92. Flight altitude distribution of cormorants during visual observations in spring and autumn 2022 from vessel-based surveys.

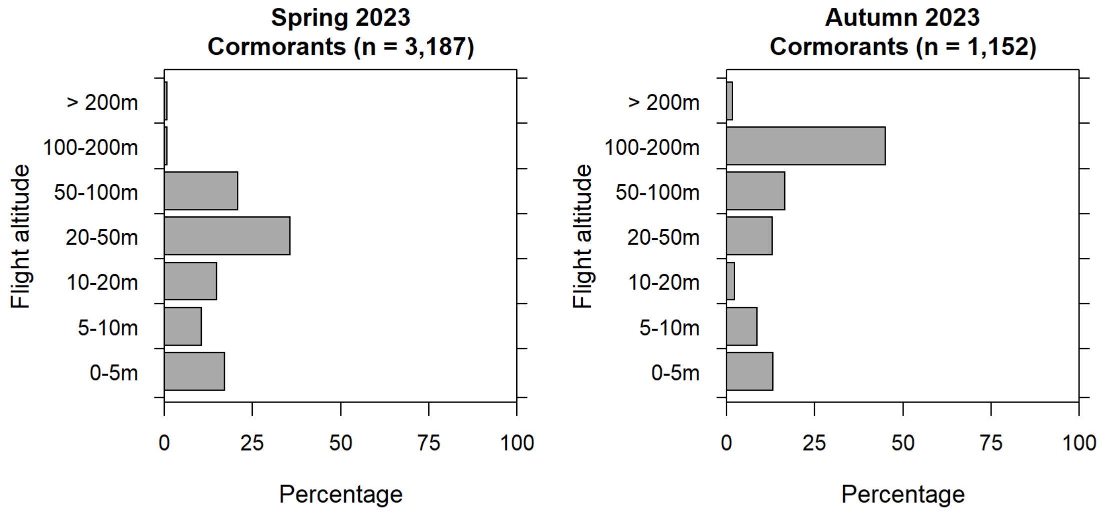


Figure 93. Flight altitude distribution of cormorants during visual observations in spring and autumn 2023 on Bornholm, Rønne.

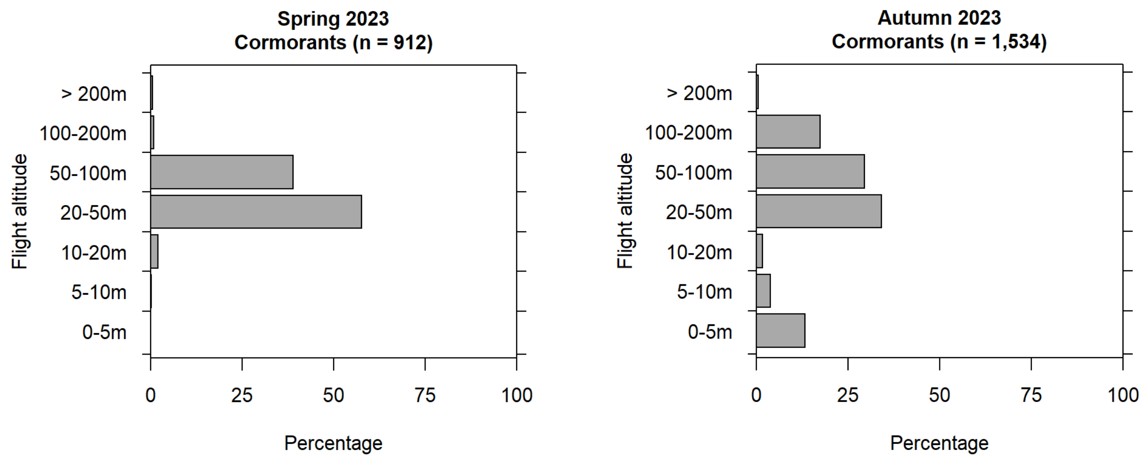


Figure 94. Flight altitude distribution of cormorants during visual observations in spring 2023 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

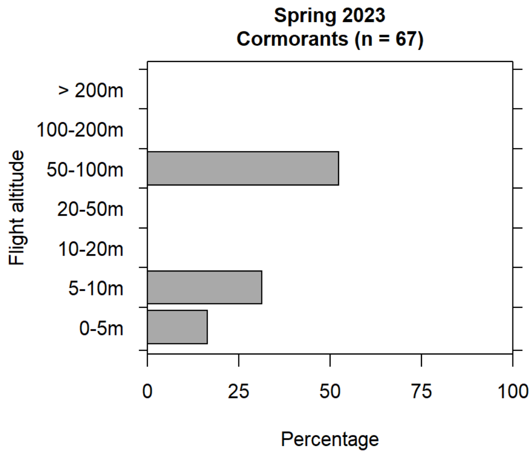


Figure 95. Flight altitude distribution of cormorants during visual observations in spring 2023 from vessel-based surveys.

FLIGHT DIRECTIONS

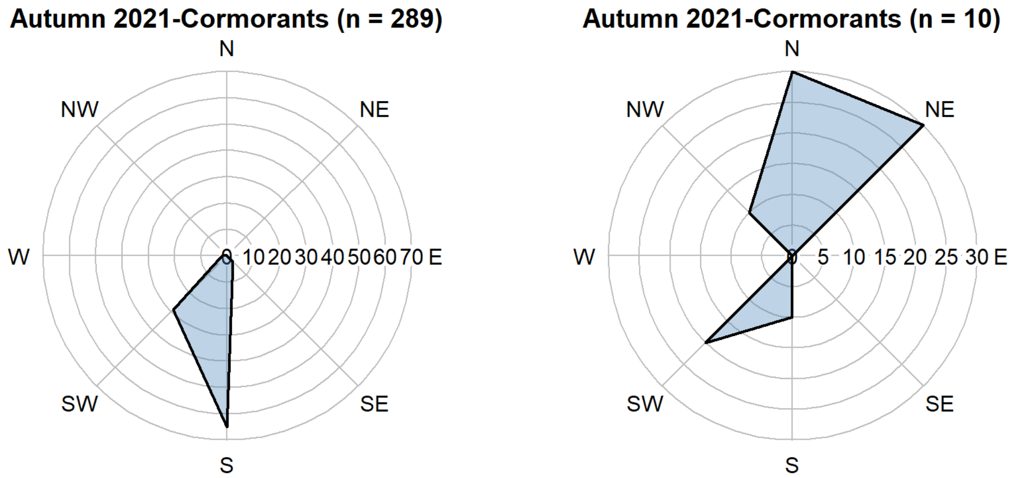


Figure 96. Flight directions of cormorants during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

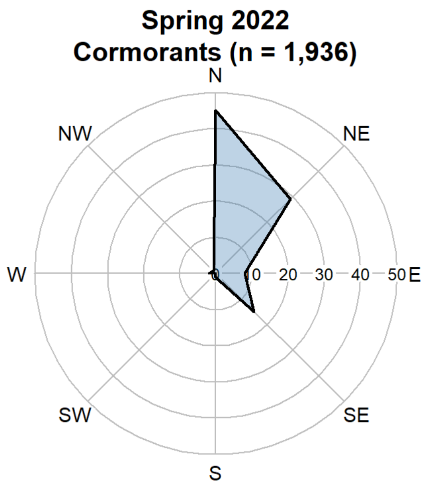


Figure 97. Flight directions of cormorants during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

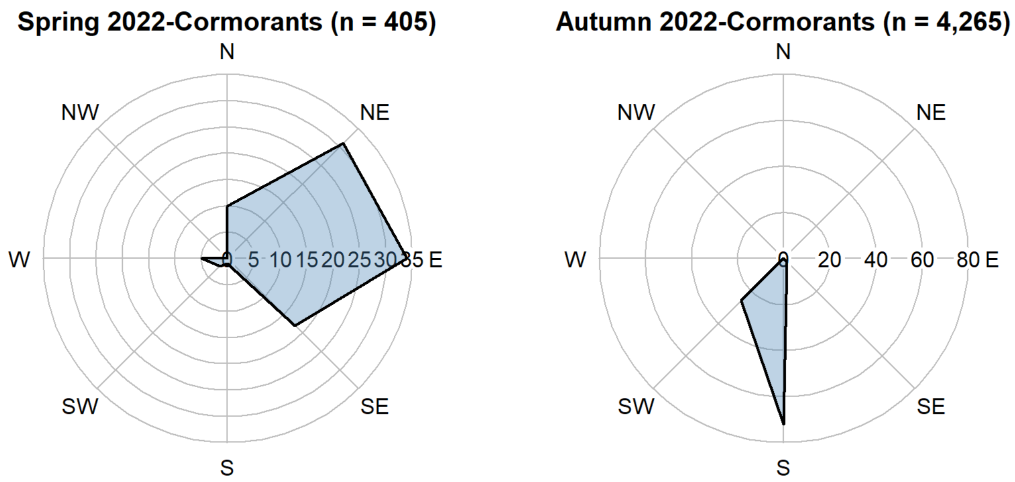


Figure 98. Flight directions of cormorants during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

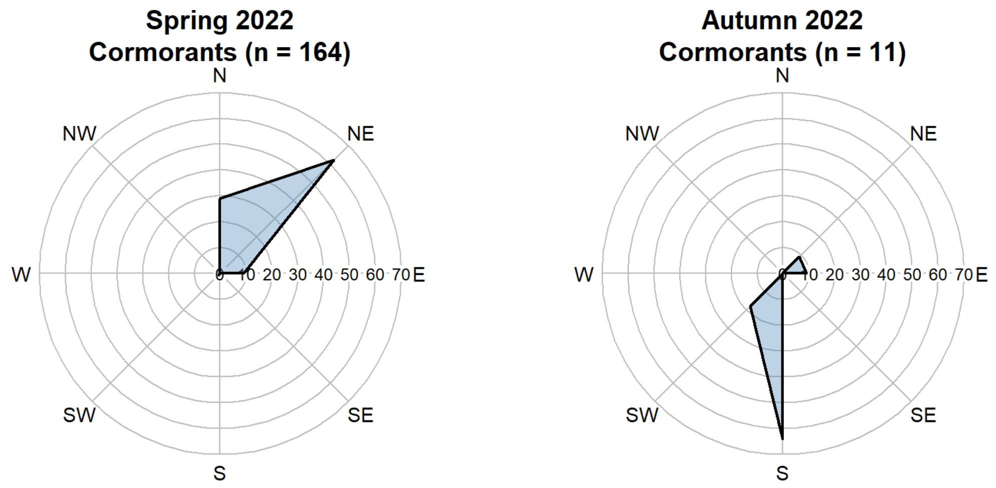


Figure 99. Flight directions of cormorants during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

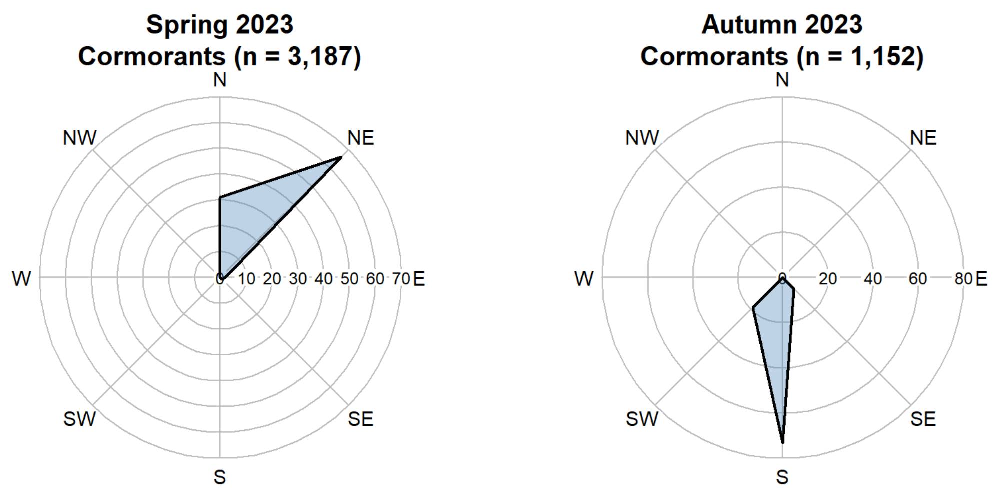


Figure 100. Flight directions of cormorants during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.

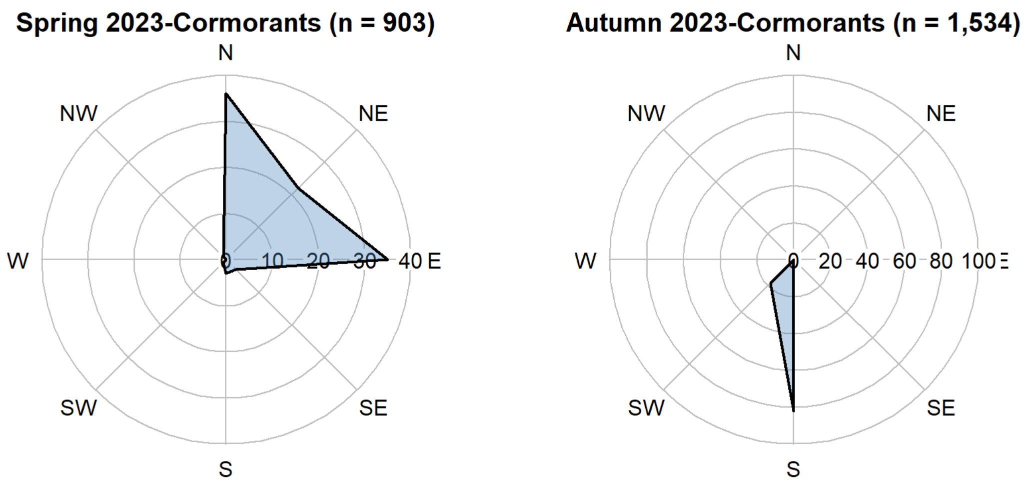


Figure 101. Flight directions of cormorants during daytime in spring 2023 on Rügen (left) and on Bornholm, Nexøø in autumn 2023 (right). For more details refer to the description of Figure 71.

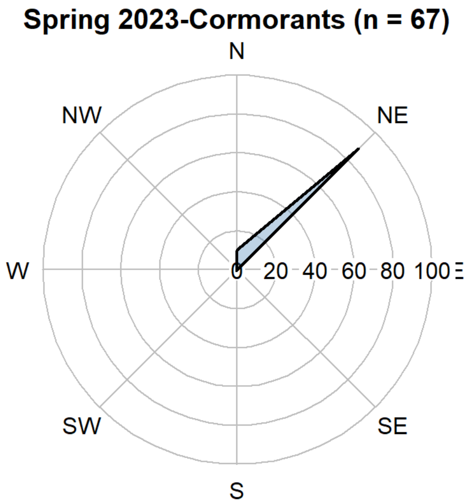


Figure 102. Flight directions of cormorants during daytime in spring 2023 from vessel-based surveys. For more details refer to the description of Figure 71.

GEESE

FLIGHT ALTITUDES

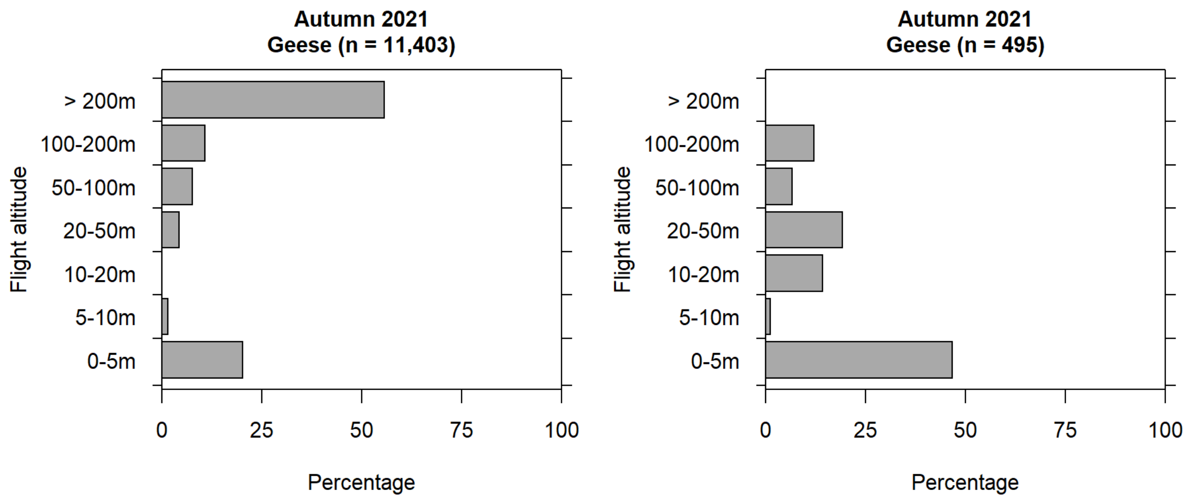


Figure 103. Flight altitude distribution of geese during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

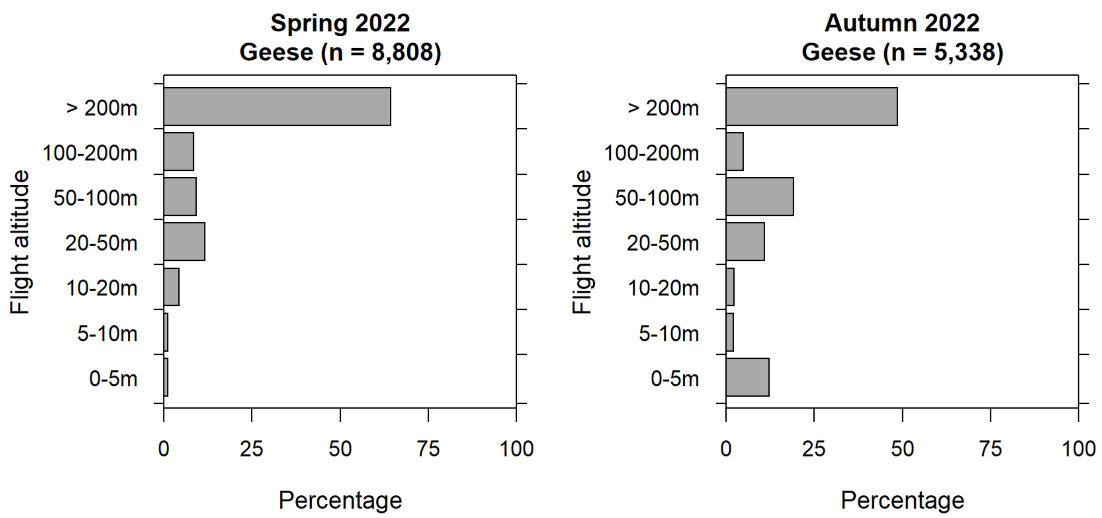


Figure 104. Flight altitude distribution of geese during visual observations in spring and autumn 2022 on Bornholm, Rønne.

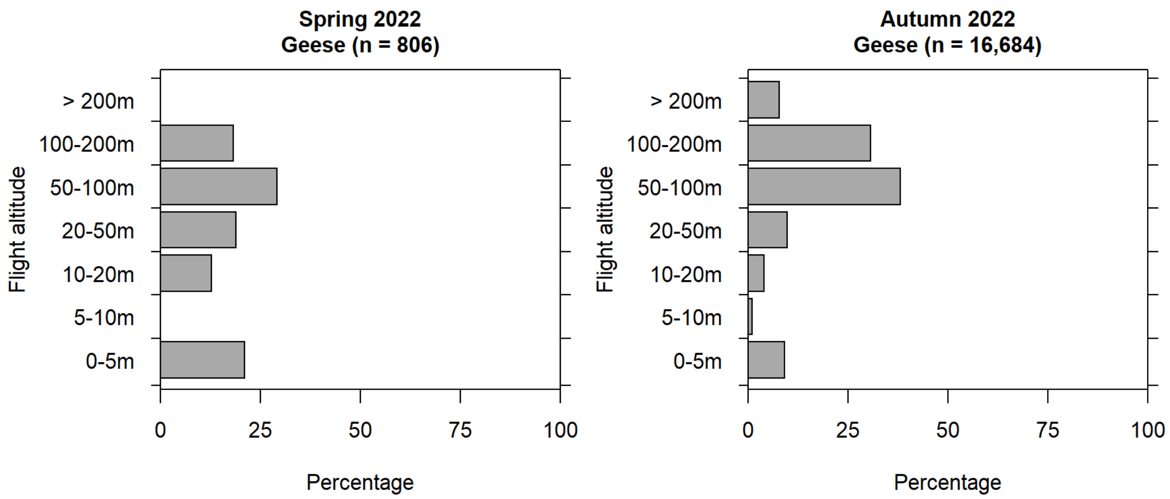


Figure 105. Flight altitude distribution of geese during visual observations in spring 2022 at Rüegen (left) and in autumn 2022 at Bornholm, Nexø (right).

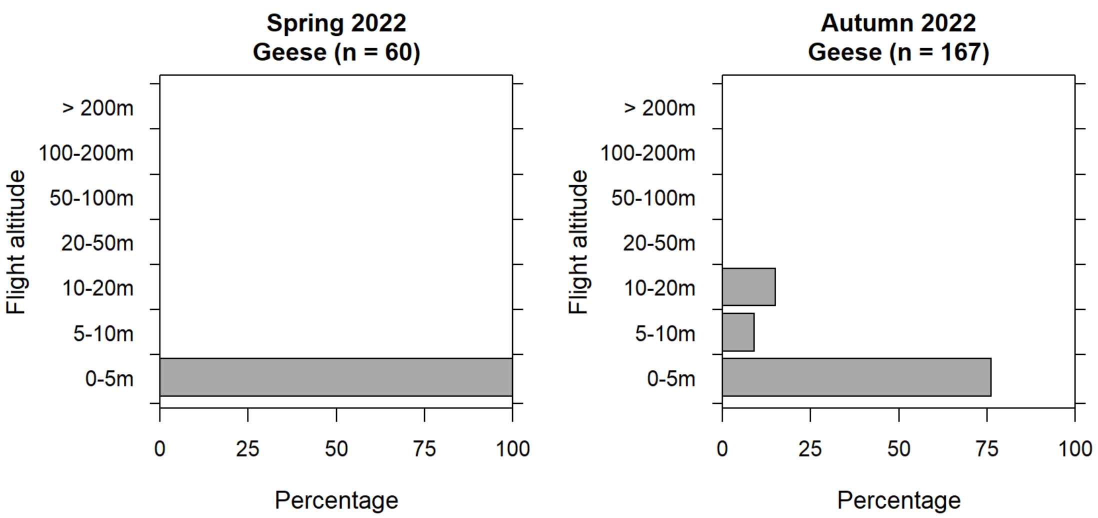


Figure 106. Flight altitude distribution of geese during visual observations in spring and autumn 2022 from vessel-based surveys.

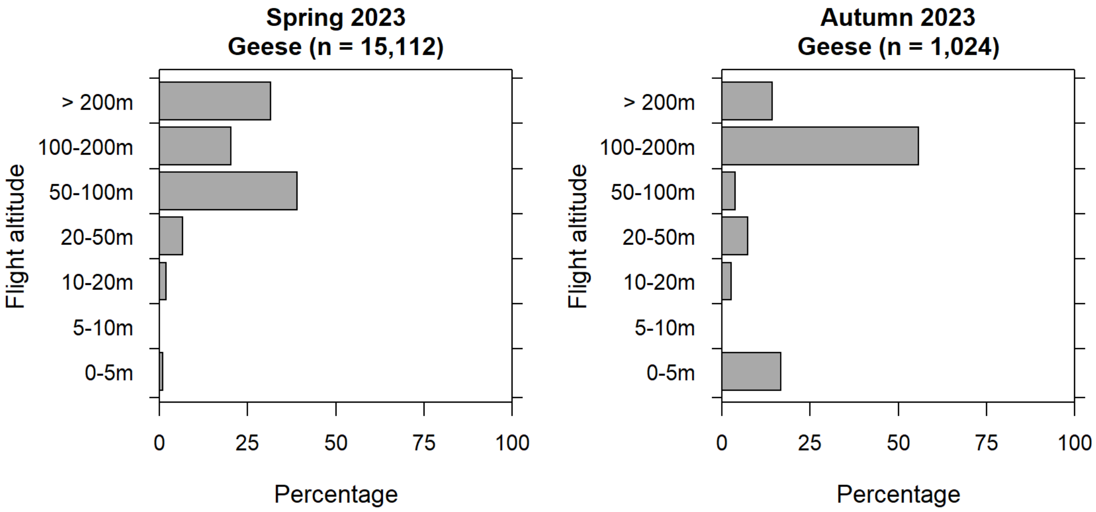


Figure 107. Flight altitude distribution of geese during visual observations in spring and autumn 2023 on Bornholm, Rønne.

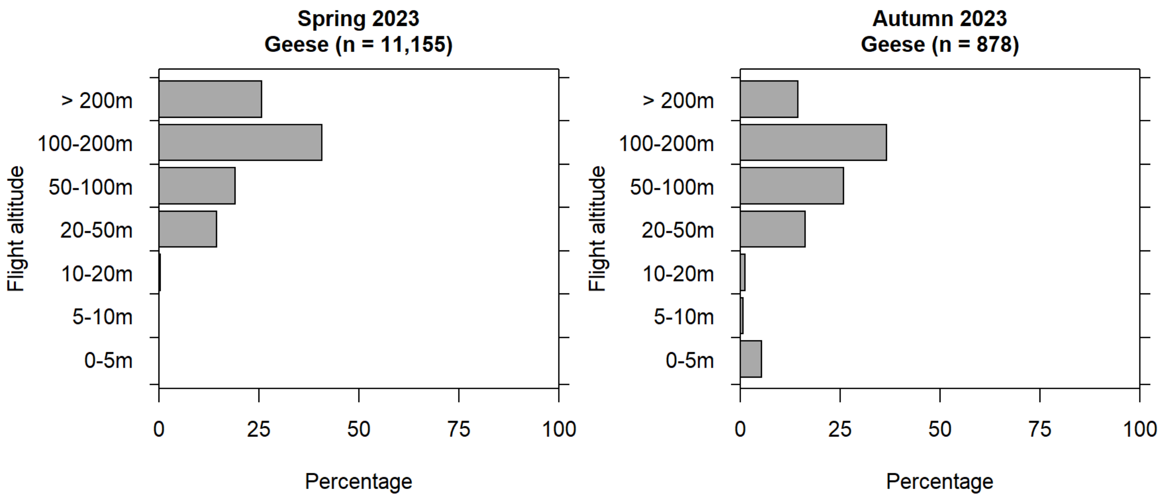


Figure 108. Flight altitude distribution of geese during visual observations in spring 2023 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

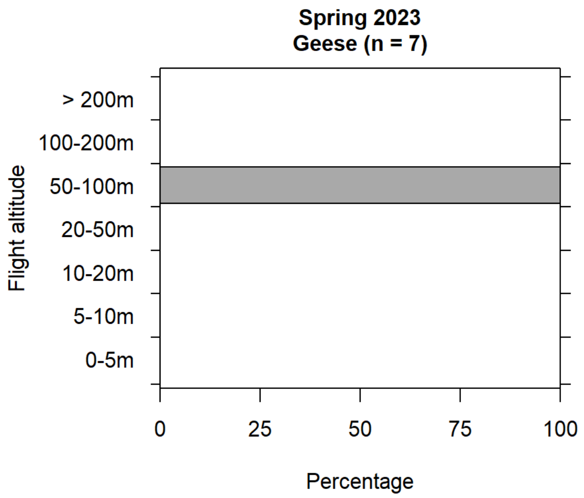


Figure 109. Flight altitude distribution of geese during visual observations in spring 2023 from vessel-based surveys.

FLIGHT DIRECTIONS

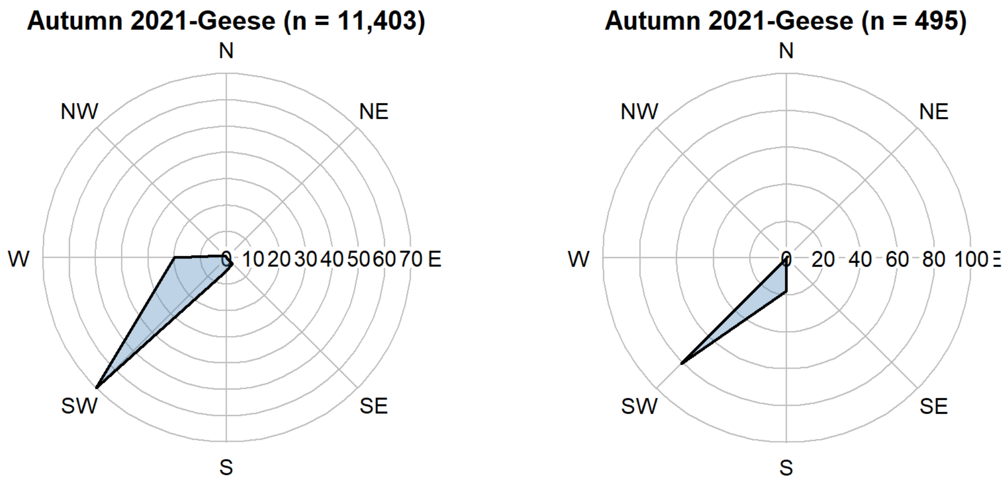


Figure 110. Flight directions of geese during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

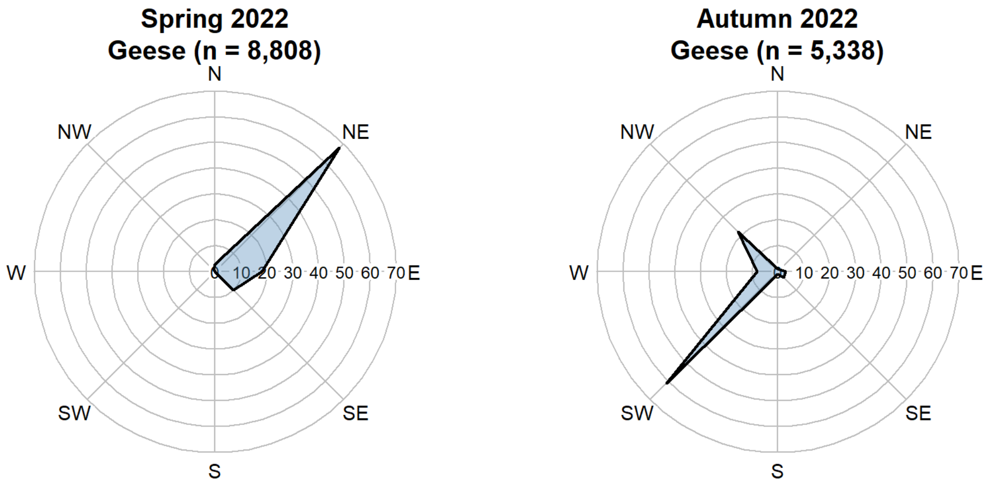


Figure 111. Flight directions of geese during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

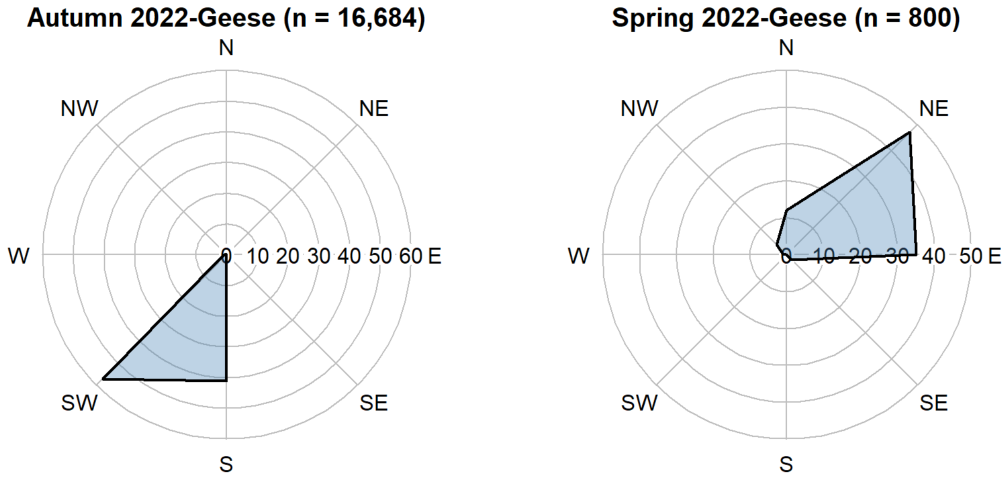


Figure 112. Flight directions of geese during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

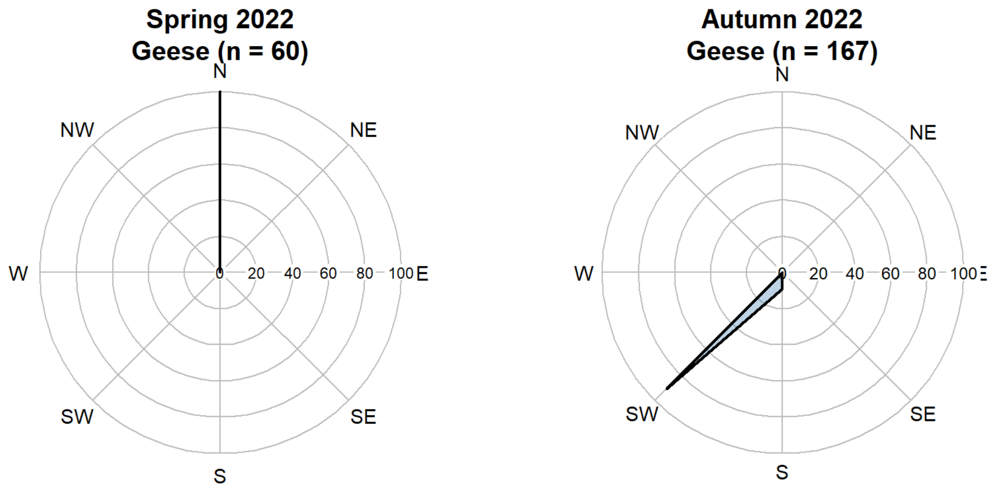


Figure 113. Flight directions of geese during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

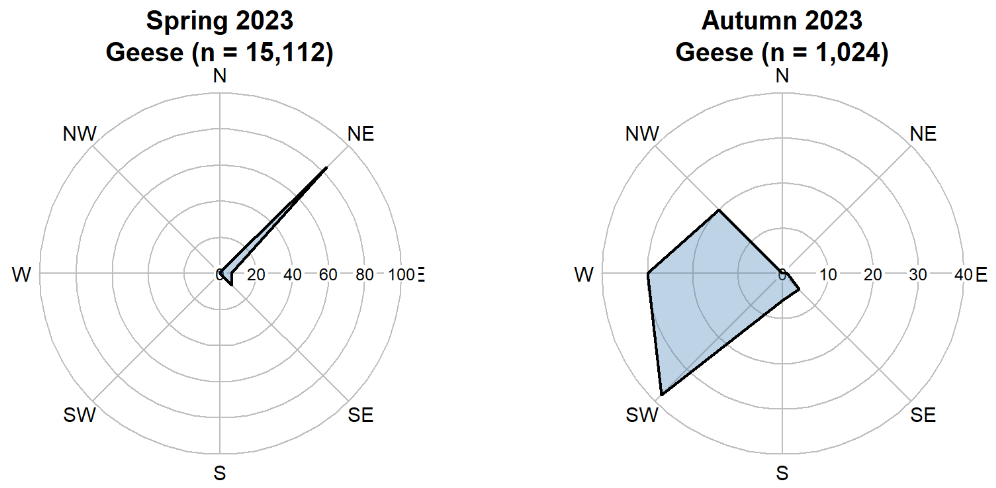


Figure 114. Flight directions of geese during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.

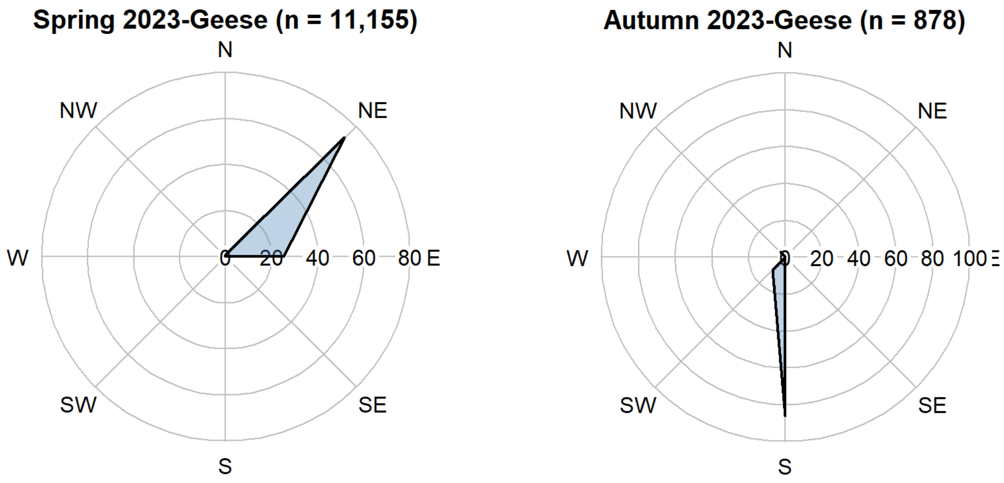


Figure 115. Flight directions of geese during daytime in spring 2023 at Rügen (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

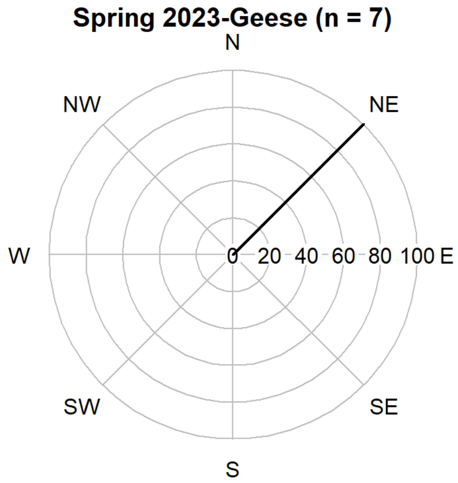


Figure 116. Flight directions of geese during daytime in spring 2023 from vessel-based surveys. For more details refer to the description of Figure 71.

DUCKS

FLIGHT ALTITUDES

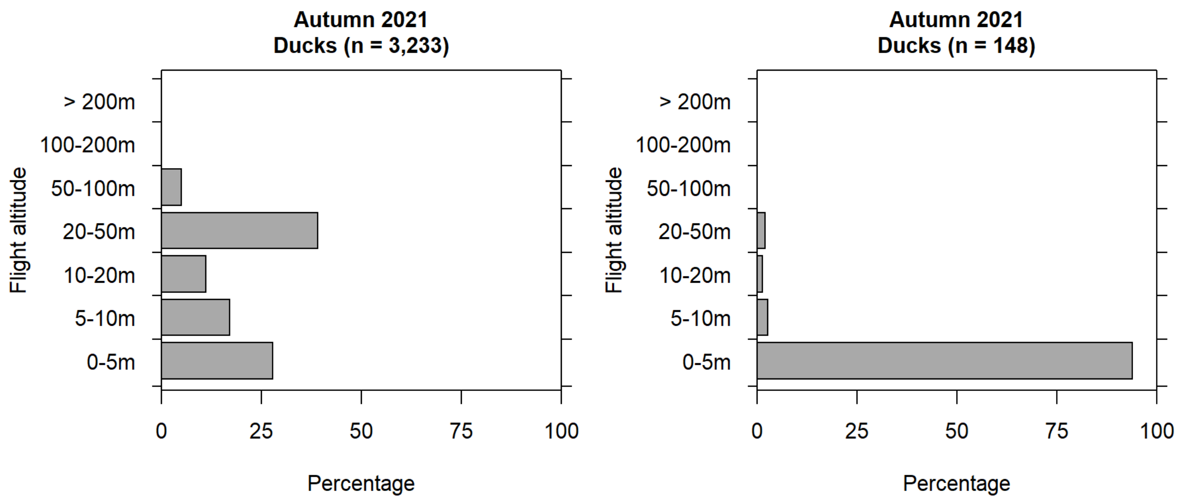


Figure 117. Flight altitude distribution of ducks during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

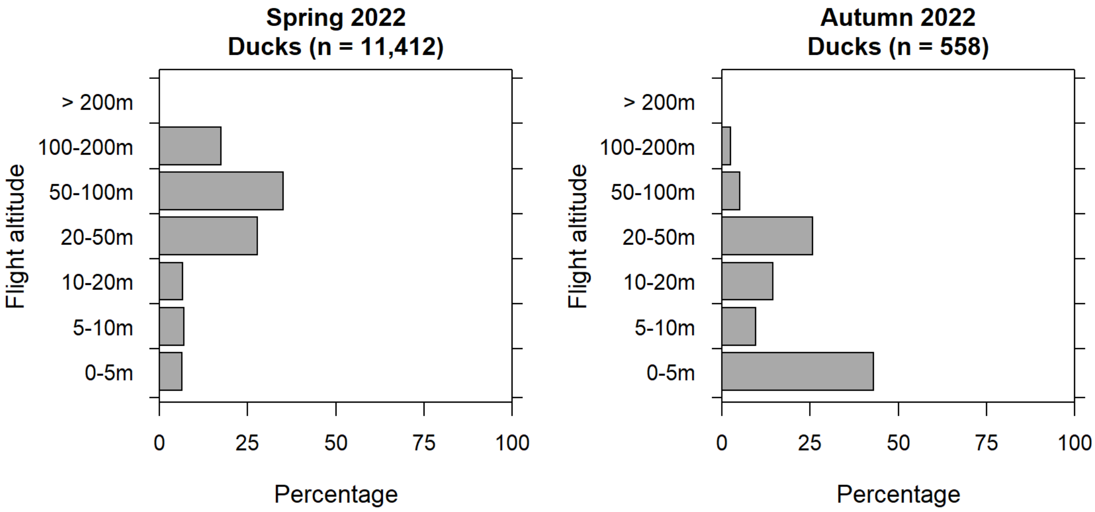


Figure 118. Flight altitude distribution of ducks during visual observations in spring and autumn 2022 on Bornholm, Rønne.

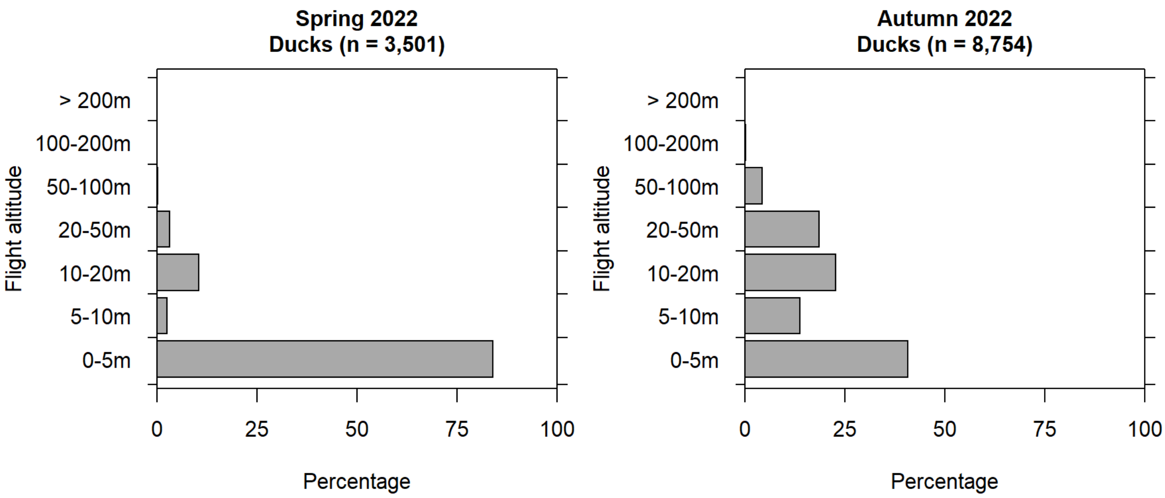


Figure 119. Flight altitude distribution of ducks during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

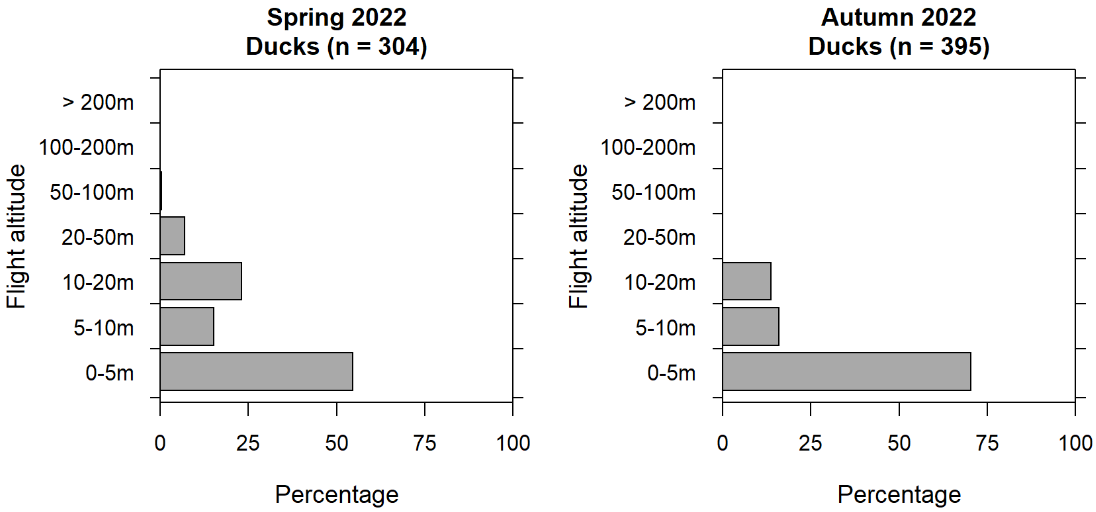


Figure 120. Flight altitude distribution of ducks during visual observations in spring and autumn 2022 from vessel-based surveys.

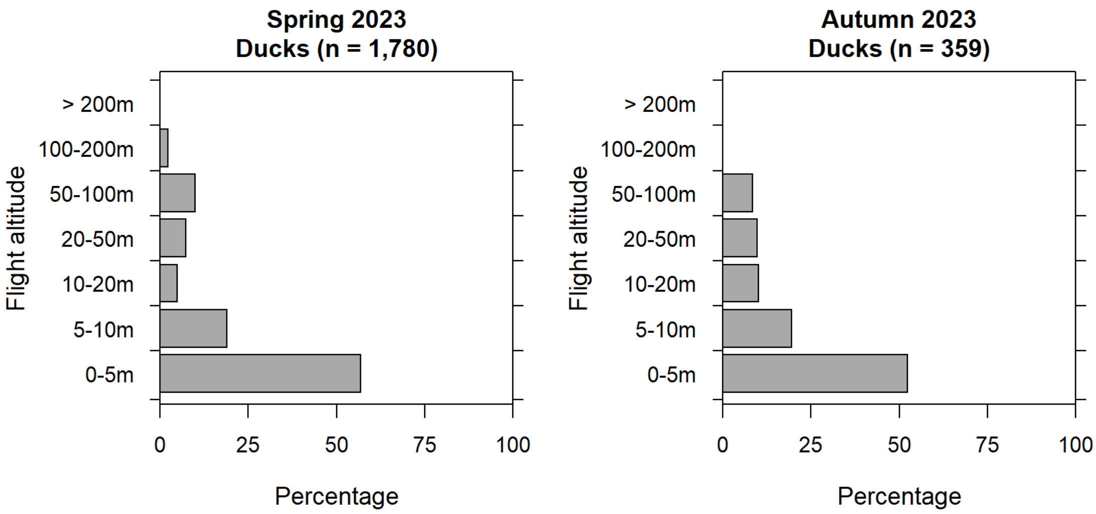
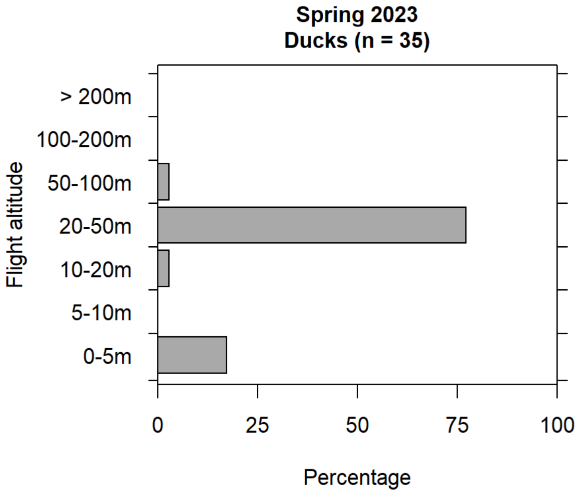


Figure 121. Flight altitude distribution of ducks during visual observations in spring and autumn 2023 on Bornholm, Rønne.



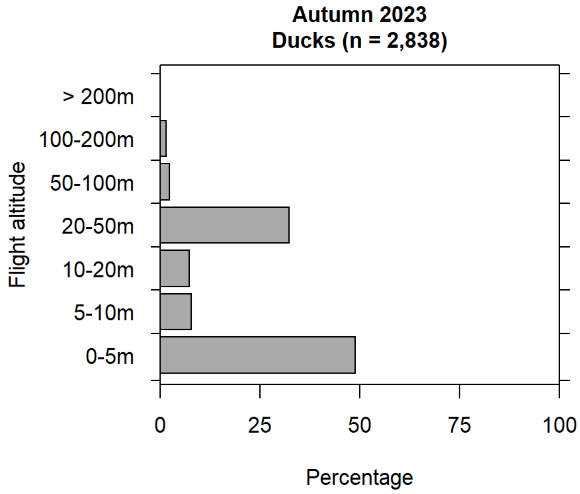


Figure 122. Flight altitude distribution of ducks during visual observations in spring 2023 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

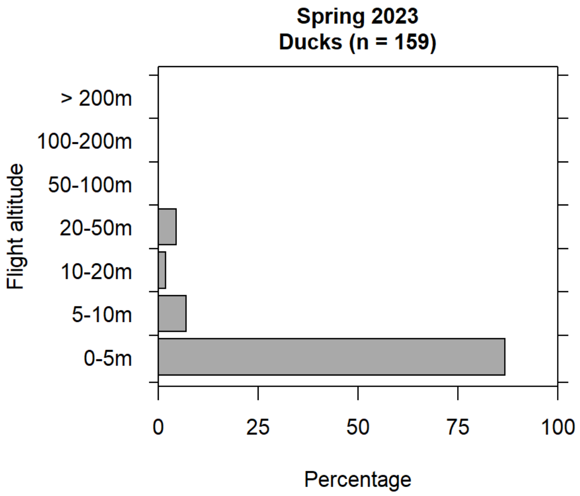


Figure 123. Flight altitude distribution of ducks during visual observations in spring 2023 from vessel-based surveys.

FLIGHT DIRECTIONS

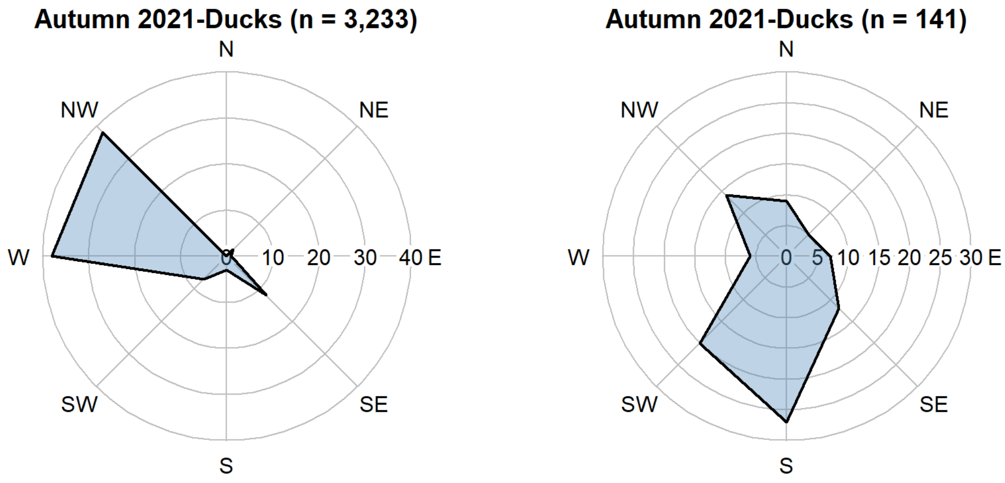


Figure 124. Flight directions of ducks during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

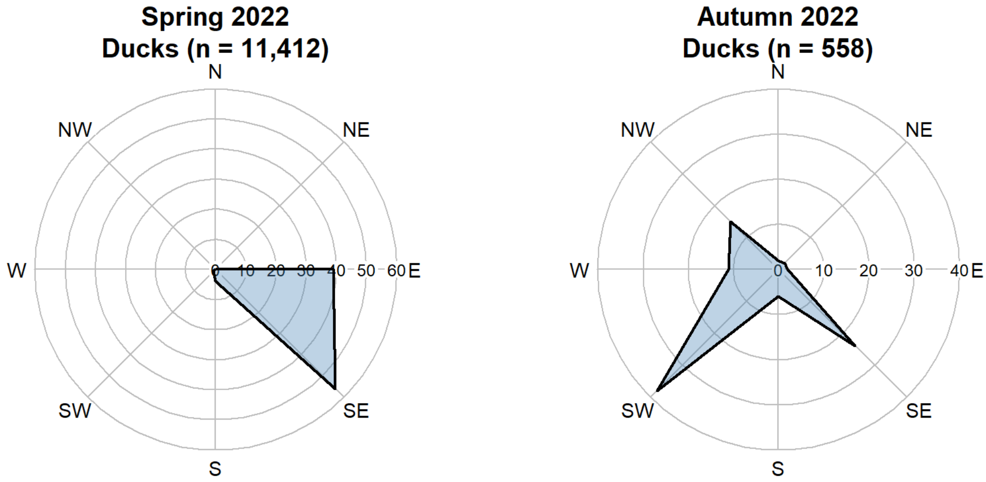


Figure 125. Flight directions of ducks during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

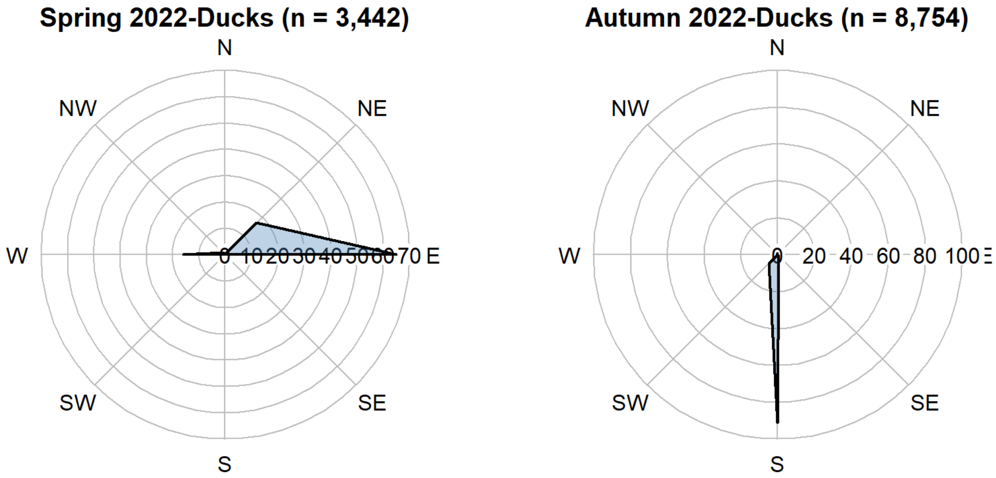


Figure 126. Flight directions of ducks during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

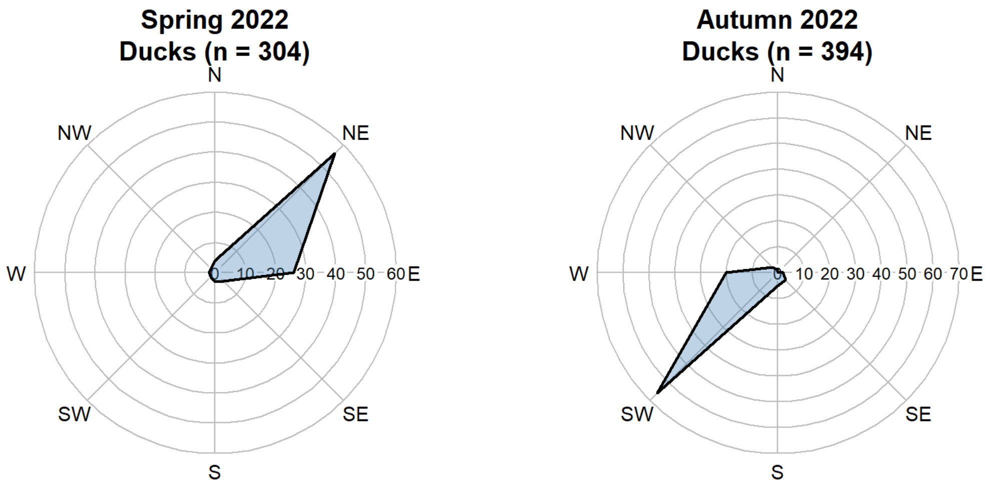


Figure 127. Flight directions of ducks during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

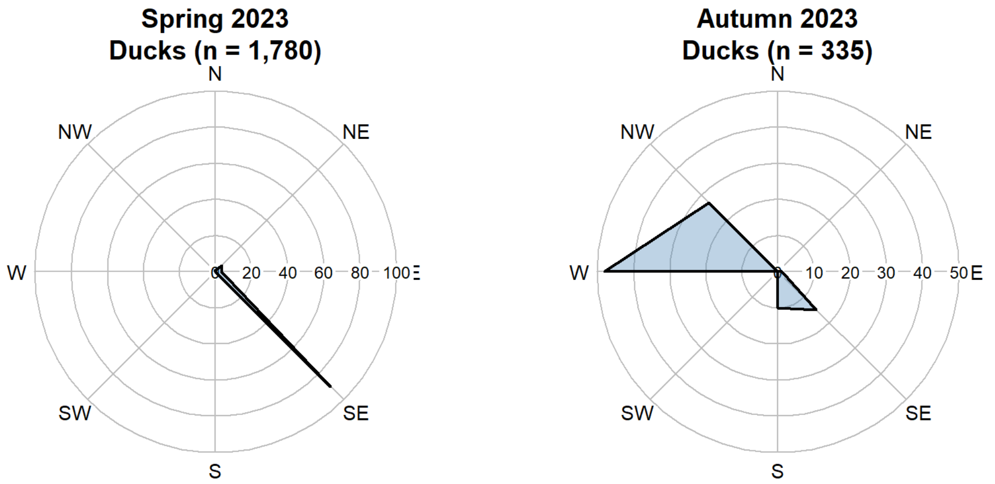


Figure 128. Flight directions of ducks during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.

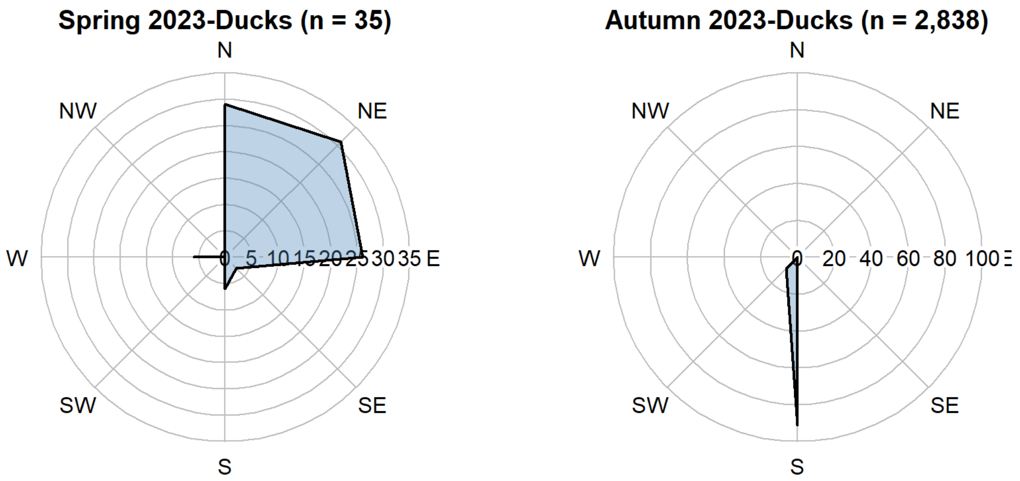


Figure 129. Flight directions of ducks during daytime in spring 2023 at Rügen (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

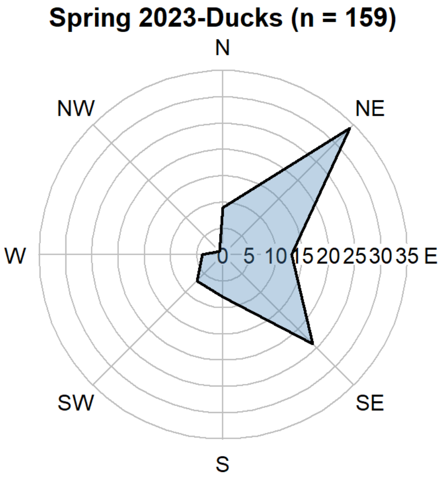


Figure 130. Flight directions of ducks during daytime in spring 2023 from vessel-based surveys. For more details refer to the description of Figure 71.

BIRDS OF PREY

FLIGHT ALTITUDES

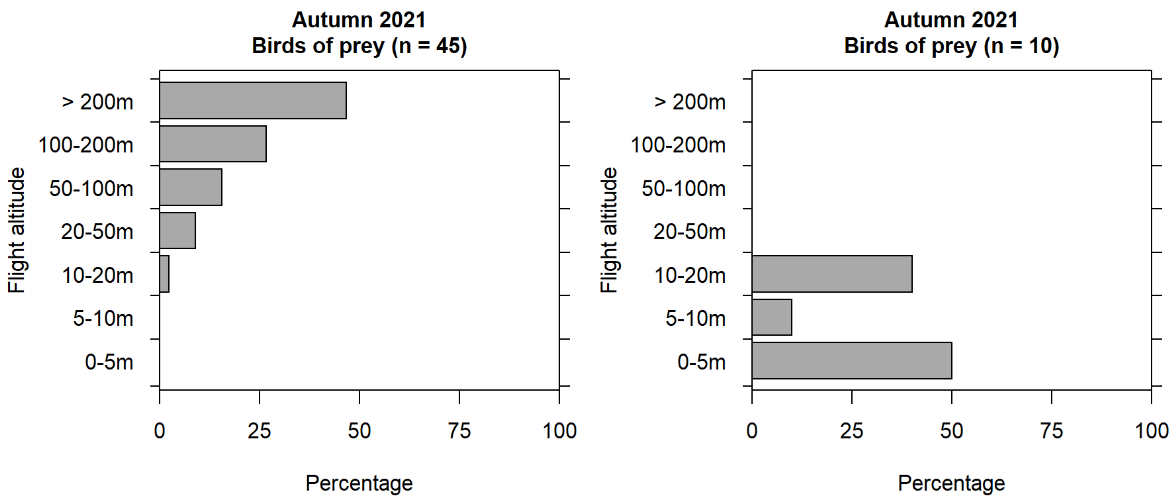


Figure 131. Flight altitude distribution of birds of prey during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

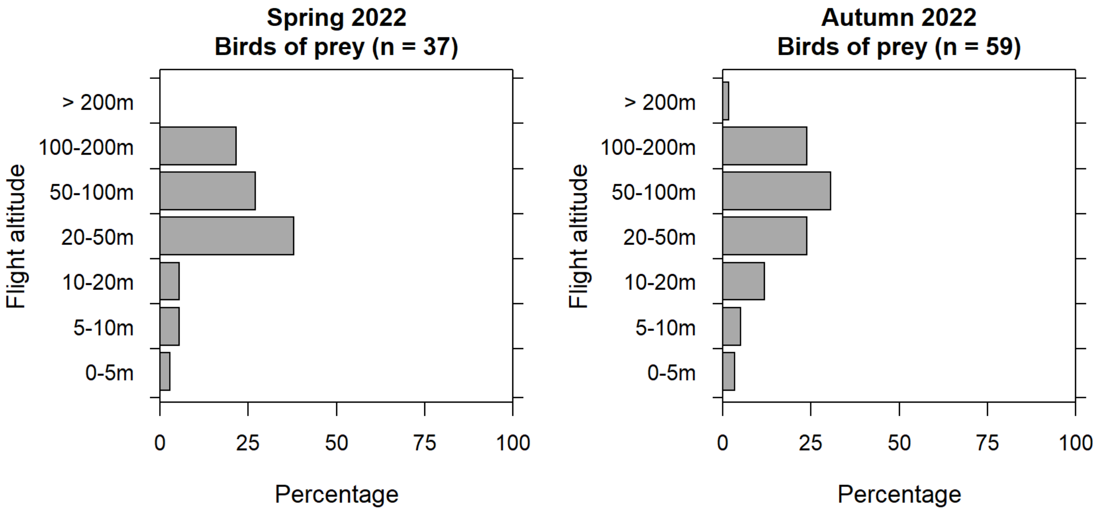


Figure 132. Flight altitude distribution of birds of prey during visual observations in spring and autumn 2022 on Bornholm, Rønne.

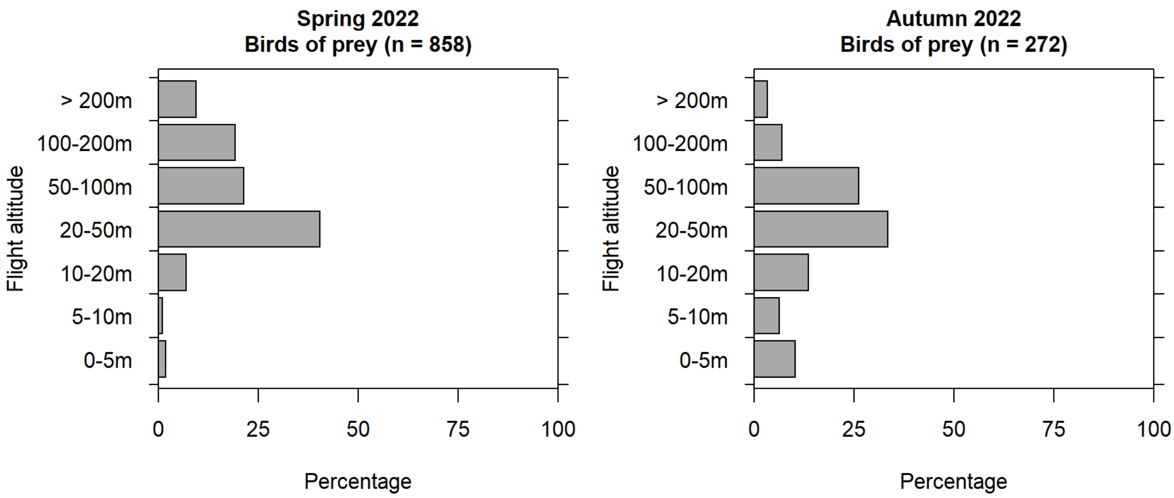


Figure 133. Flight altitude distribution of birds of prey during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

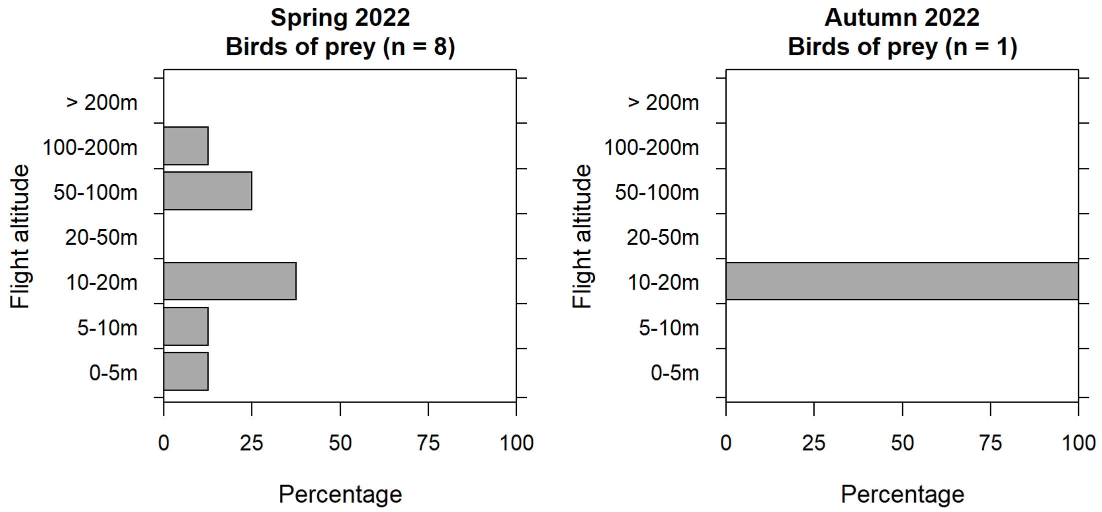


Figure 134. Flight altitude distribution of birds of prey during visual observations in spring and autumn 2022 from vessel-based surveys.

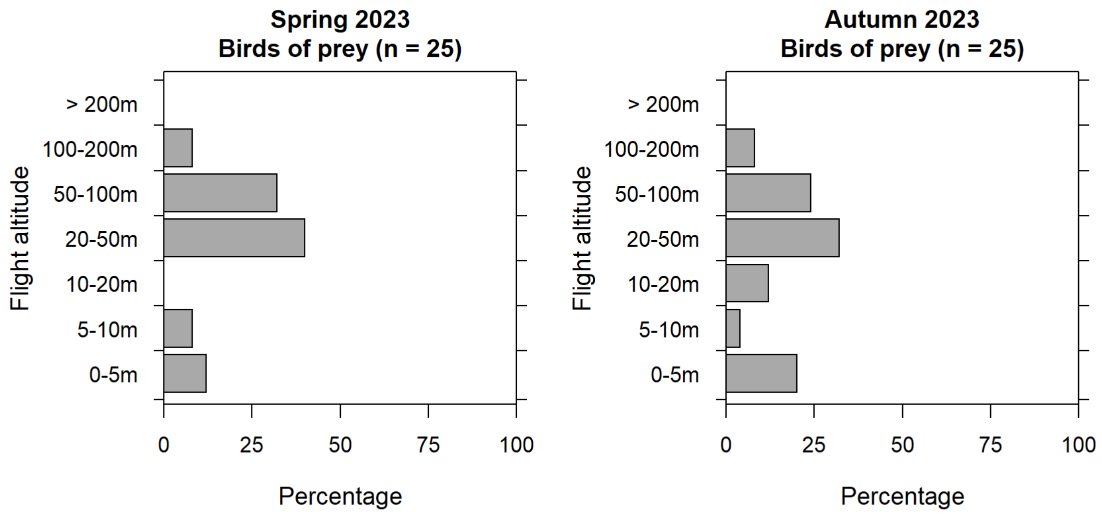


Figure 135. Flight altitude distribution of birds of prey during visual observations in spring and autumn 2023 on Bornholm, Rønne.

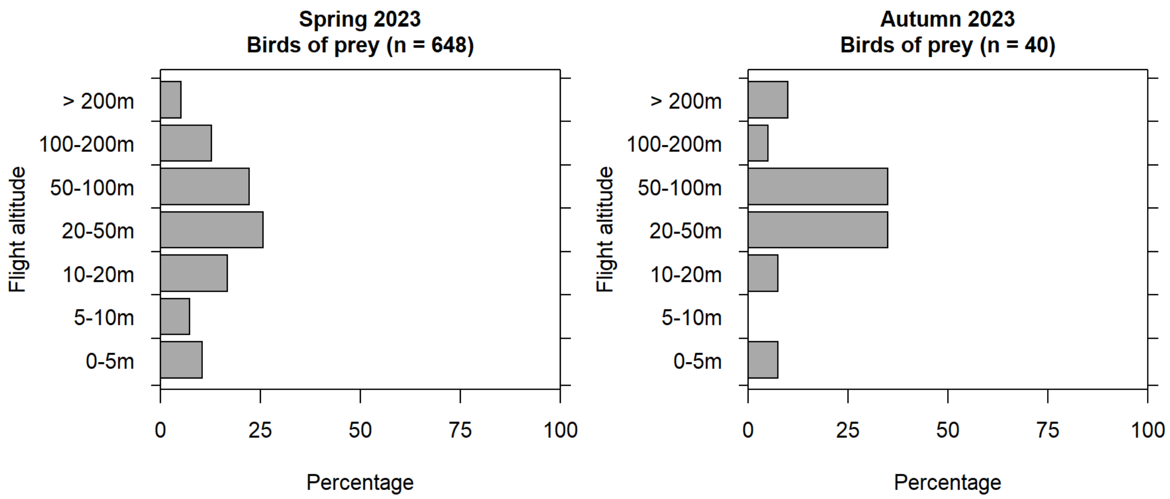


Figure 136. Flight altitude distribution of birds of prey during visual observations in spring 2023 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

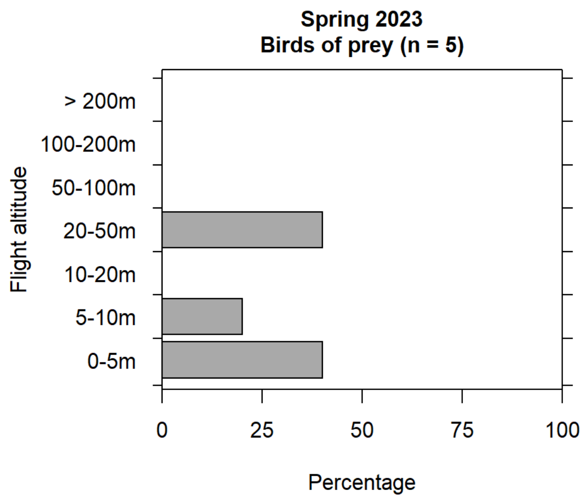


Figure 137. Flight altitude distribution of birds of prey during visual observations in spring 2023 from vessel-based surveys.

FLIGHT DIRECTIONS

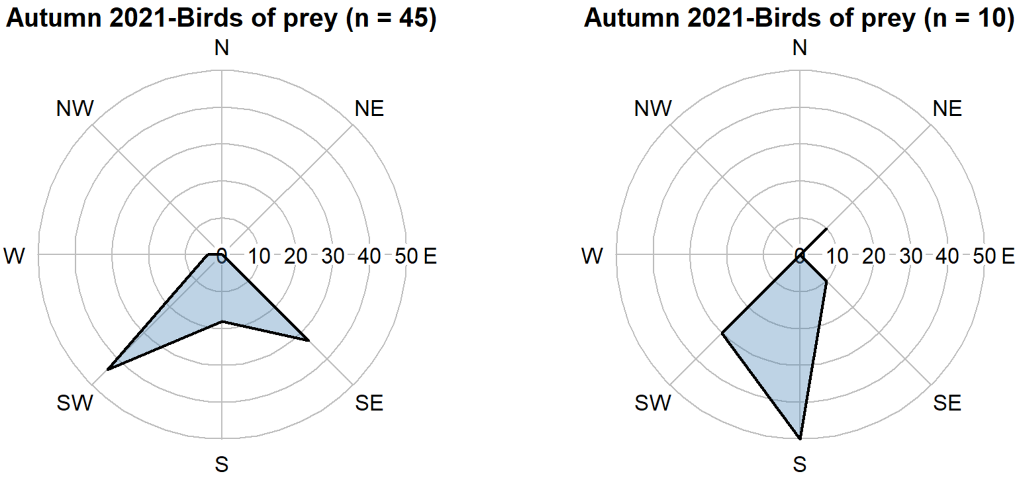


Figure 138. Flight directions of birds of prey during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

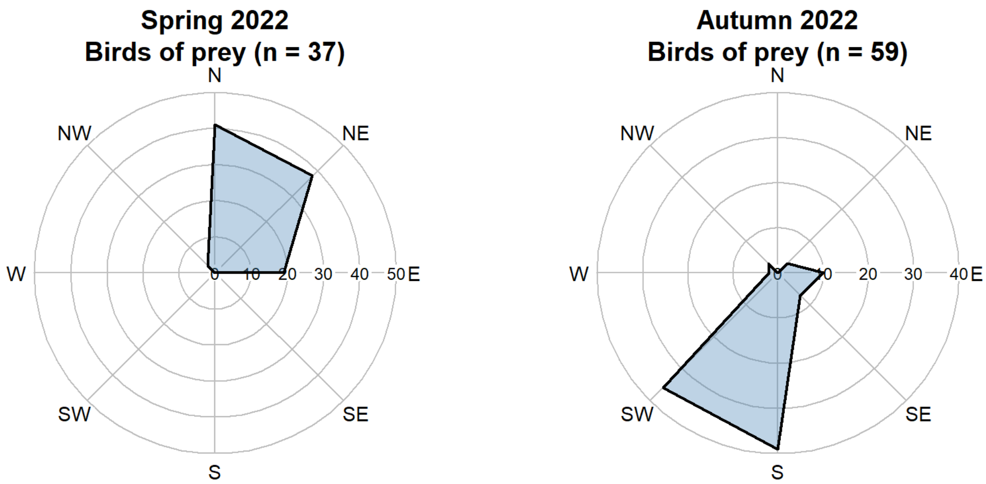


Figure 139. Flight directions of birds of prey during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

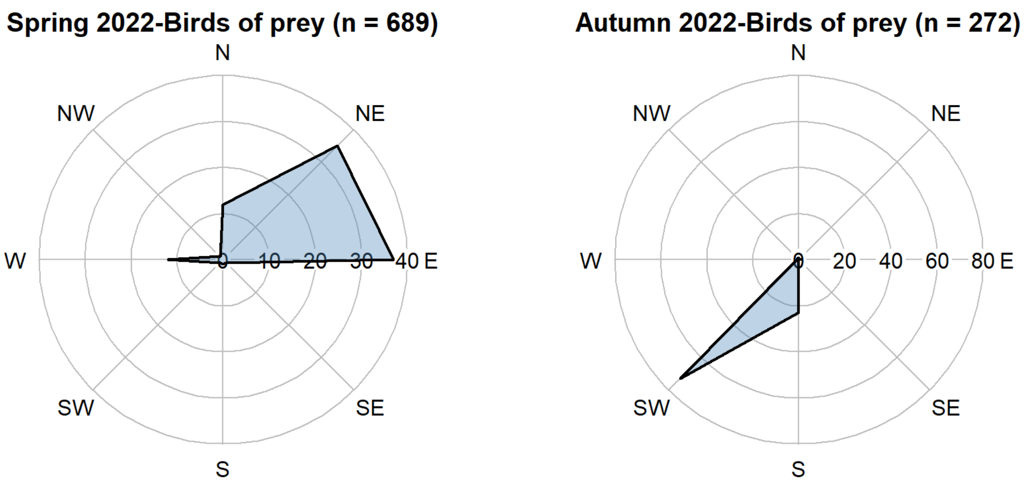


Figure 140. Flight directions of birds of prey during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

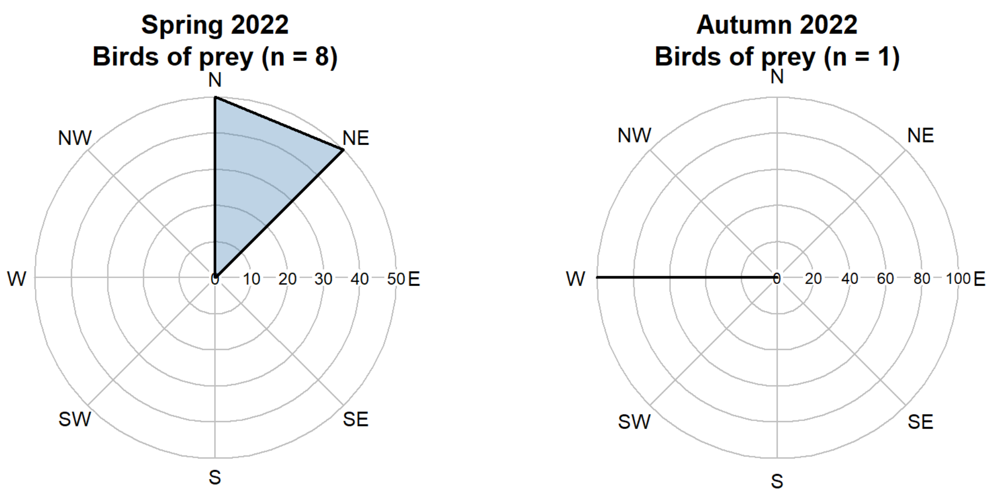


Figure 141. Flight directions of birds of prey during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

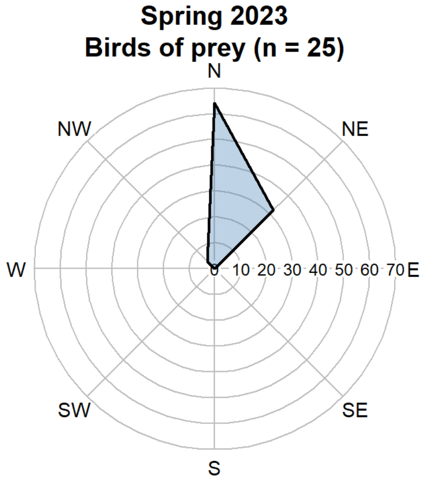


Figure 142. Flight directions of birds of prey during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.

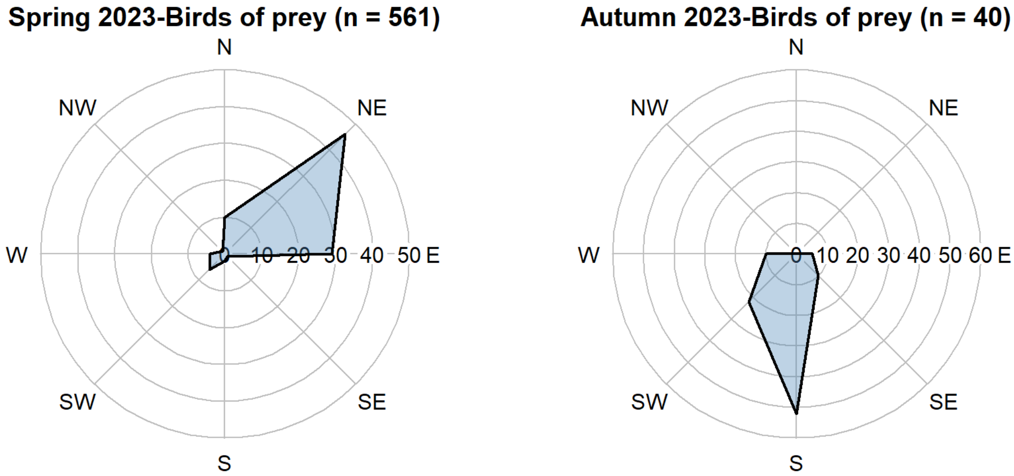


Figure 143. Flight directions of birds of prey during daytime in spring 2023 at Rügen (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

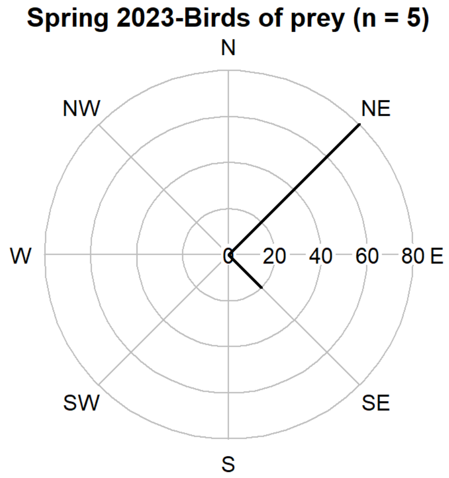


Figure 144. Flight directions of birds of prey during daytime in spring 2023 from vessel-based surveys. For more details refer to the description of Figure 71.

CRANES

FLIGHT ALTITUDES

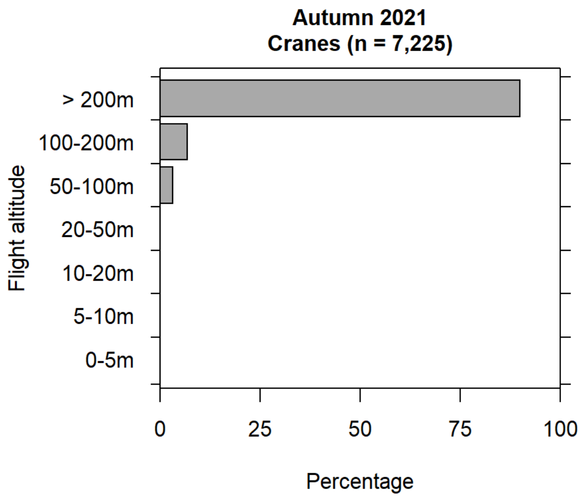


Figure 145. Flight altitude distribution of cranes during visual observations in autumn 2021 on Bornholm, Rønne.

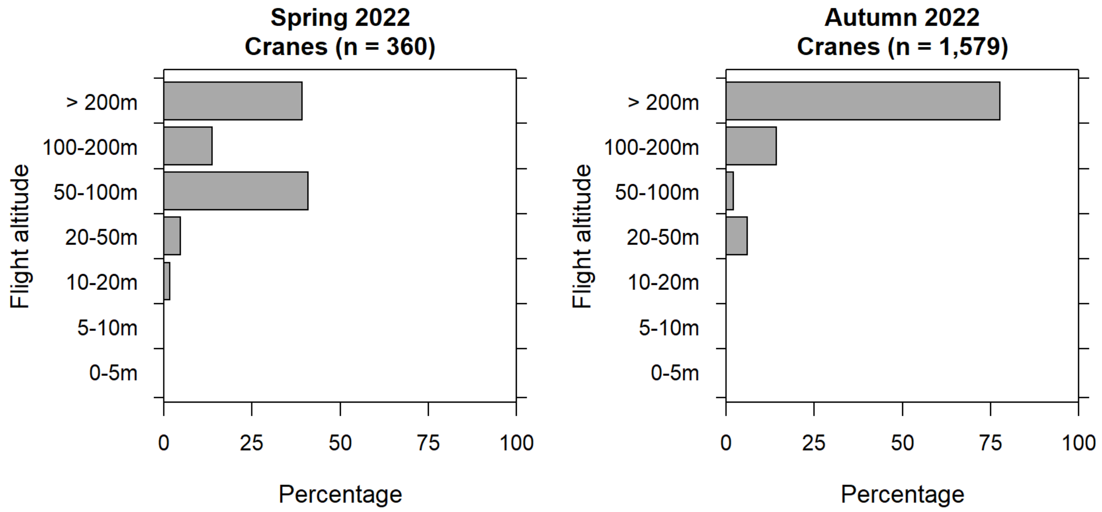


Figure 146. Flight altitude distribution of cranes during visual observations in spring and autumn 2022 on Bornholm, Rønne.

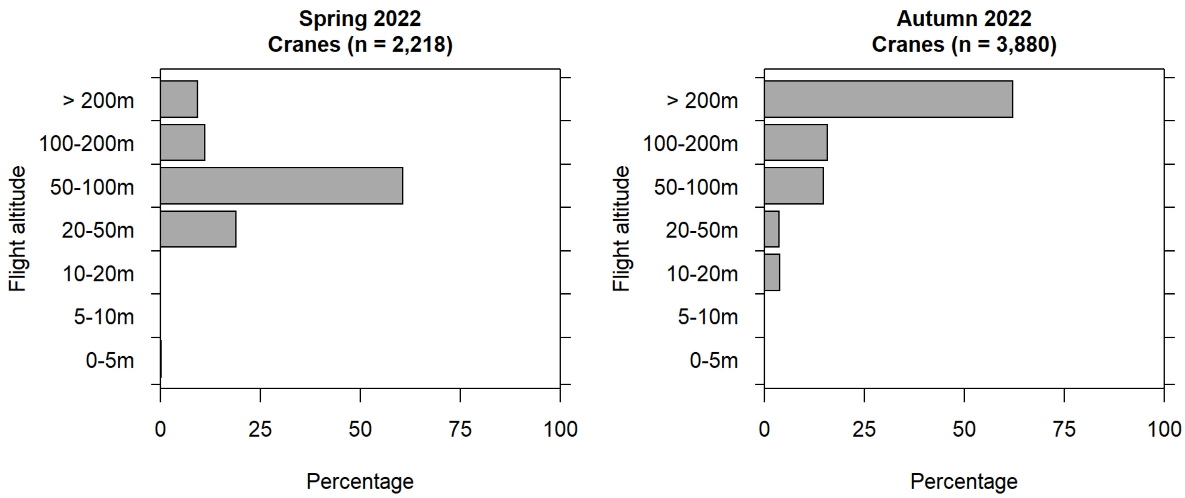


Figure 147. Flight altitude distribution of cranes during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

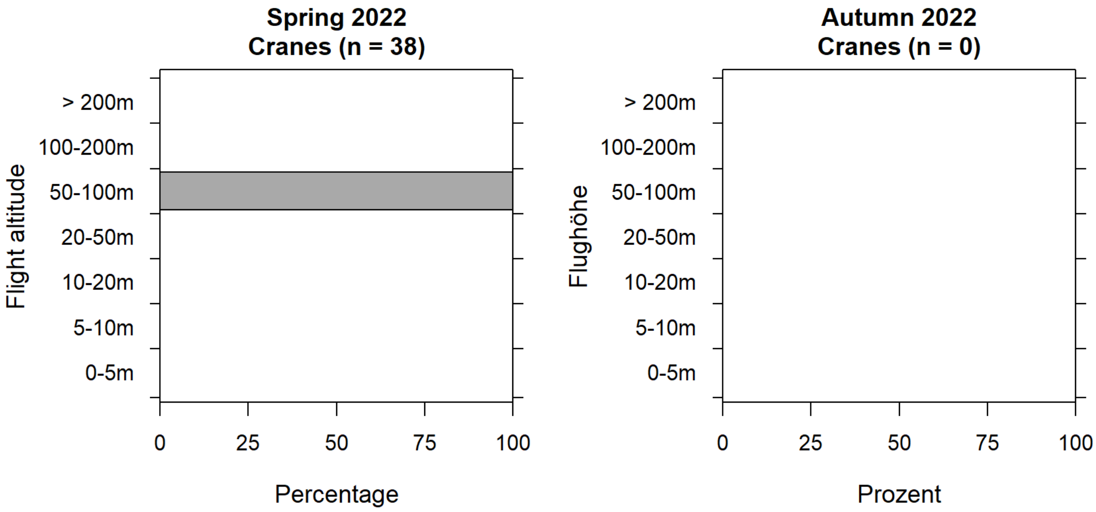


Figure 148. Flight altitude distribution of cranes during visual observations in spring and autumn 2022 from vessel-based surveys.

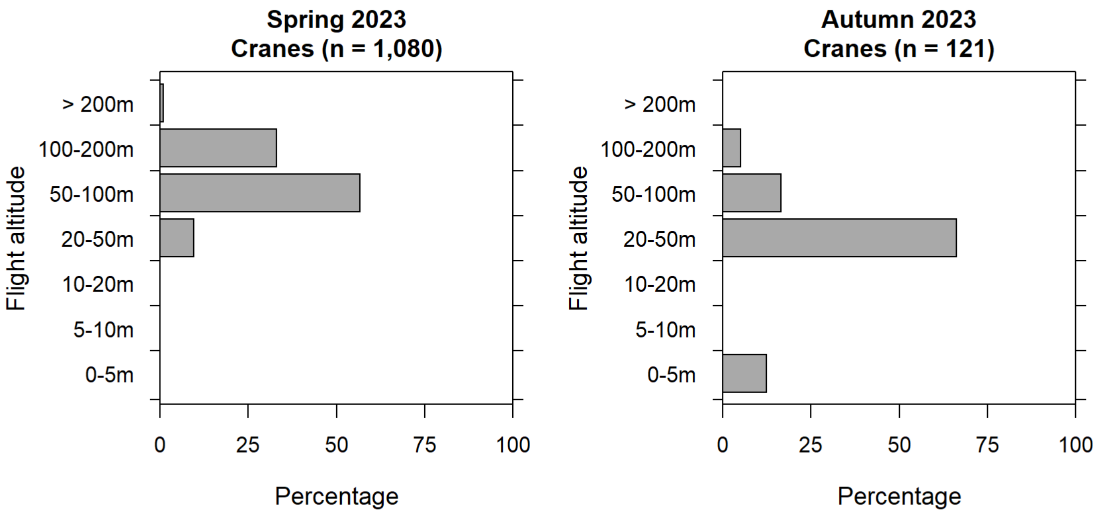


Figure 149. Flight altitude distribution of cranes during visual observations in spring and autumn 2023 on Bornholm, Rønne.

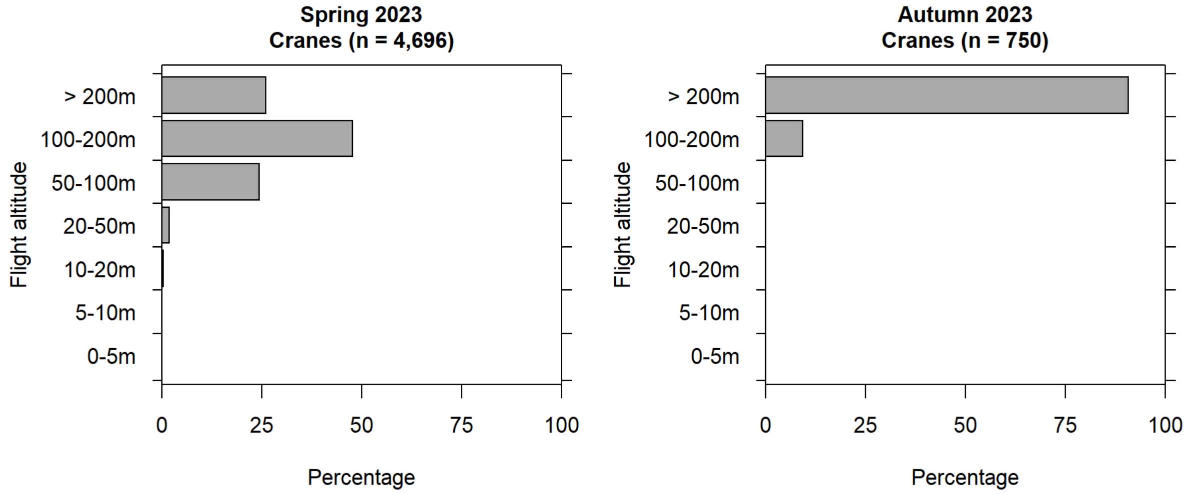


Figure 150. Flight altitude distribution of cranes during visual observations in spring 2023 at Rügen (left) and in autumn 2023 on Bornholm, Nexø (right).

FLIGHT DIRECTIONS

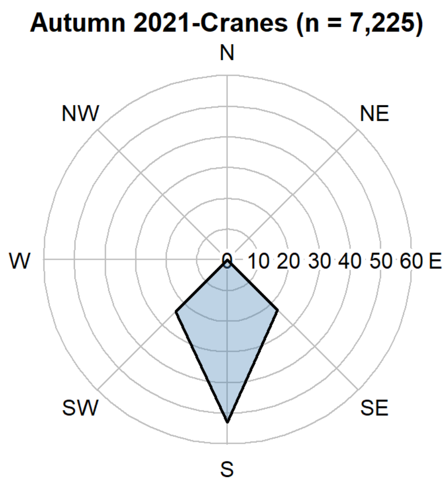


Figure 151. Flight directions of cranes during daytime in autumn 2021 on Bornholm, Rønne. For more details refer to the description of Figure 71.

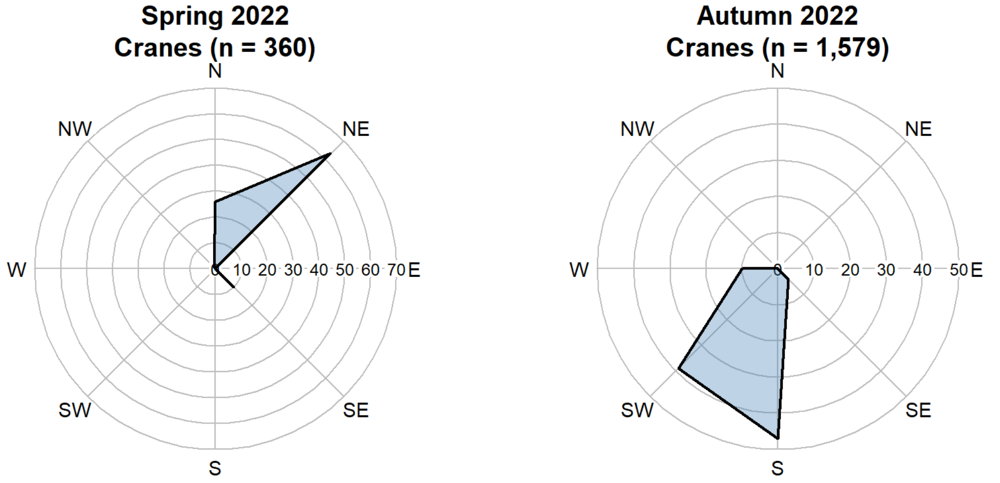


Figure 152. Flight directions of cranes during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

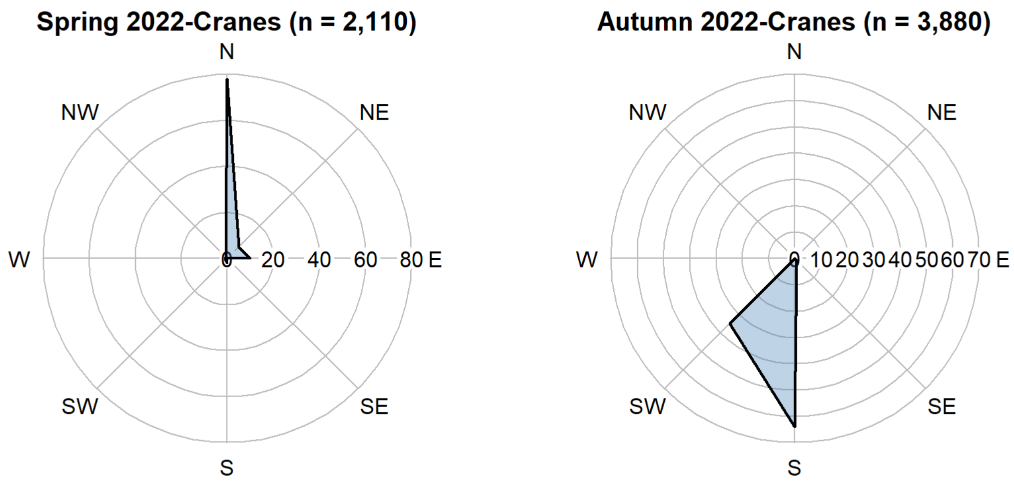


Figure 153. Flight directions of cranes during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

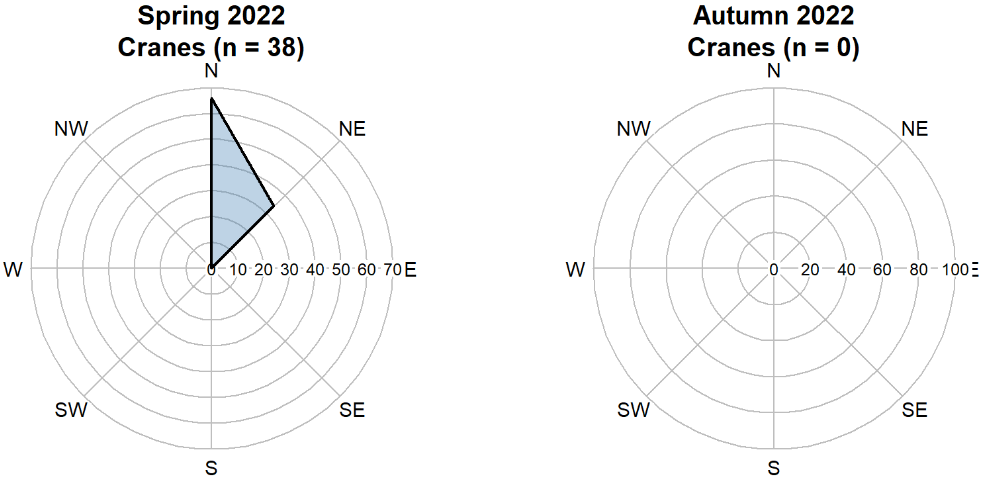


Figure 154. Flight directions of cranes during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

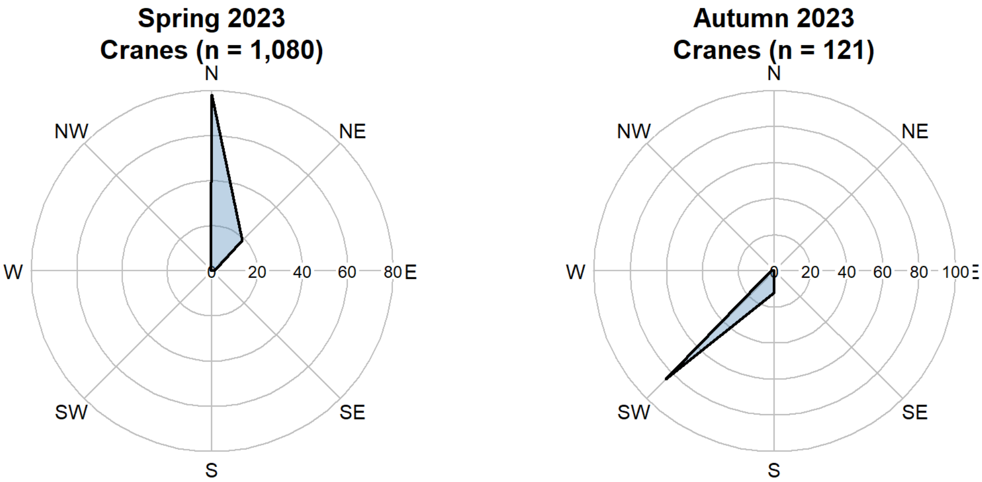
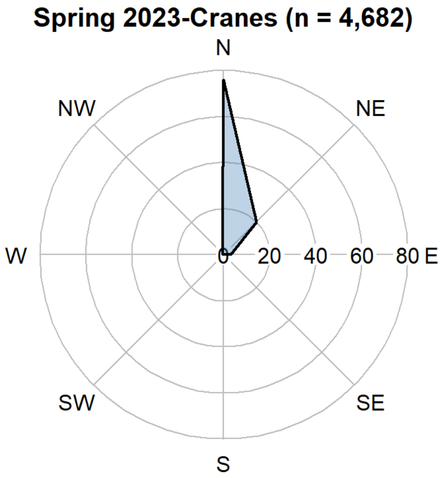


Figure 155. Flight directions of cranes during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.



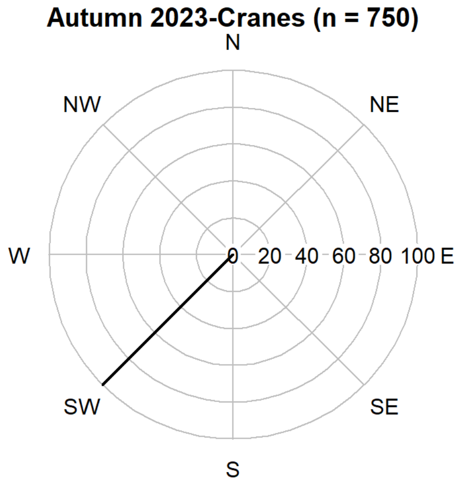
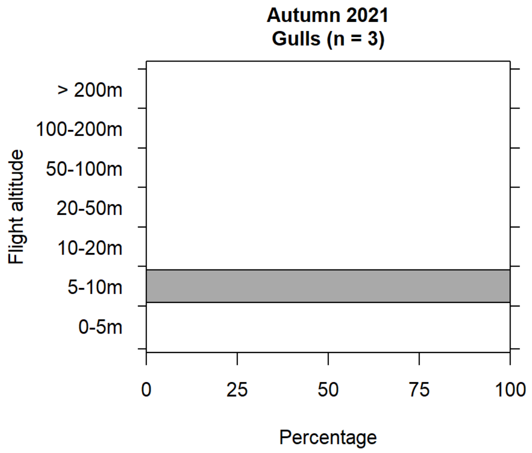


Figure 156. Flight directions of cranes during daytime in spring 2023 at Rügen (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

GULLS

FLIGHT ALTITUDES



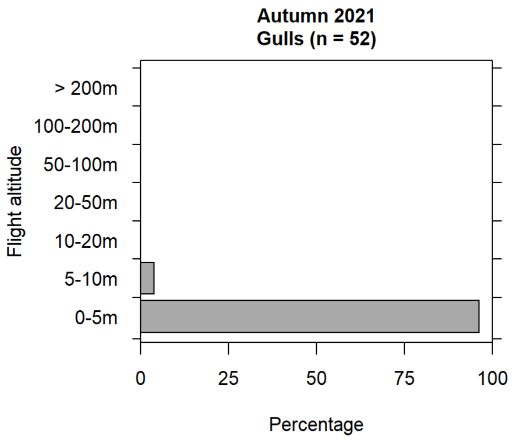


Figure 157. Flight altitude distribution of gulls during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

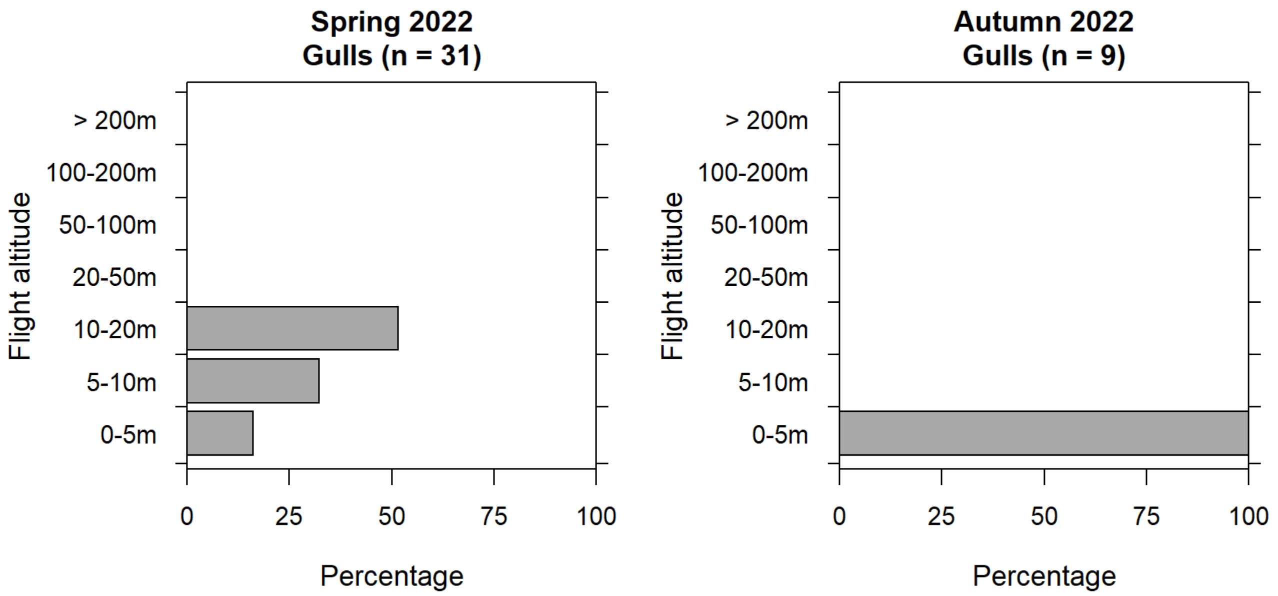


Figure 158. Flight altitude distribution of gulls during visual observations in spring and autumn 2022 on Bornholm, Rønne.

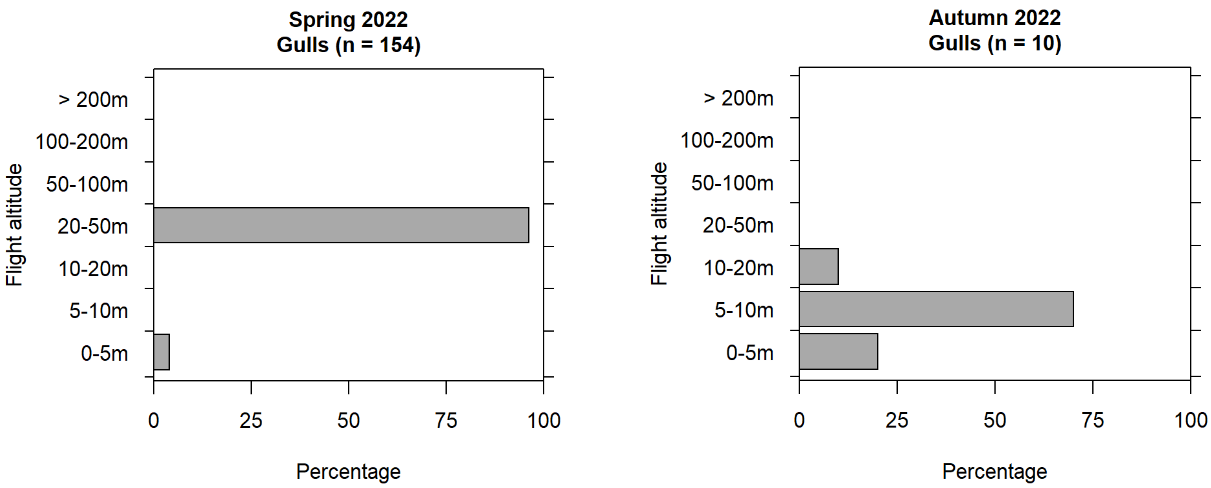


Figure 159. Flight altitude distribution of gulls during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

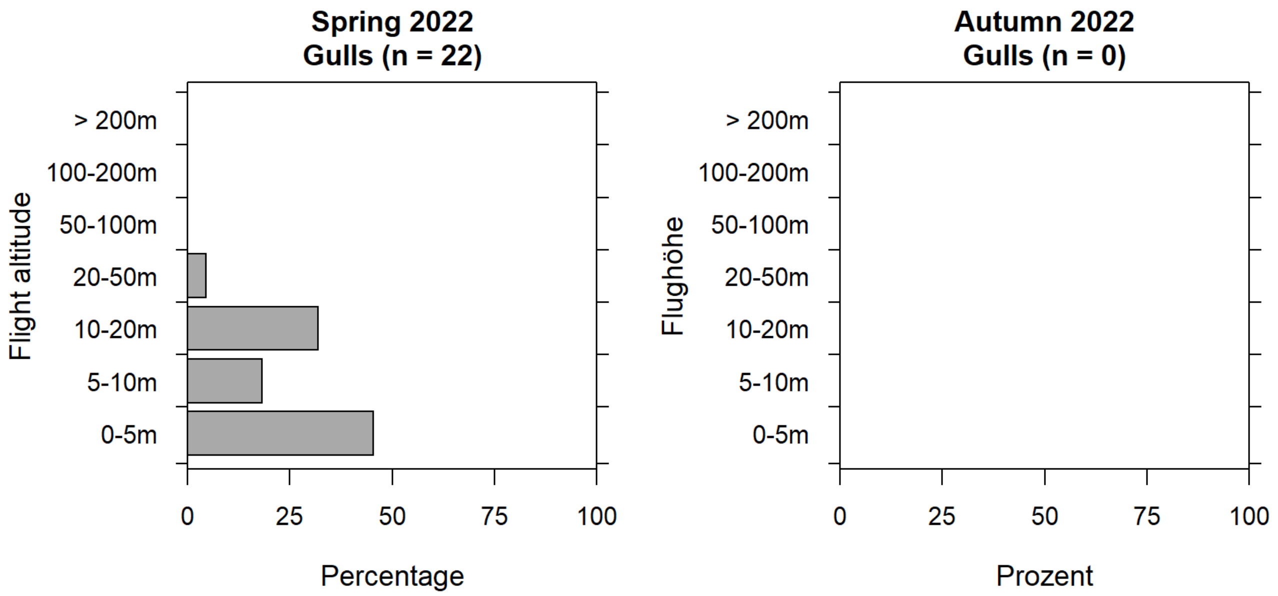


Figure 160. Flight altitude distribution of gulls during visual observations in spring and autumn 2022 from vessel-based surveys.

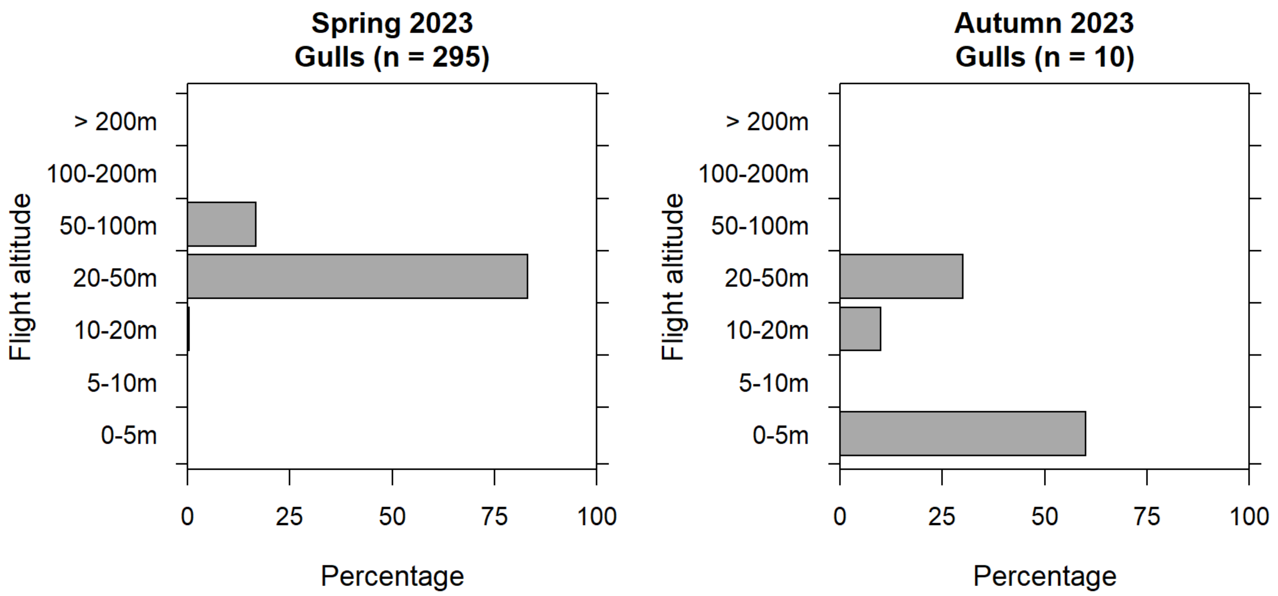
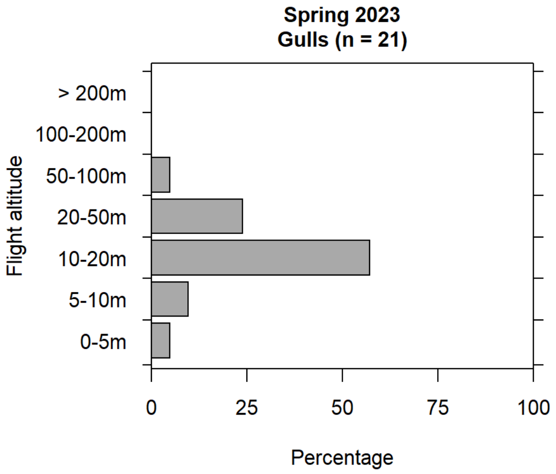


Figure 161. Flight altitude distribution of gulls during visual observations in spring and autumn 2023 on Bornholm, Rønne.



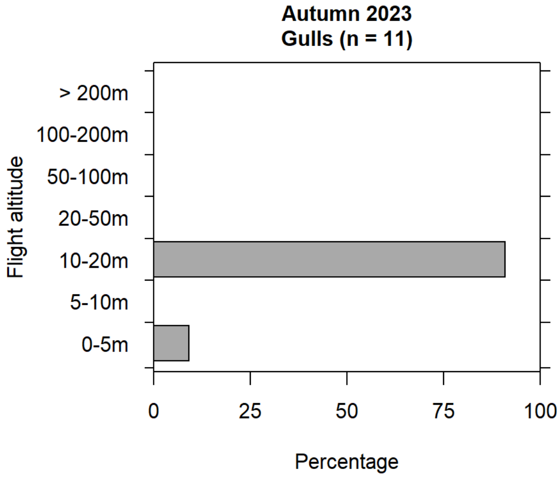
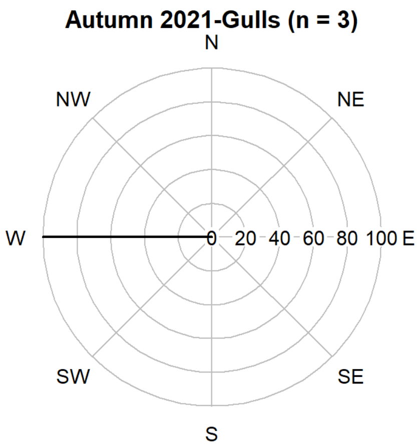


Figure 162. Flight altitude distribution of gulls during visual observations in spring 2023 from vessel-based surveys (left) and in autumn 2023 on Bornholm, Nexø (right).

FLIGHT DIRECTIONS



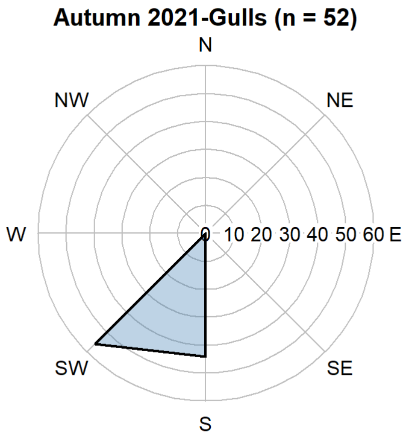


Figure 163. Flight directions of gulls during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

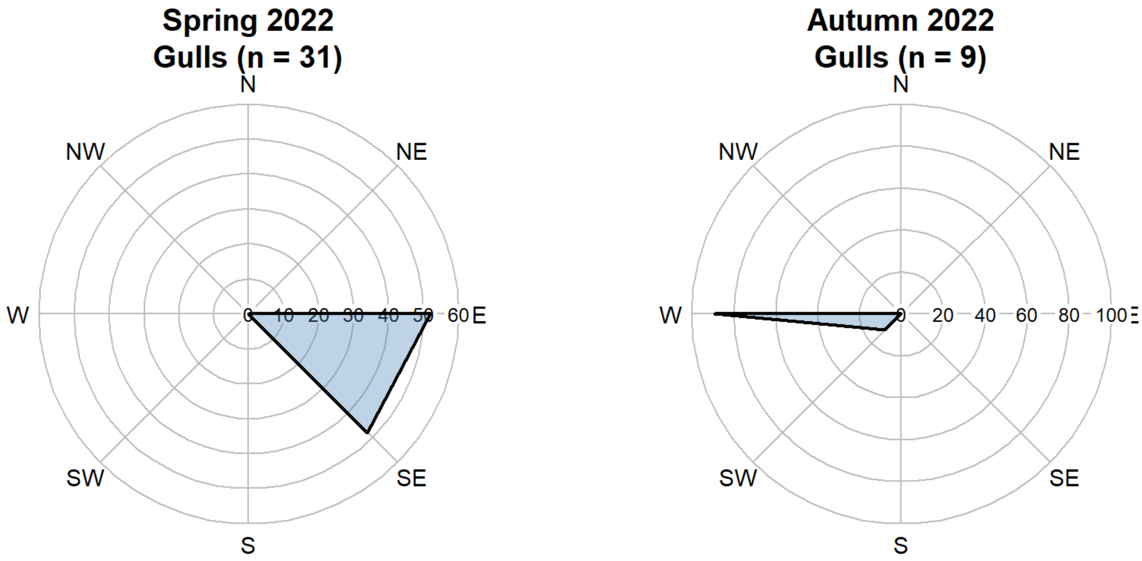


Figure 164. Flight directions of gulls during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

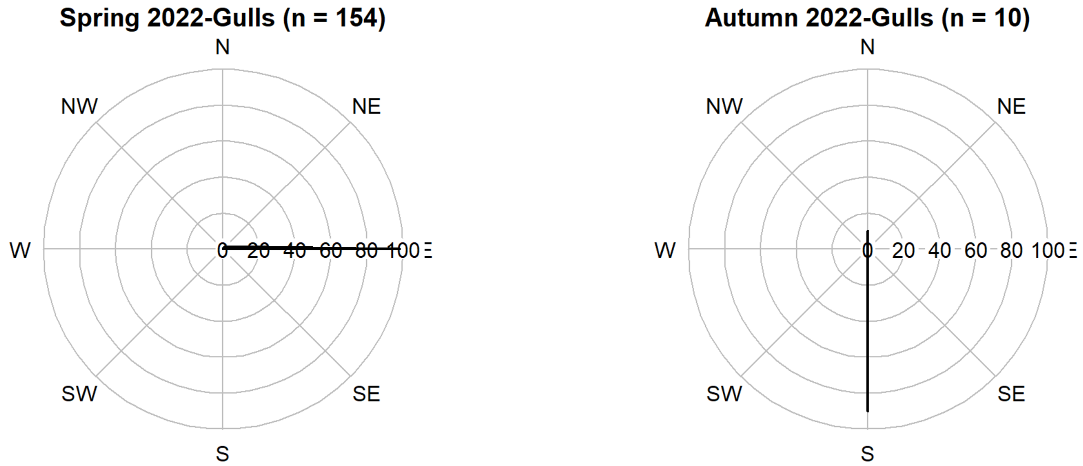


Figure 165. Flight directions of gulls during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

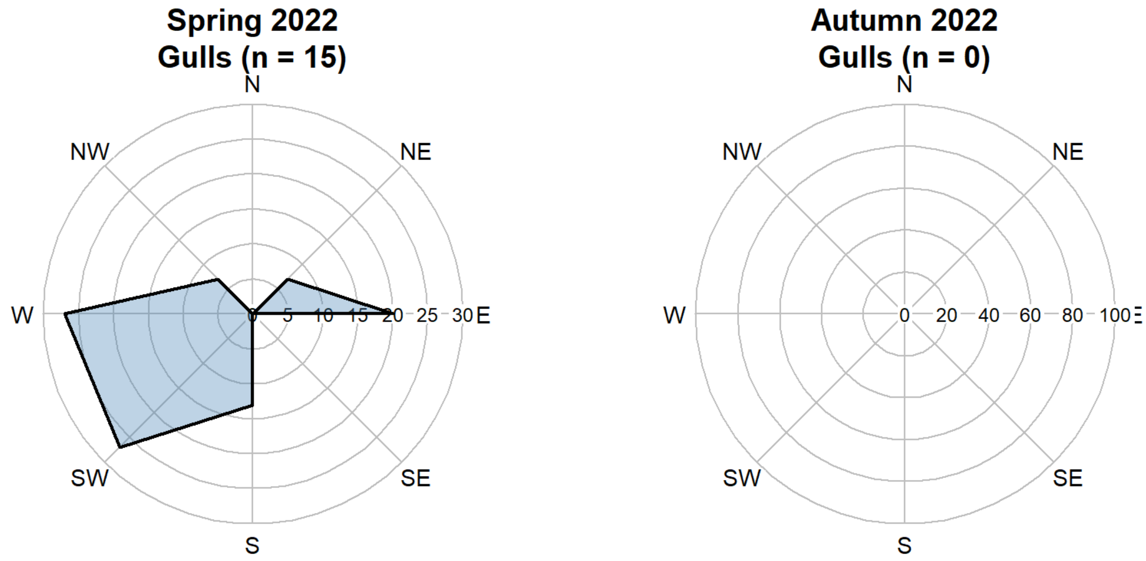


Figure 166. Flight directions of gulls during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

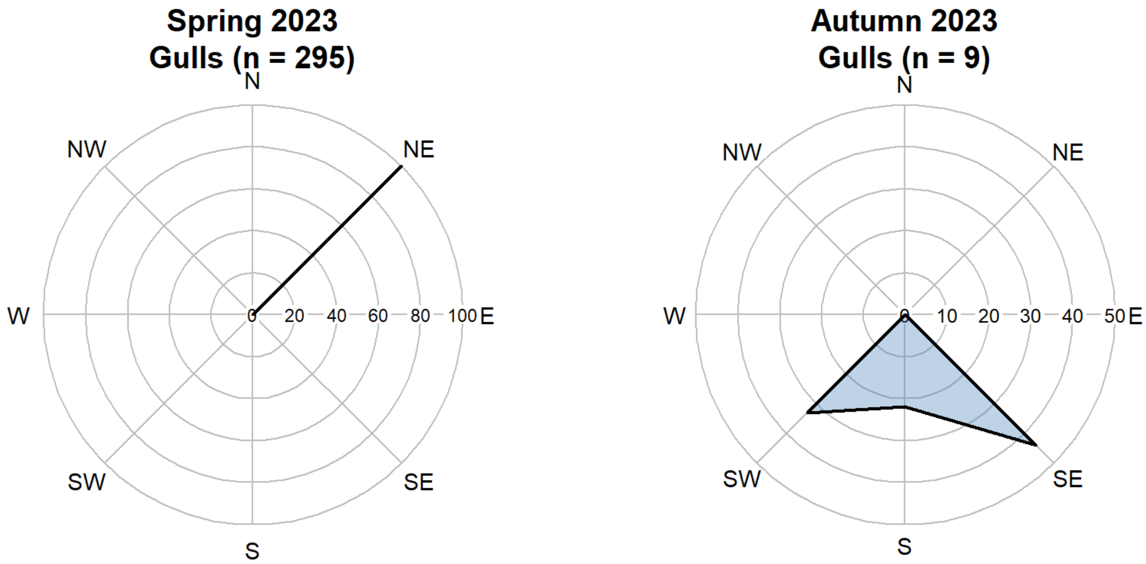


Figure 167. Flight directions of gulls during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.

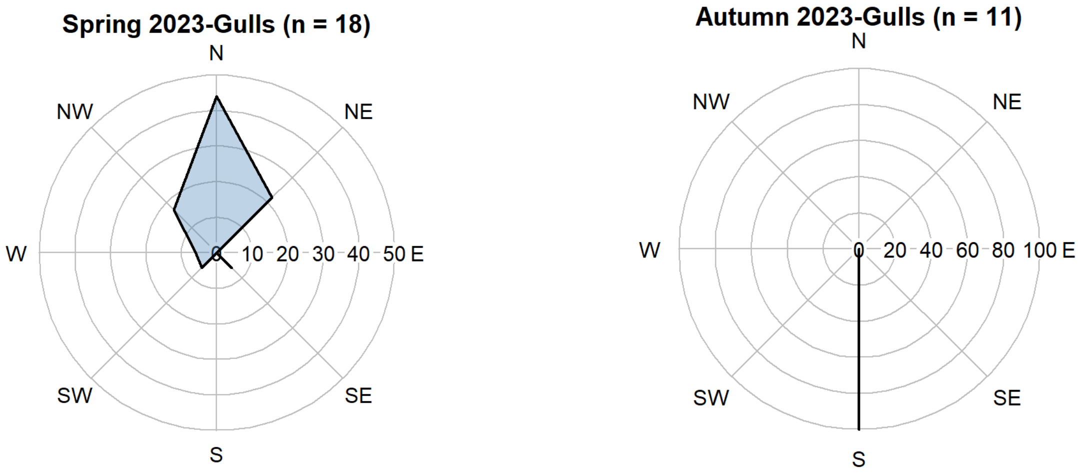


Figure 168. Flight directions of gulls during daytime in spring 2023 from vessel-based surveys (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

TERNS

FLIGHT ALTITUDES

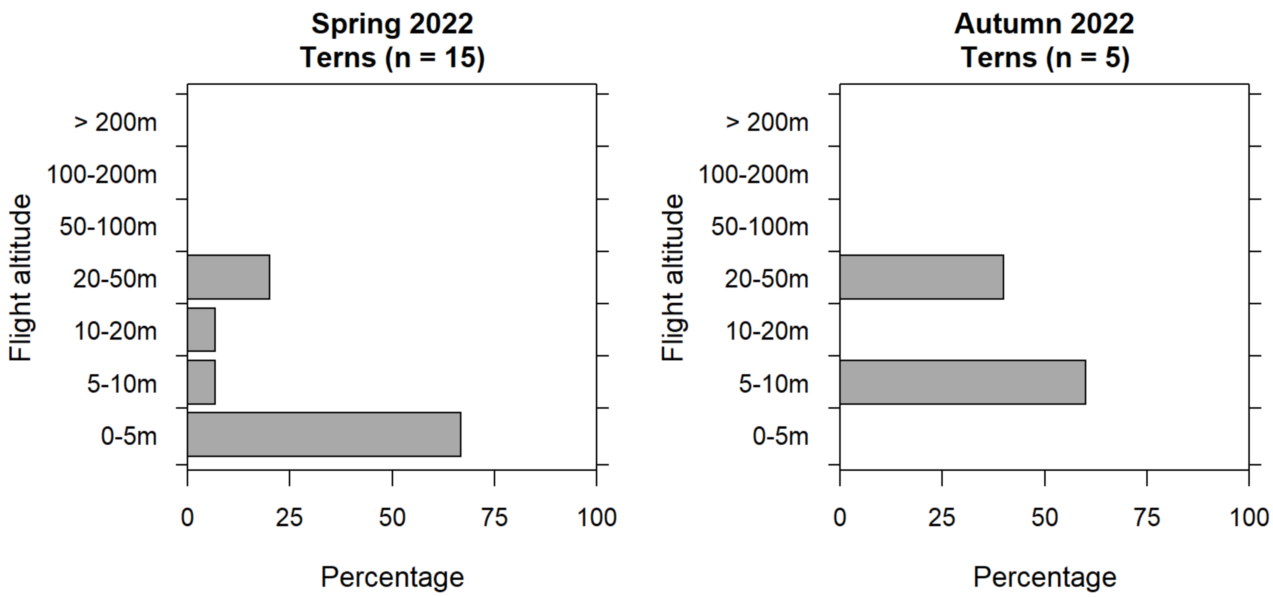


Figure 169. Flight altitude distribution of terns during visual observations in spring and autumn 2022 on Bornholm, Rønne.

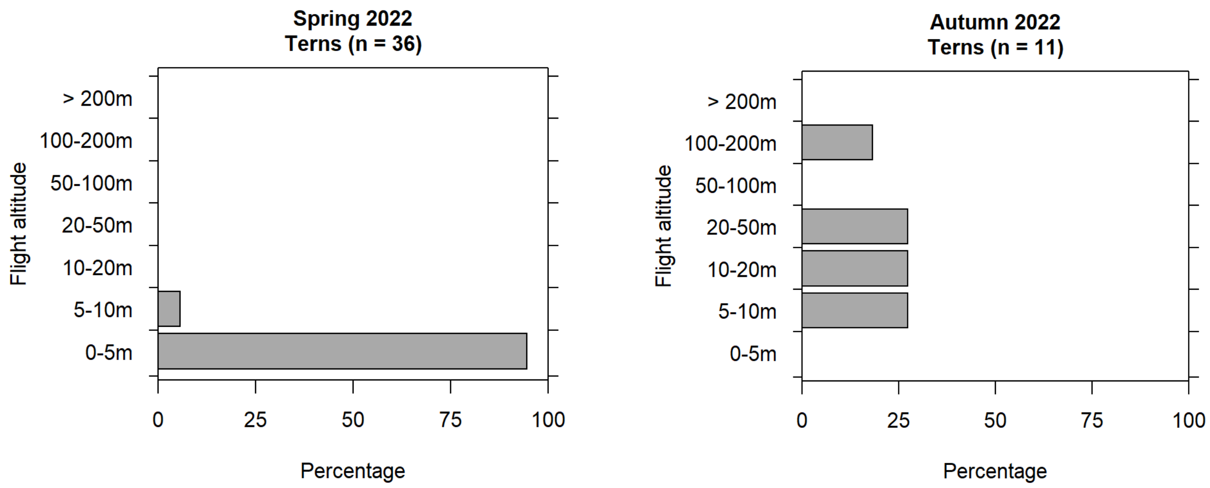


Figure 170. Flight altitude distribution of terns during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

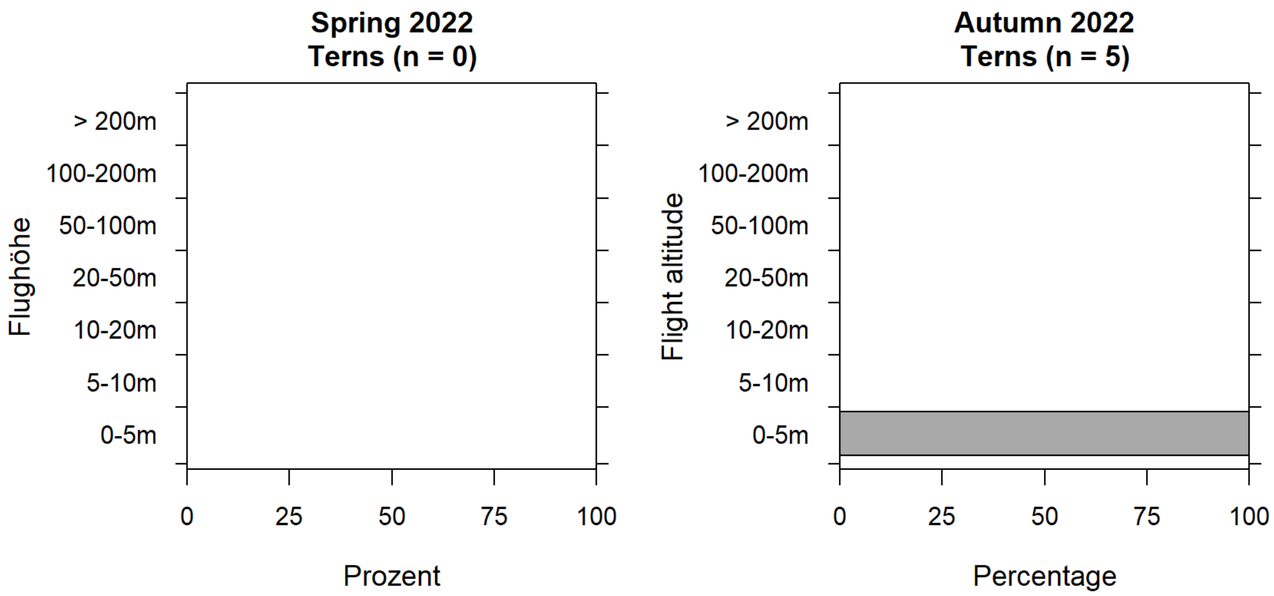


Figure 171. Flight altitude distribution of terns during visual observations in spring and autumn 2022 from vessel-based surveys.

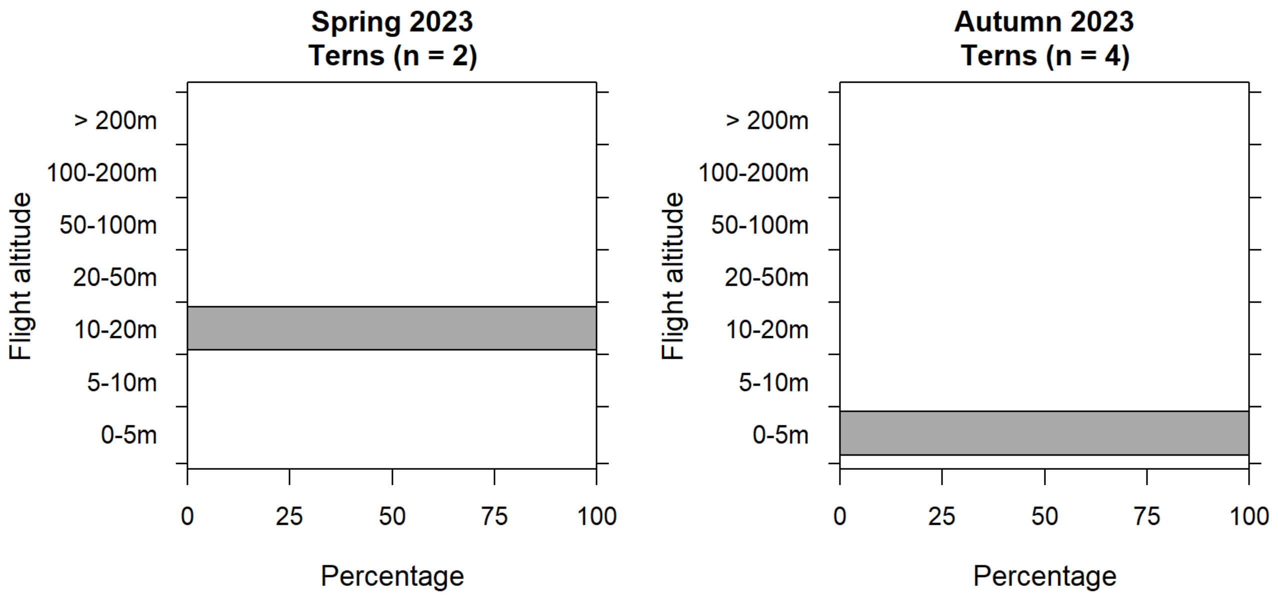


Figure 172. Flight altitude distribution of terns during visual observations in spring and autumn 2023 on Bornholm, Rønne.

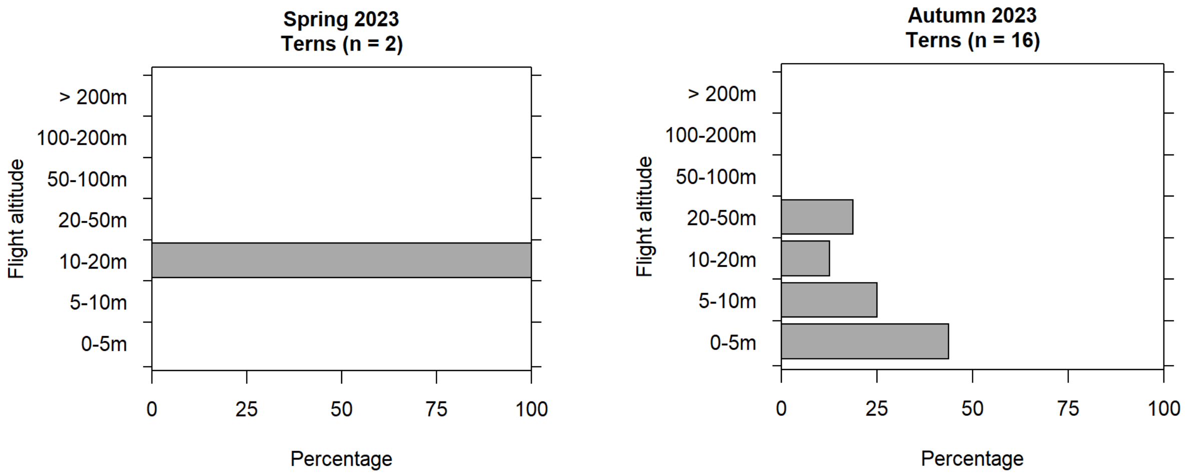


Figure 173. Flight altitude distribution of terns during visual observations in spring 2023 from vessel-based surveys (left) and in autumn 2023 on Bornholm, Nexø (right).

FLIGHT DIRECTIONS

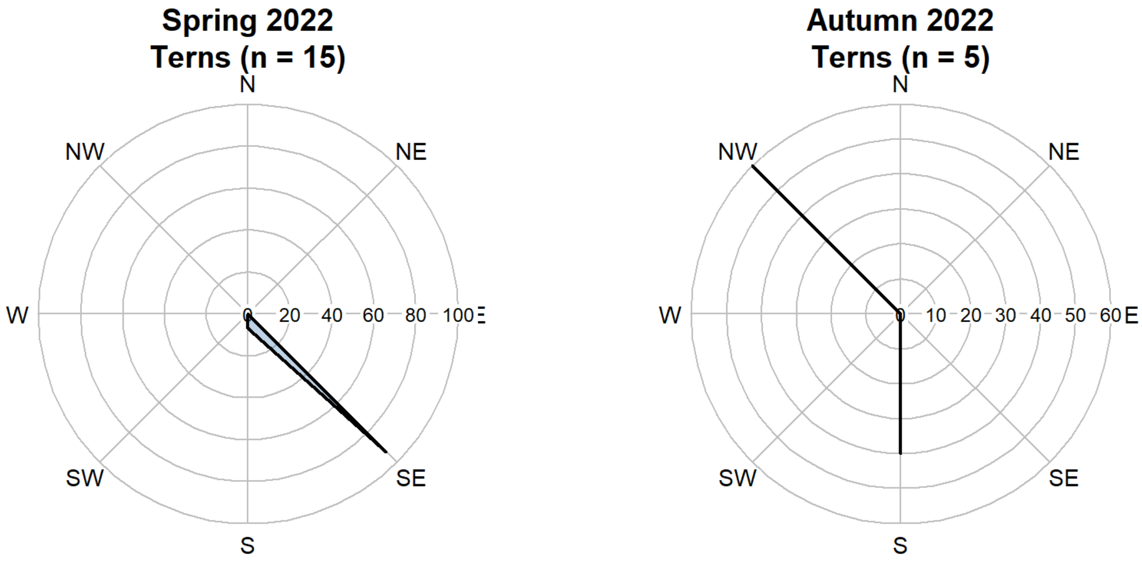


Figure 174. Flight directions of terns during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

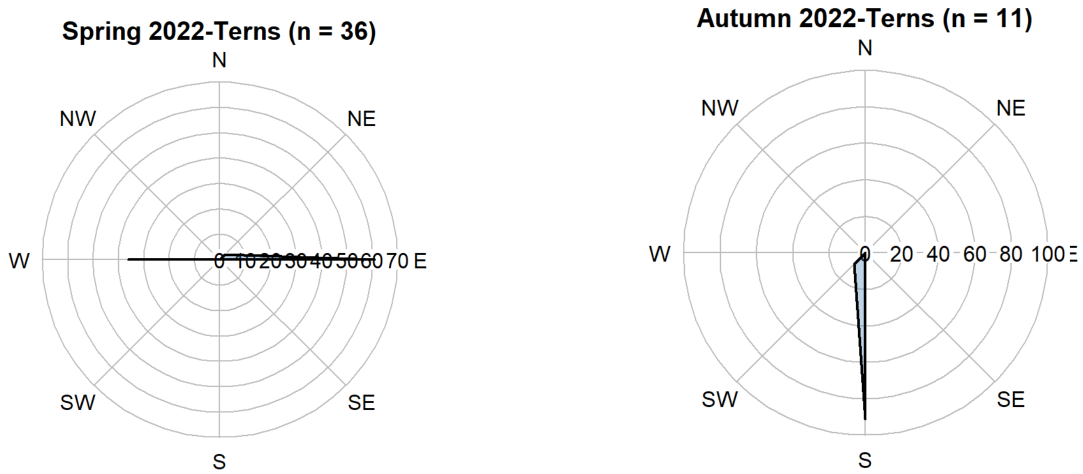


Figure 175. Flight directions of terns during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

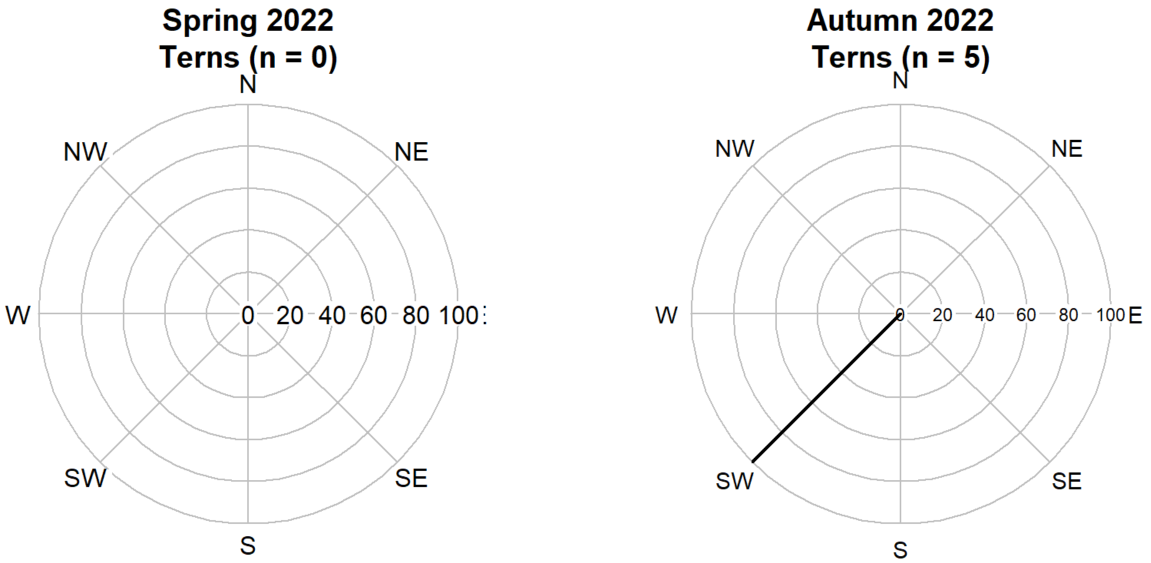


Figure 176. Flight directions of terns during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

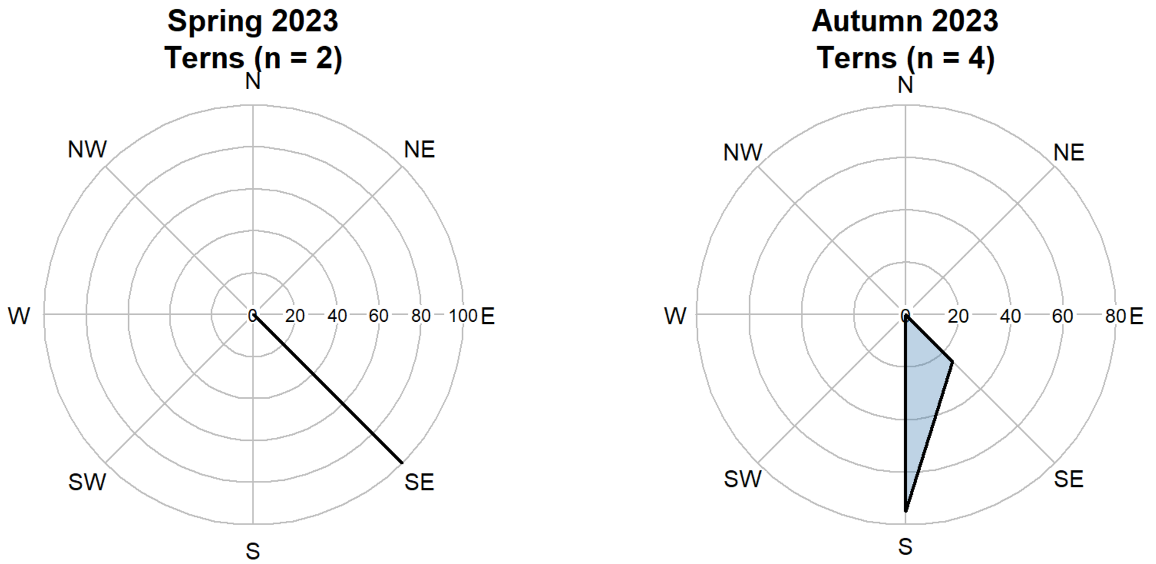
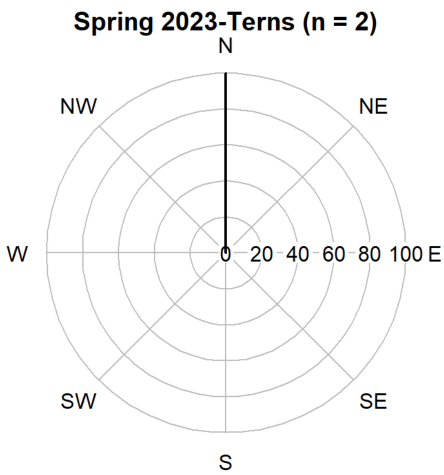


Figure 177. Flight directions of terns during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.



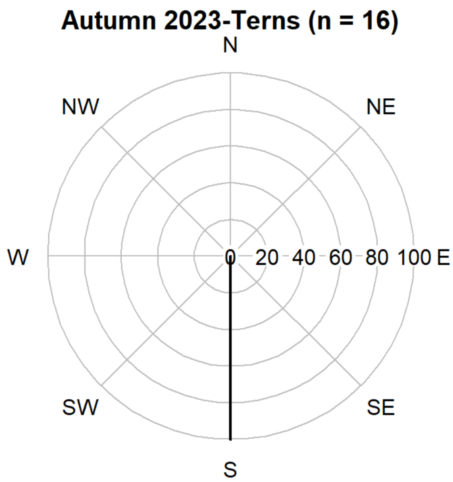
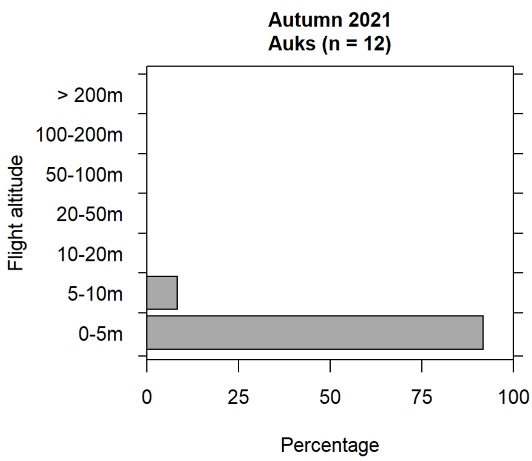


Figure 178. Flight directions of terns during daytime in spring 2023 from vessel-based surveys (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

AUKS

FLIGHT ALTITUDES



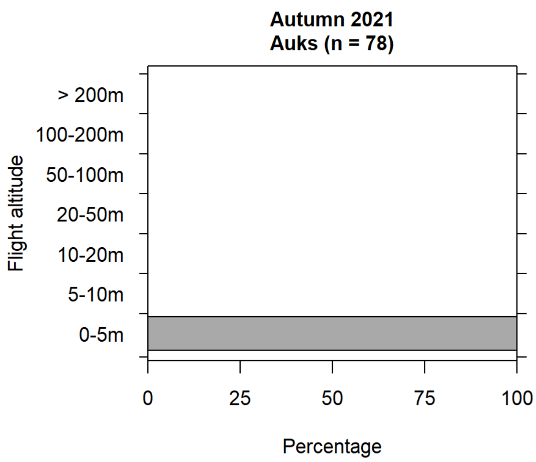


Figure 179. Flight altitude distribution of auks during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

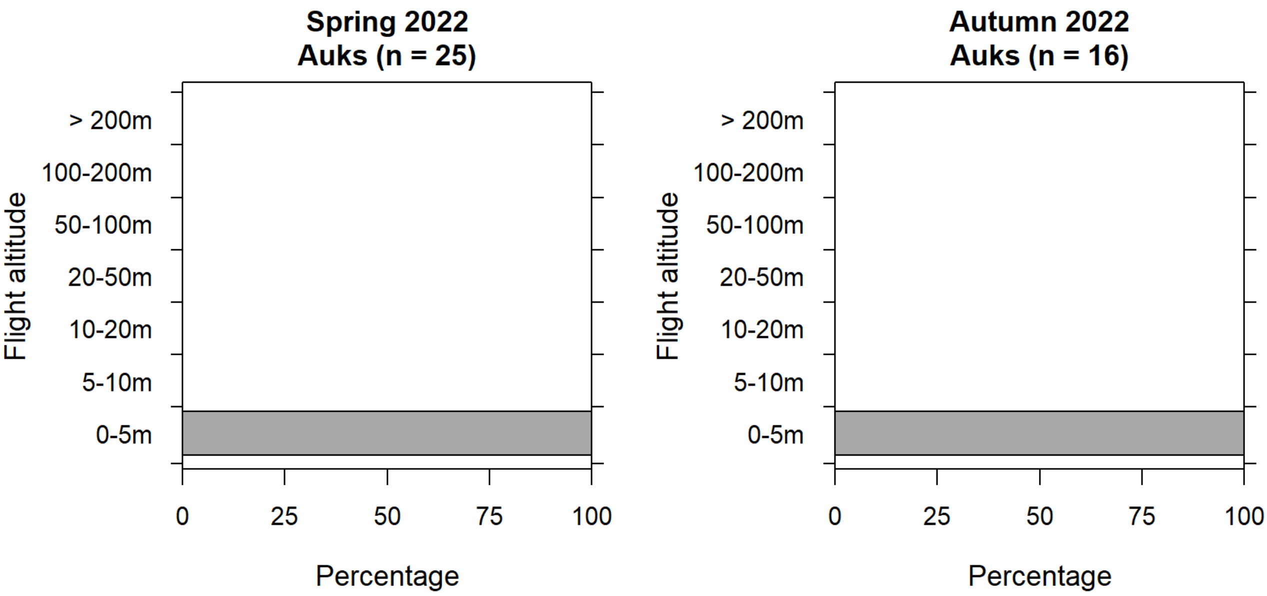


Figure 180. Flight altitude distribution of auks during visual observations in spring and autumn 2022 on Bornholm, Rønne.

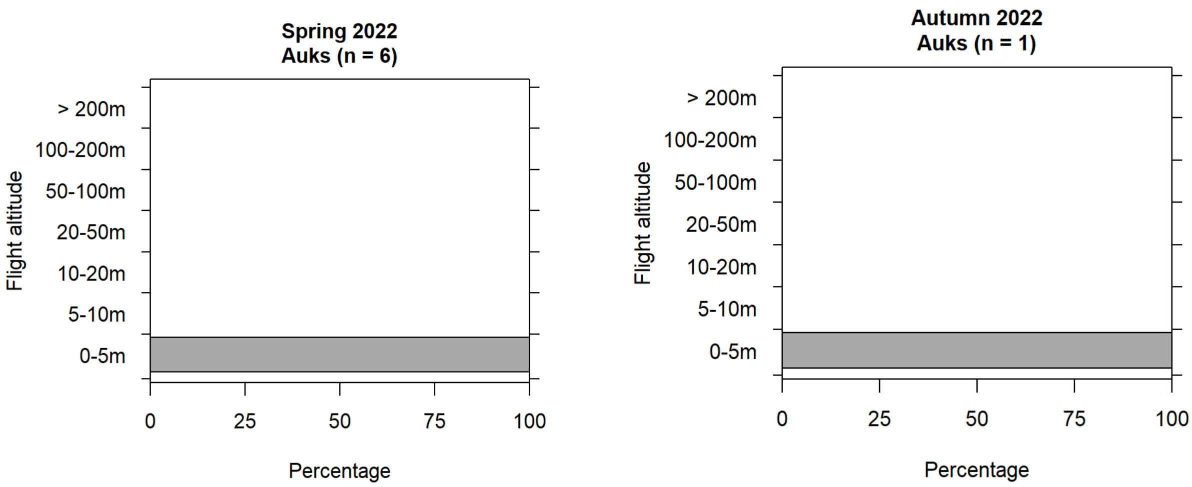


Figure 181. Flight altitude distribution of auks during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

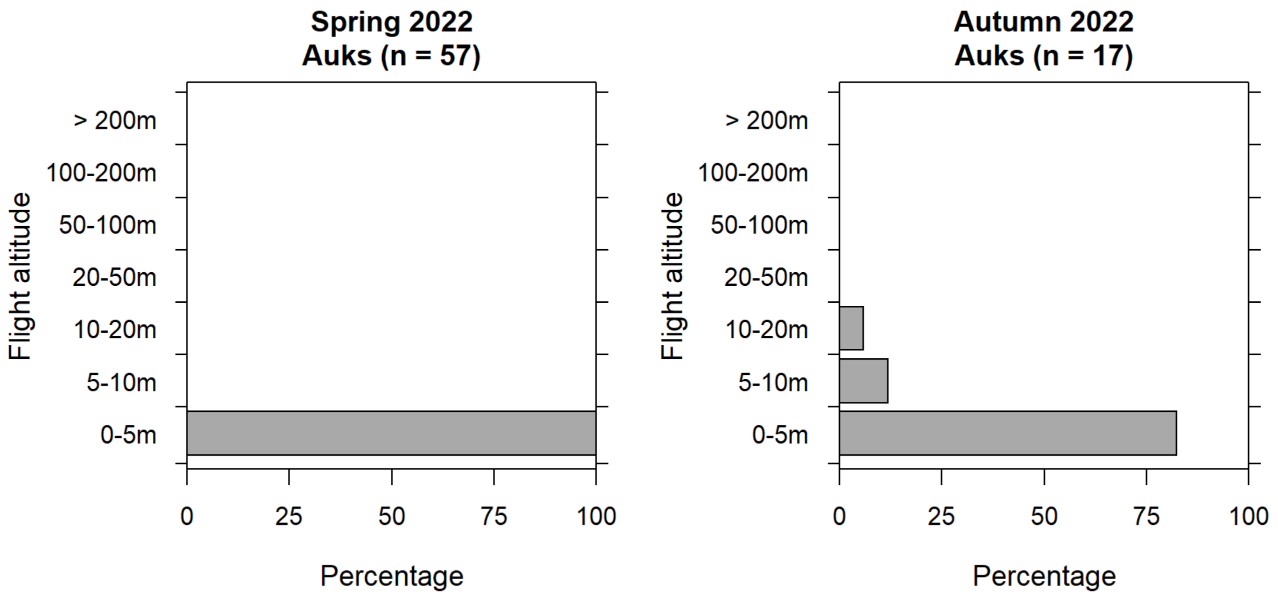


Figure 182. Flight altitude distribution of auks during visual observations in spring and autumn 2022 from vessel-based surveys.

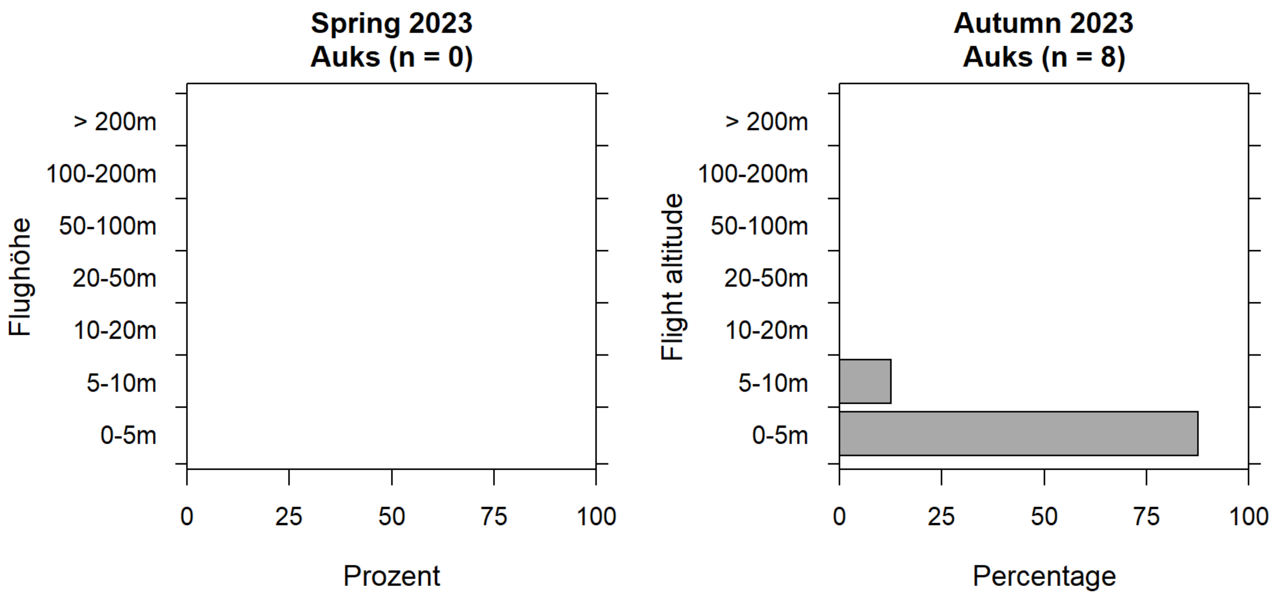
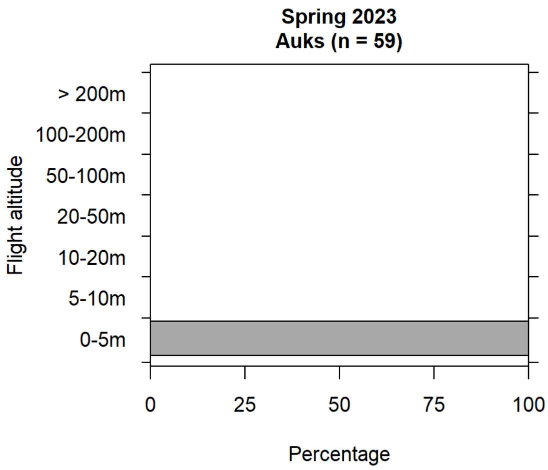


Figure 183. Flight altitude distribution of auks during visual observations in spring and autumn 2023 on Bornholm, Rønne.



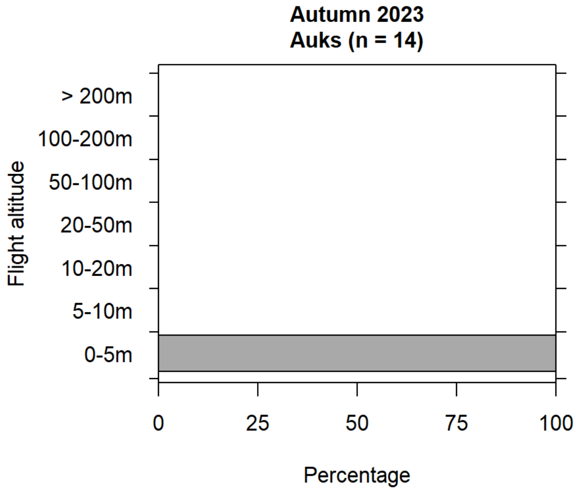
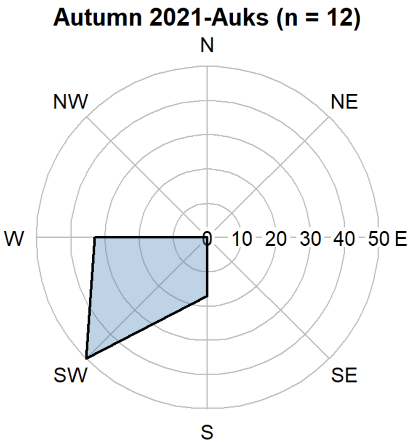


Figure 184. Flight altitude distribution of auks during visual observations in spring 2023 from vessel-based surveys (left) and in autumn 2023 on Bornholm, Nexø (right).

FLIGHT DIRECTIONS



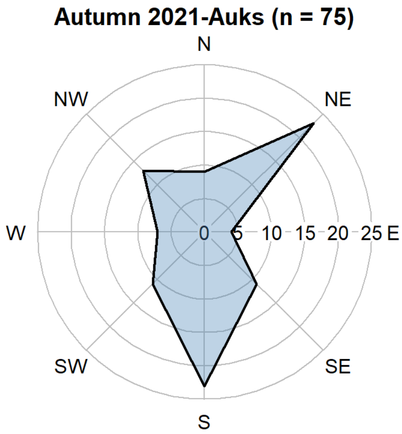


Figure 185. Flight directions of auks during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

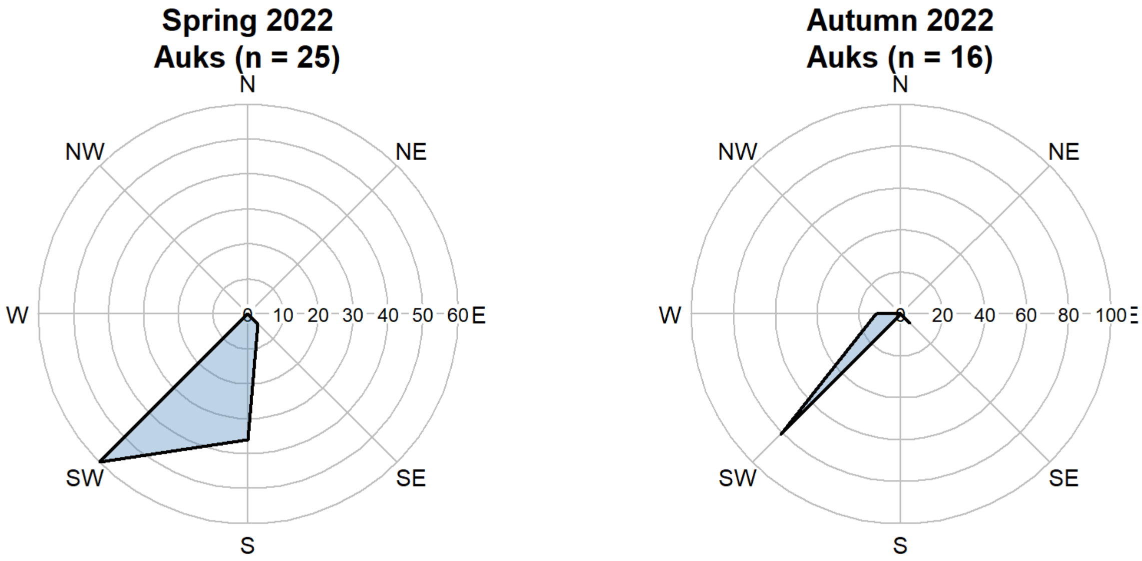


Figure 186. Flight directions of auks during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71.

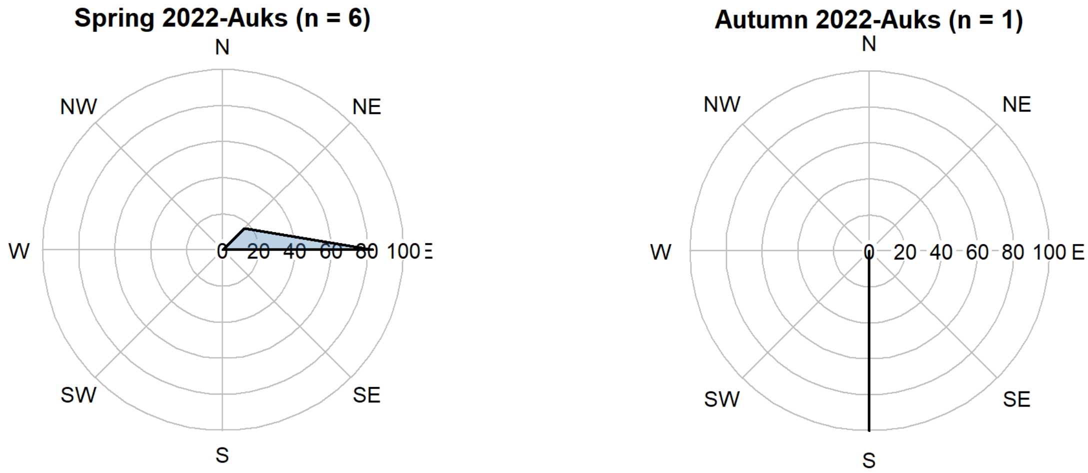


Figure 187. Flight directions of auks during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

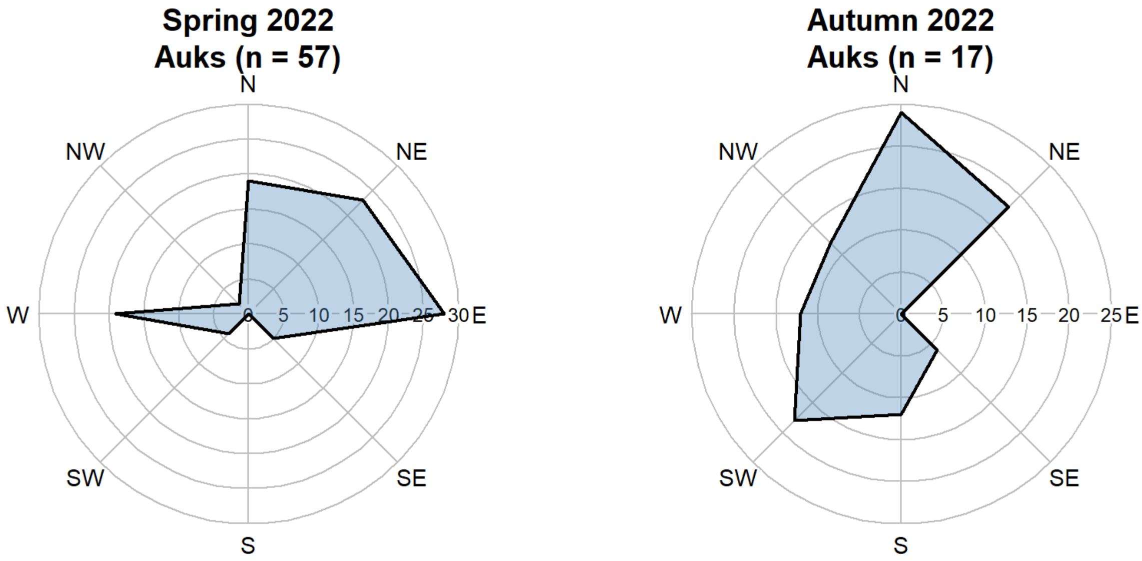


Figure 188. Flight directions of auks during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 71.

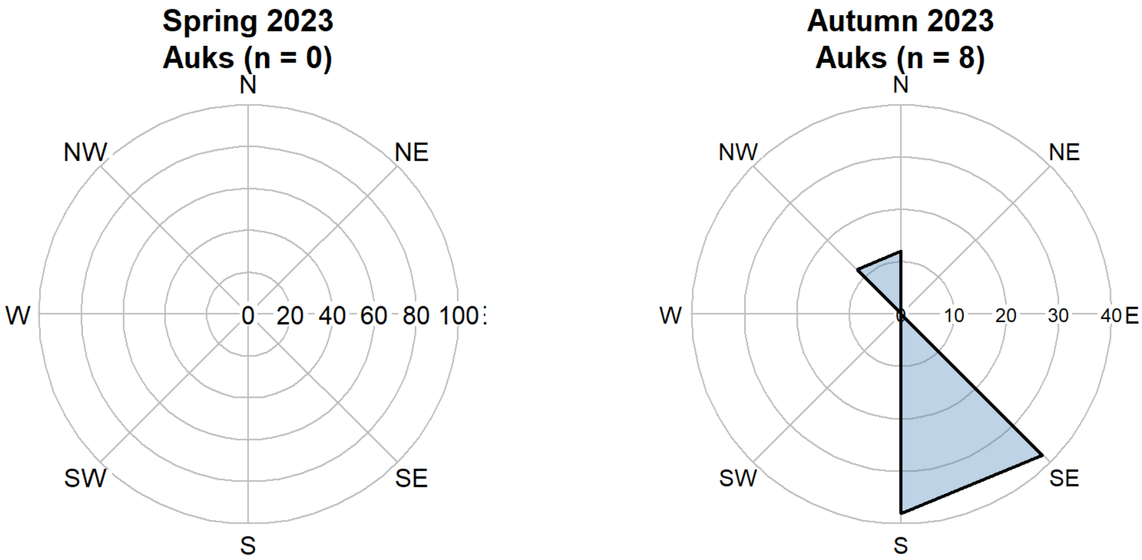
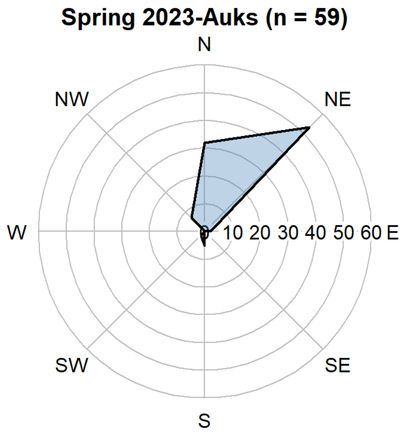


Figure 189. Flight directions of auks during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 71.



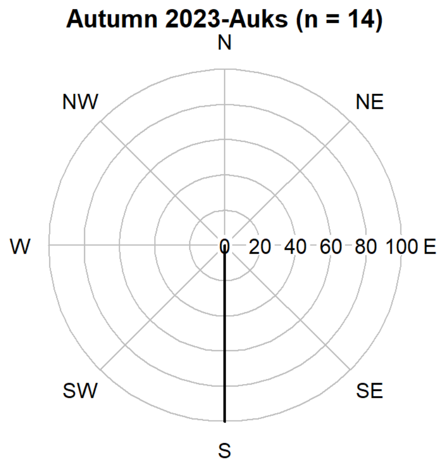
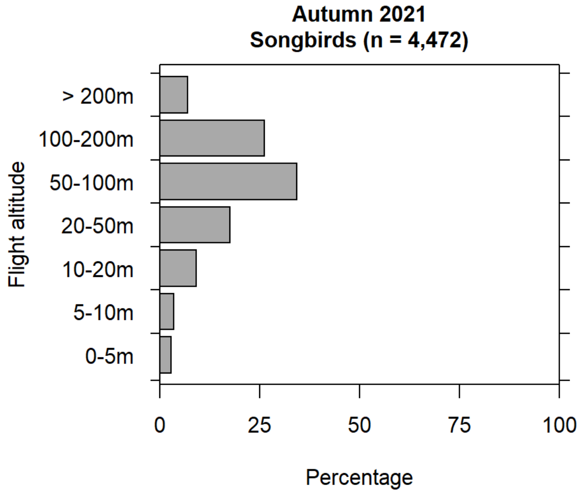


Figure 190. Flight directions of auks during daytime in spring 2023 from vessel-based surveys (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 71.

SONGBIRDS

FLIGHT ALTITUDES



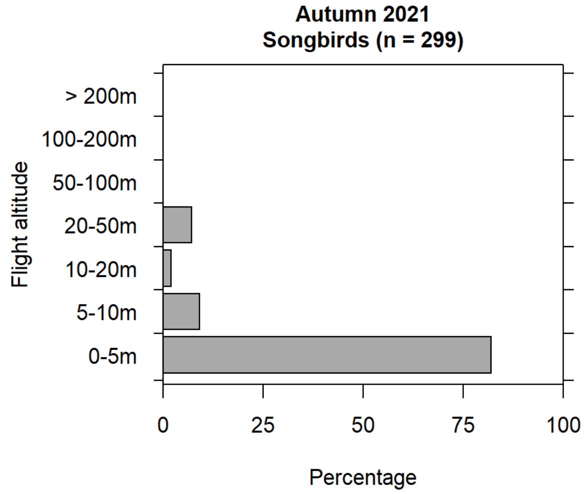


Figure 191. Flight altitude distribution of songbirds during visual observations in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right).

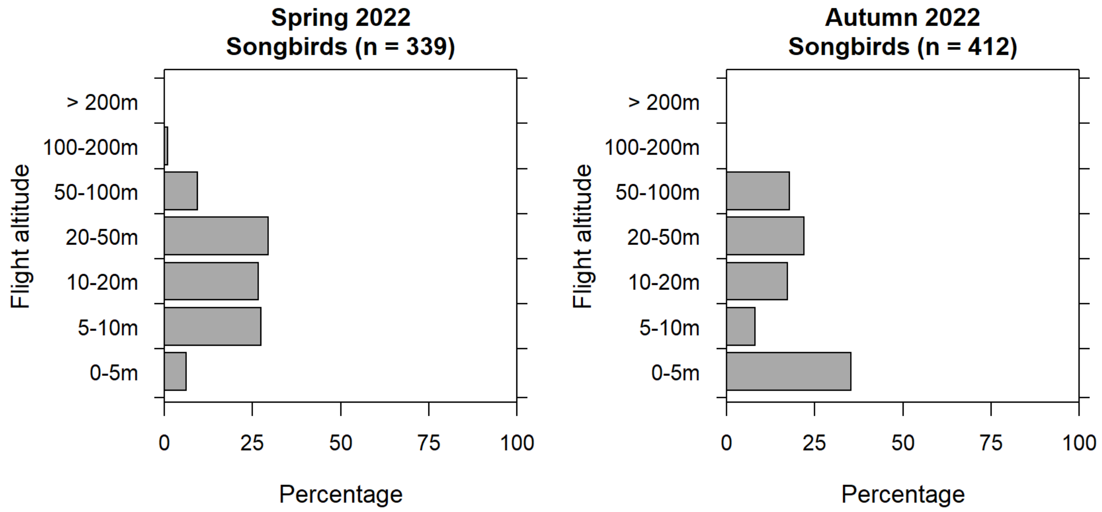


Figure 192. Flight altitude distribution of songbirds during visual observations in spring and autumn 2022 on Bornholm, Rønne.

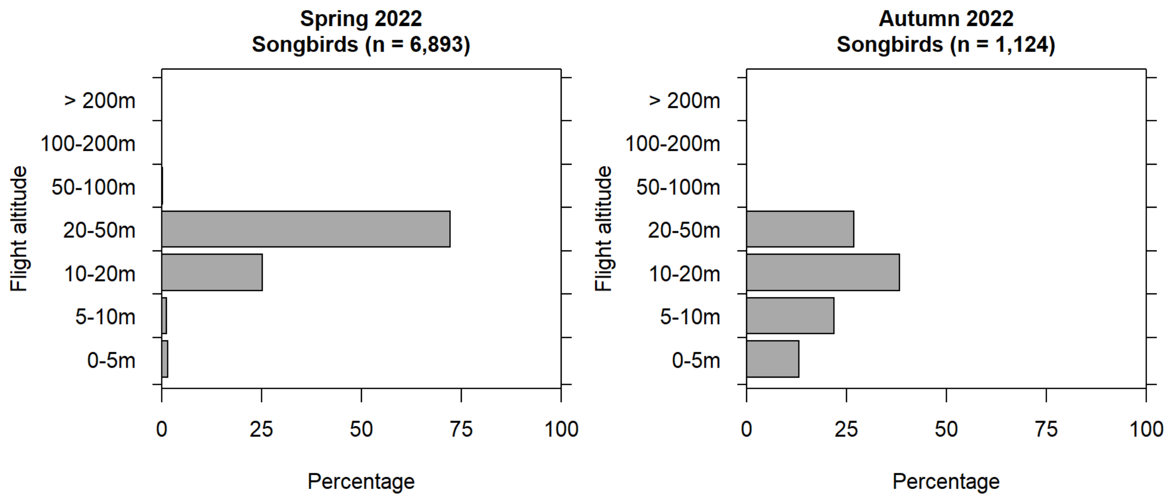


Figure 193. Flight altitude distribution of songbirds during visual observations in spring 2022 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

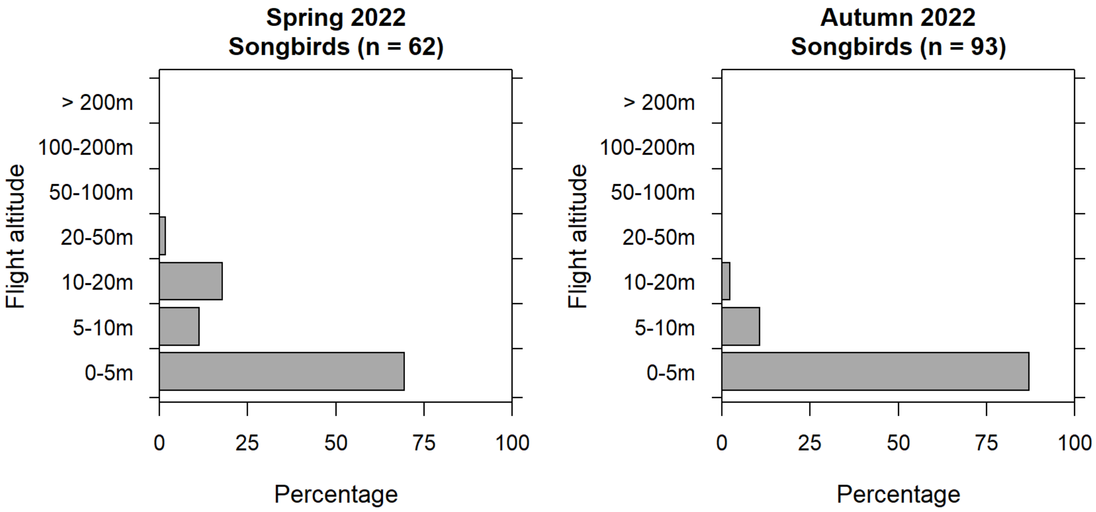


Figure 194. Flight altitude distribution of songbirds during visual observations in spring and autumn 2022 from vessel-based surveys.

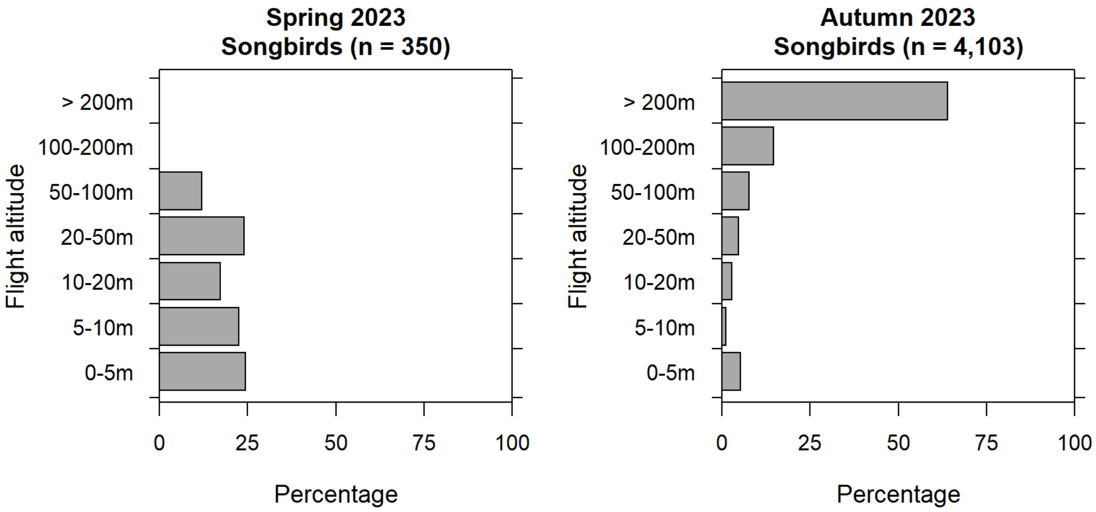


Figure 195. Flight altitude distribution of songbirds during visual observations in spring and autumn 2023 on Bornholm, Rønne.

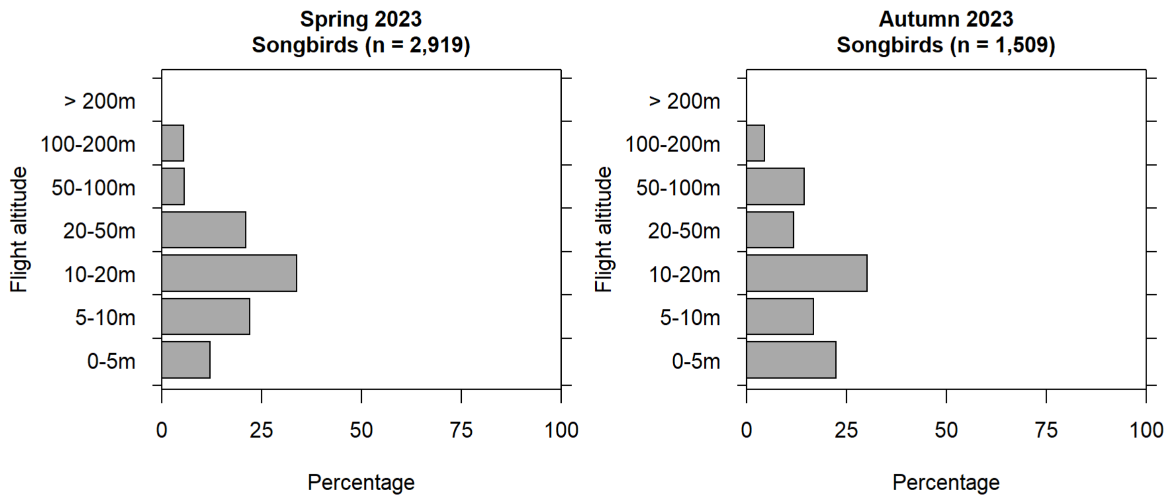


Figure 196. Flight altitude distribution of songbirds during visual observations in spring 2023 at Rügen (left) and in autumn 2022 on Bornholm, Nexø (right).

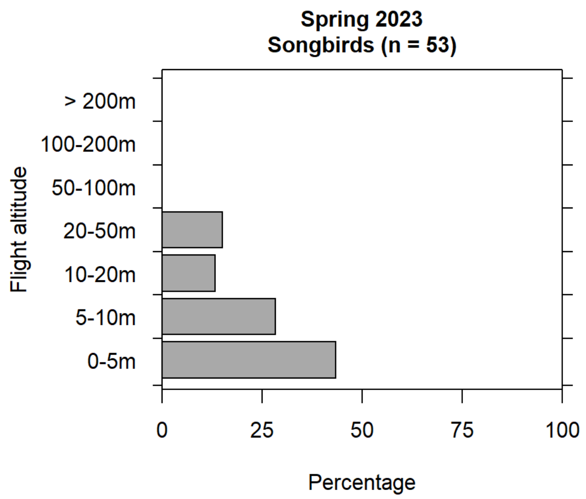


Figure 197. Flight altitude distribution of songbirds during visual observations in spring 2023 from vessel-based surveys.

FLIGHT DIRECTIONS

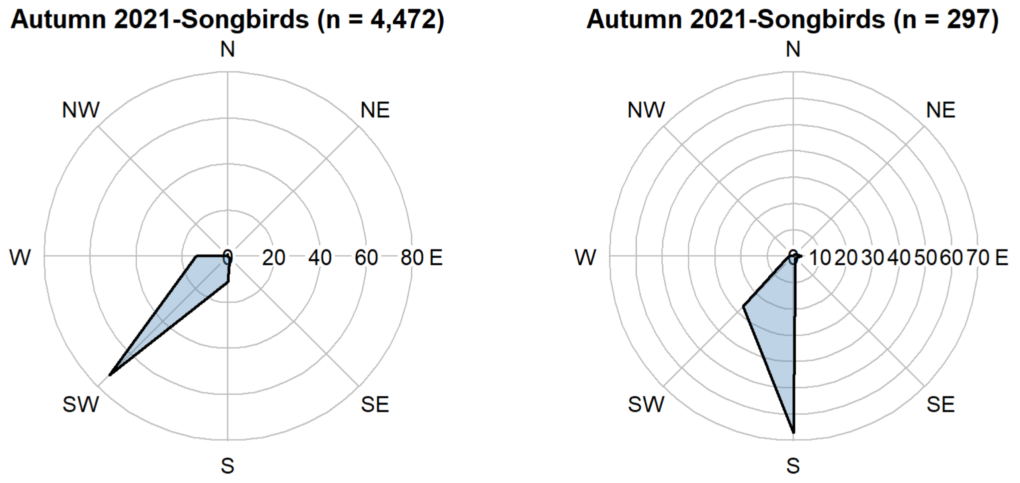


Figure 198. Flight directions of songbirds during daytime in autumn 2021 on Bornholm, Rønne (left) and from vessel-based surveys (right). For more details refer to the description of Figure 71.

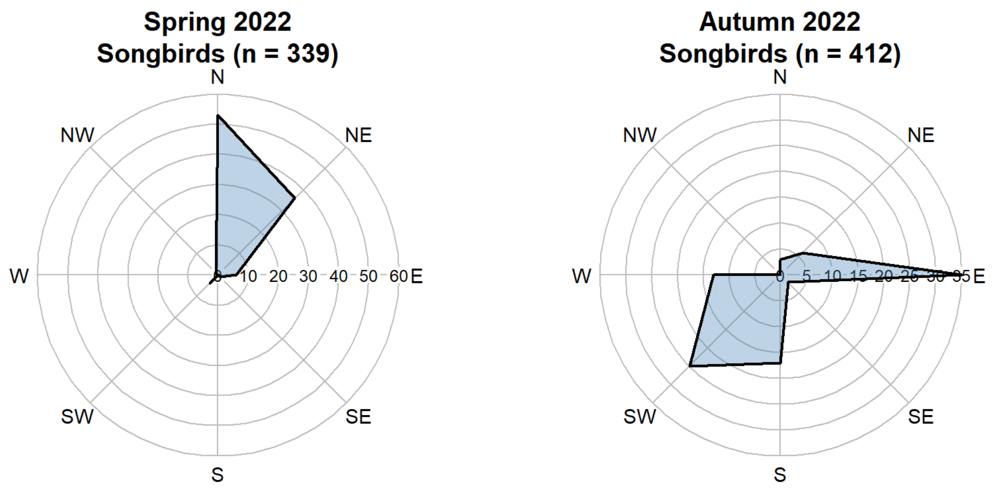


Figure 199. Flight directions of songbirds during daytime in spring and autumn 2022 on Bornholm, Rønne. For more details refer to the description of Figure 71

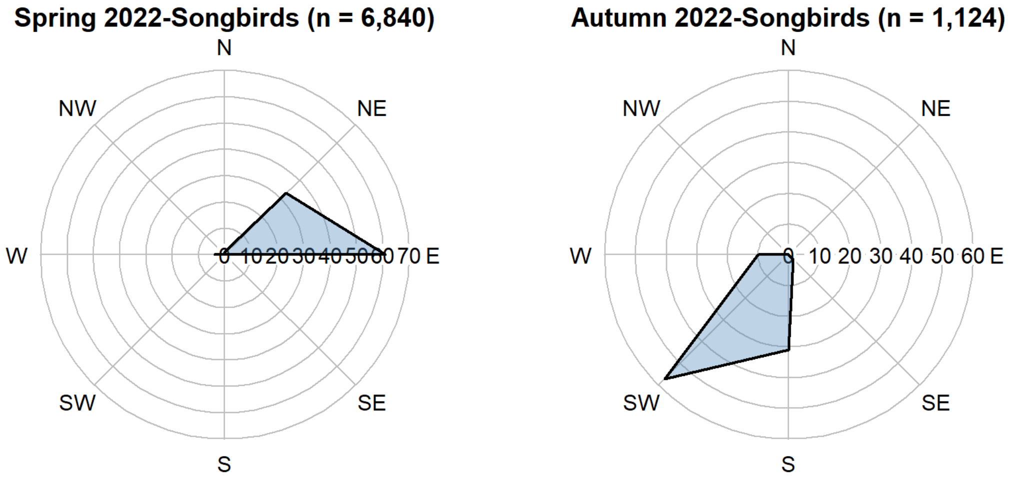


Figure 200. Flight directions of songbirds during daytime in spring 2022 at Rügen (left) and on Bornholm, Nexø in autumn 2022 (right). For more details refer to the description of Figure 71.

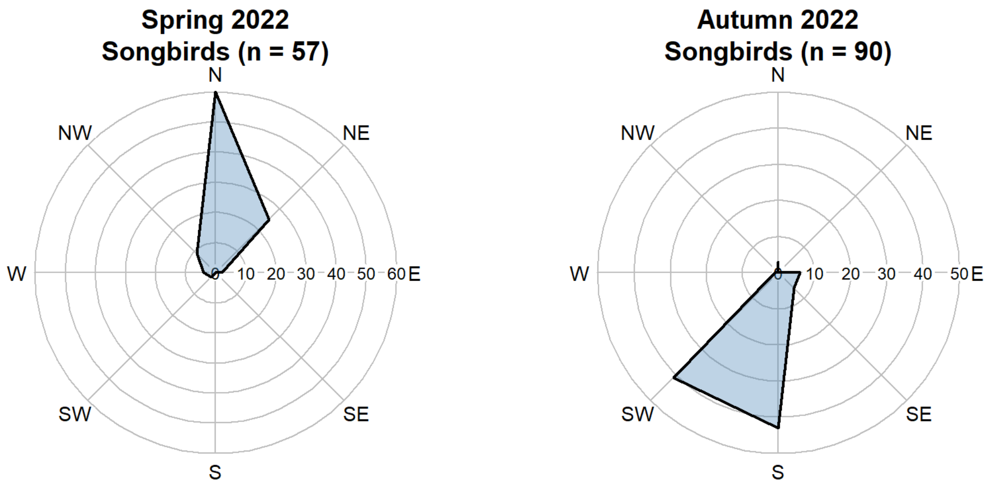


Figure 201. Flight directions of songbirds during daytime in spring and autumn 2022 from vessel-based surveys. For more details refer to the description of Figure 69.

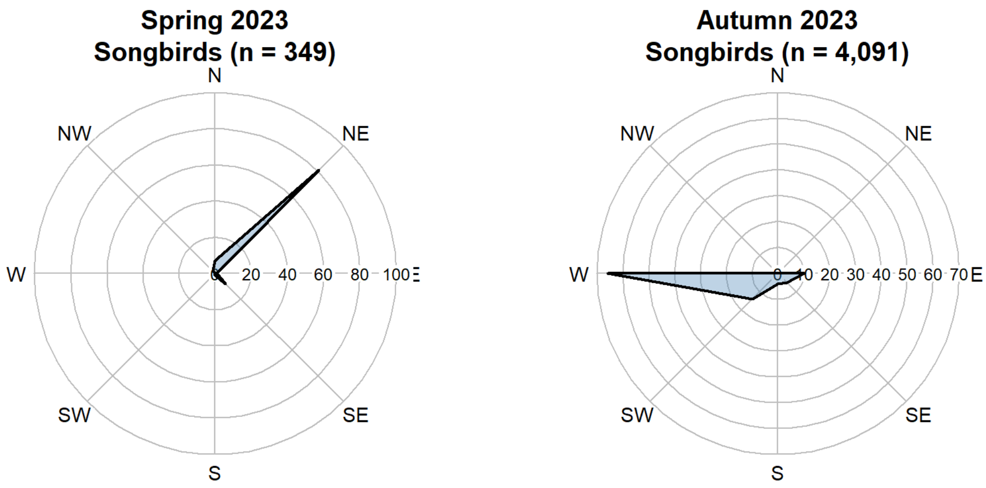


Figure 202. Flight directions of songbirds during daytime in spring and autumn 2023 from Bornholm, Rønne. For more details refer to the description of Figure 69

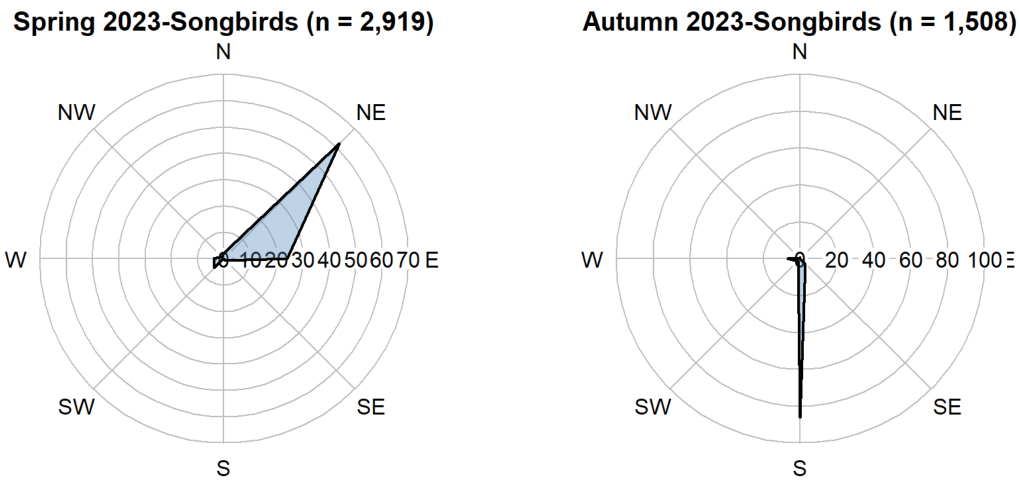


Figure 203. Flight directions of songbirds during daytime in spring 2023 at Rügen (left) and on Bornholm, Nexø in autumn 2023 (right). For more details refer to the description of Figure 69

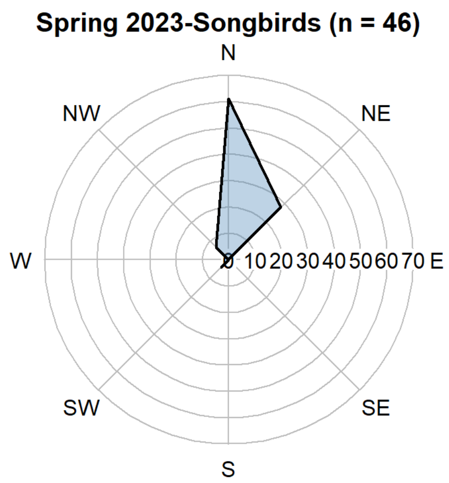


Figure 204. Flight directions of songbirds during daytime in spring 2023 from vessel-based surveys. For more details refer to the description of Figure 71

DIURNAL MIGRATION INTENSITY – VERTICAL RADAR OFFSHORE

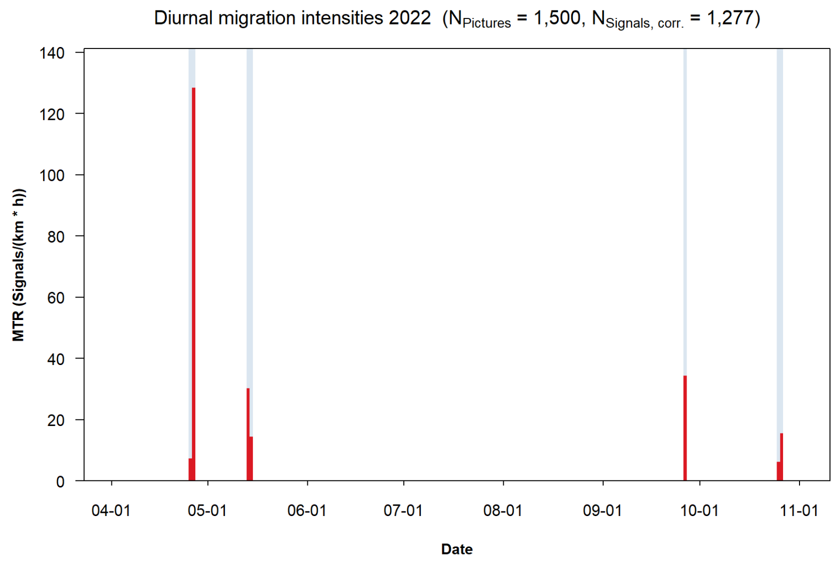


Figure 205. **Diurnal migration intensity in spring and autumn 2022 based on daily migration traffic rates (MTR) calculated from the vertical radar at an offshore location. MTR is specified as radar signals per km and hour (up to 1,000 m altitude). Areas highlighted in light grey indicate the survey days.**

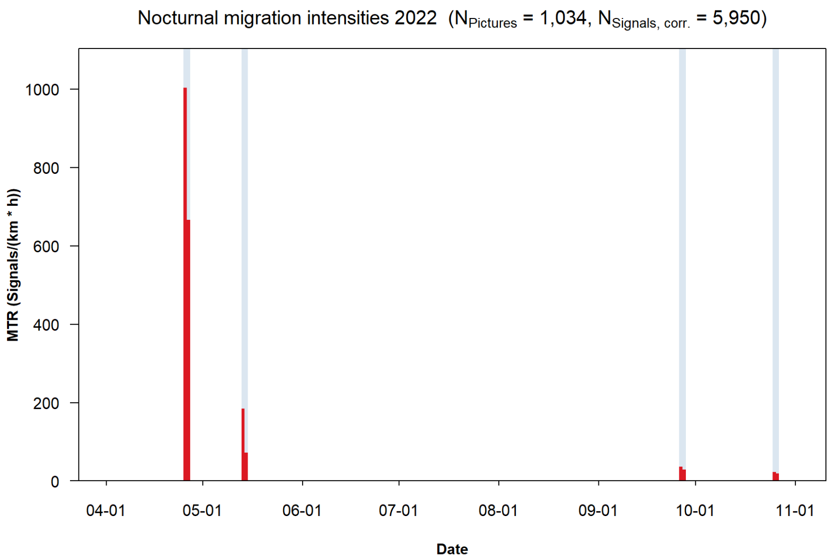


Figure 206. Nocturnal migration intensity in spring and autumn 2022 based on daily migration traffic rates (MTR) calculated from the vertical radar at an offshore location. Note the different y-axis scale, when comparing with diurnal migration intensity.

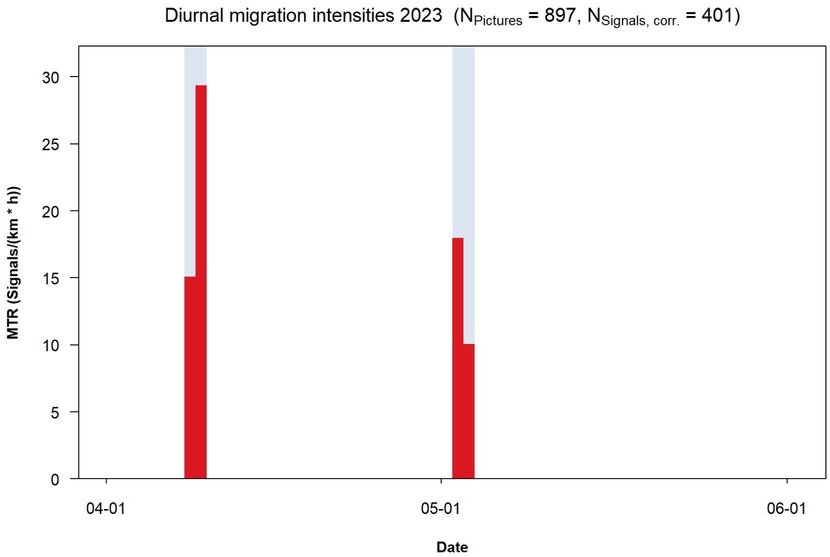


Figure 207. Diurnal migration intensity in spring 2023 based on daily migration traffic rates (MTR) calculated from the vertical radar at an offshore location. Note the different y-axis scale, when comparing with nocturnal migration intensity.

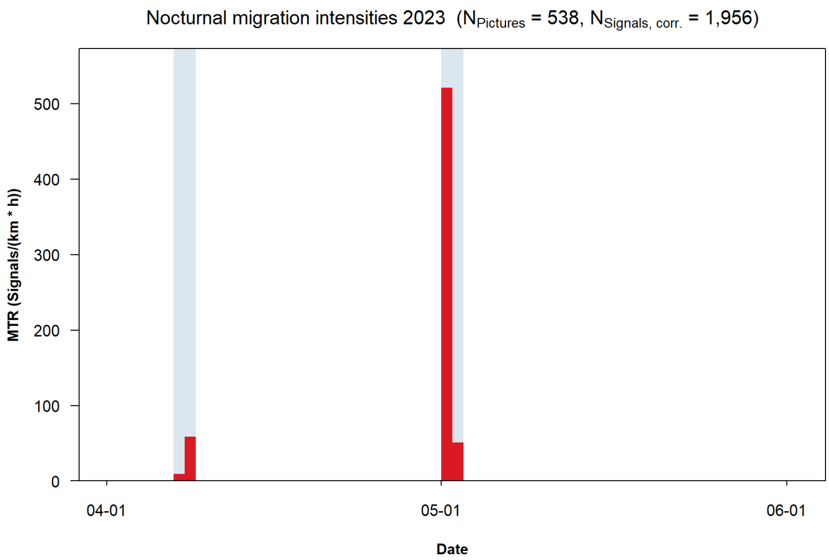


Figure 208. Nocturnal migration intensity in spring 2023 based on daily migration traffic rates (MTR) calculated from the vertical radar at an offshore location. Note the different y-axis scale, when comparing with diurnal migration intensity.

MONTHLY AND SEASONAL MIGRATION INTENSITY – VERTICAL RADAR

Table 28. Monthly and seasonal migration rates obtained from vertical radar data at the offshore location in 2022 and 2023. MTR: migration traffic rate, signals/(km*h).

Year	Diurnal migration			Nocturnal migration		
	MTR mean	MTR median	MTR maximum	MTR mean	MTR median	MTR maximum
			2022			
April	67.89	67.89	128.44	834.92	834.92	1,003.49
May	22.33	22.33	30.24	128.31	128.31	184.72
Spring total	45.11	22.33	128.44	481.61	425.53	1003.49
September	34.32	34.32	34.32	32.84	32.84	36.64
October	10.95	10.95	15.59	20.41	20.41	22.25
Autumn total	18.74	15.59	34.32	26.62	25.64	36.64
All Year	33.81	15.59	128.44	254.12	54.27	1003.49
			2023			
April	22.23	22.23	29.36	33.91	33.91	58.69
May	14.02	14.02	17.97	286.04	286.04	520.92
Spring total	18.13	16.53	29.36	159.97	54.93	520.92

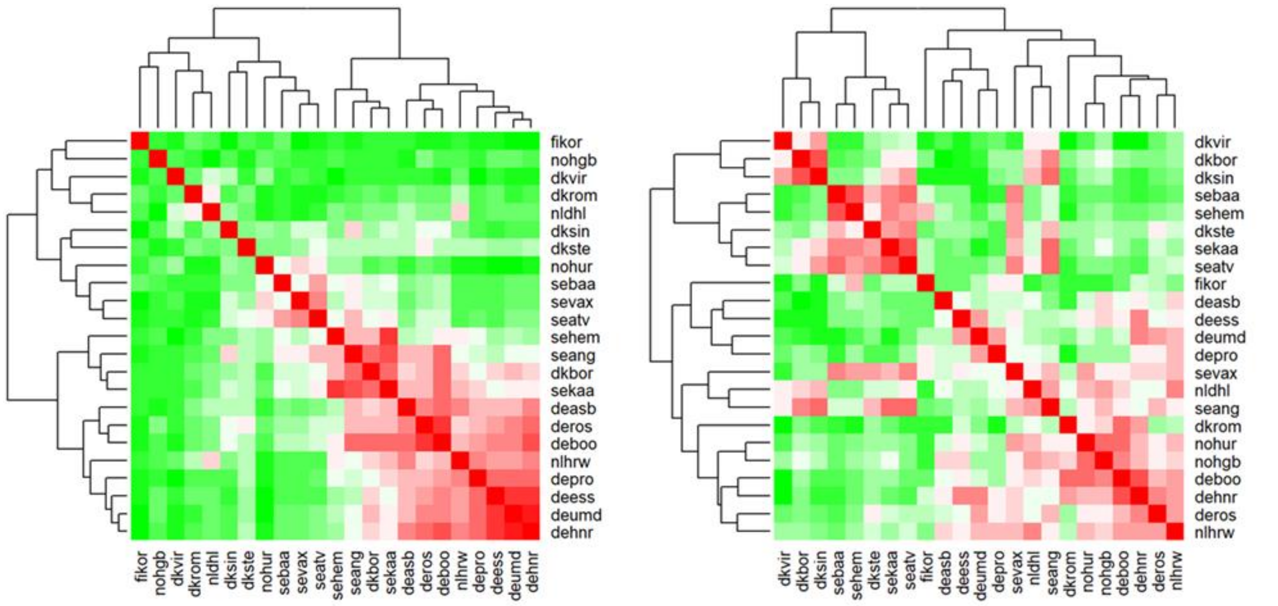


Figure 209. Correlation plot of median MTR values per night for night migration between all radars in the region for spring (left panel) and autumn 2020 (right panel).

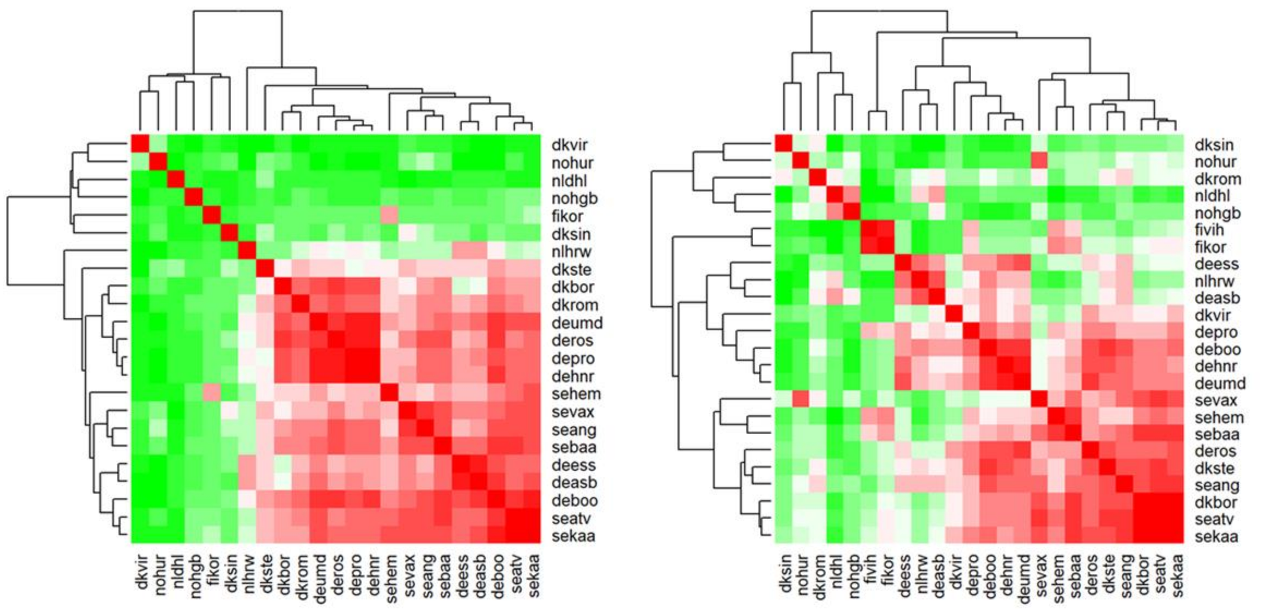


Figure 210. Correlation plot of median MTR values per night for night migration between all radars in the region for spring (left panel) and autumn 2021 (right panel).

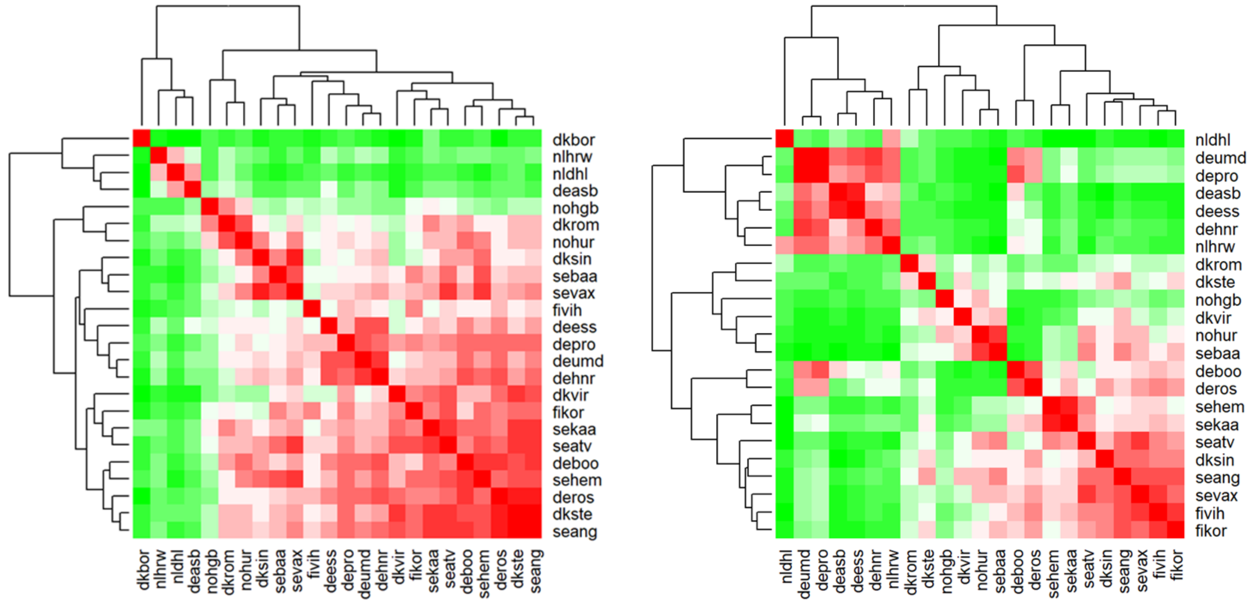


Figure 211. Correlation plot of median MTR values per night for night migration between all radars in the region for spring 2022 (left panel) and spring 2023 (right panel).

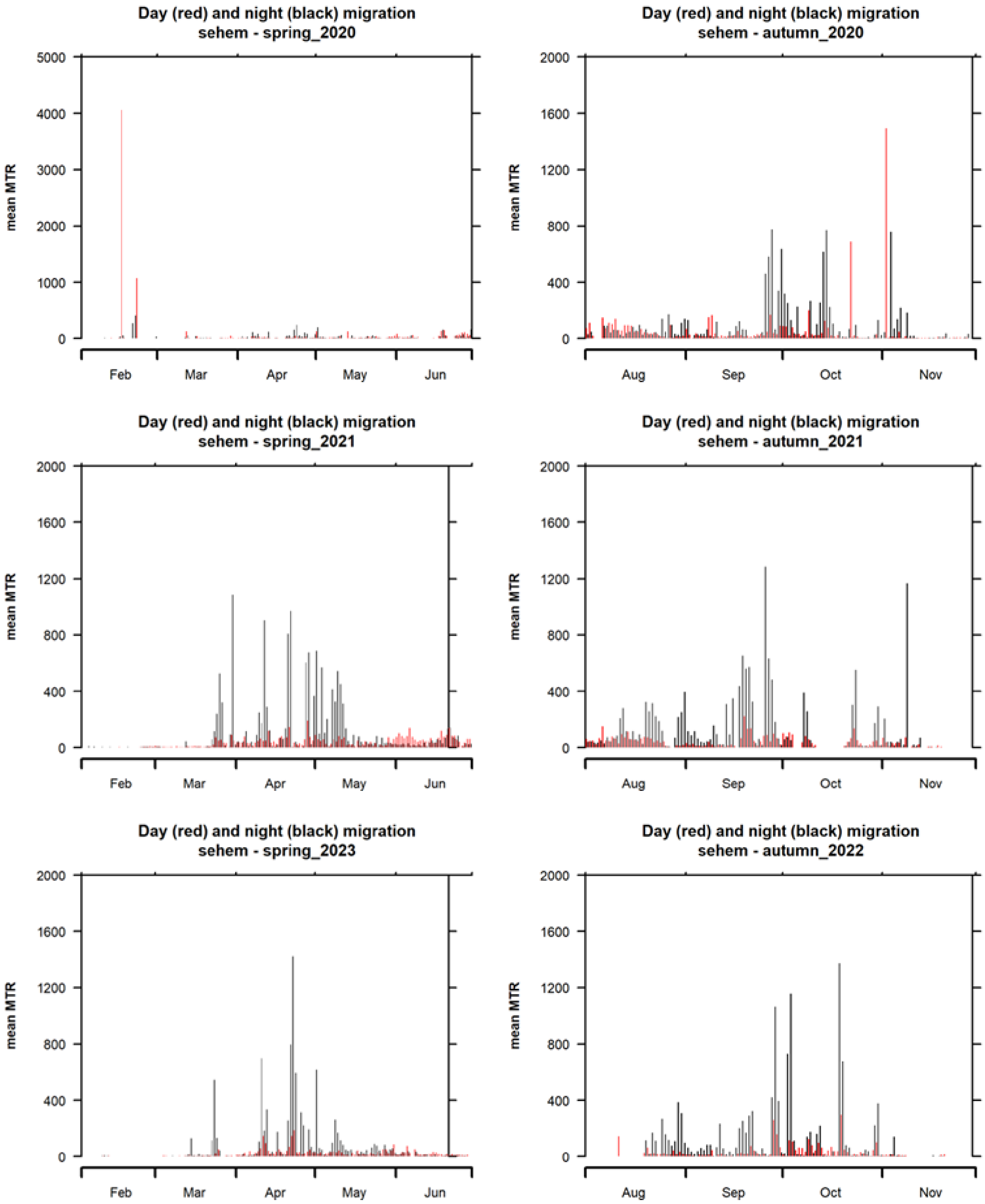


Figure 212. Seasonal dynamics of day (red) and night (black) migration at weather radar station sehem, Gotland, Sweden.

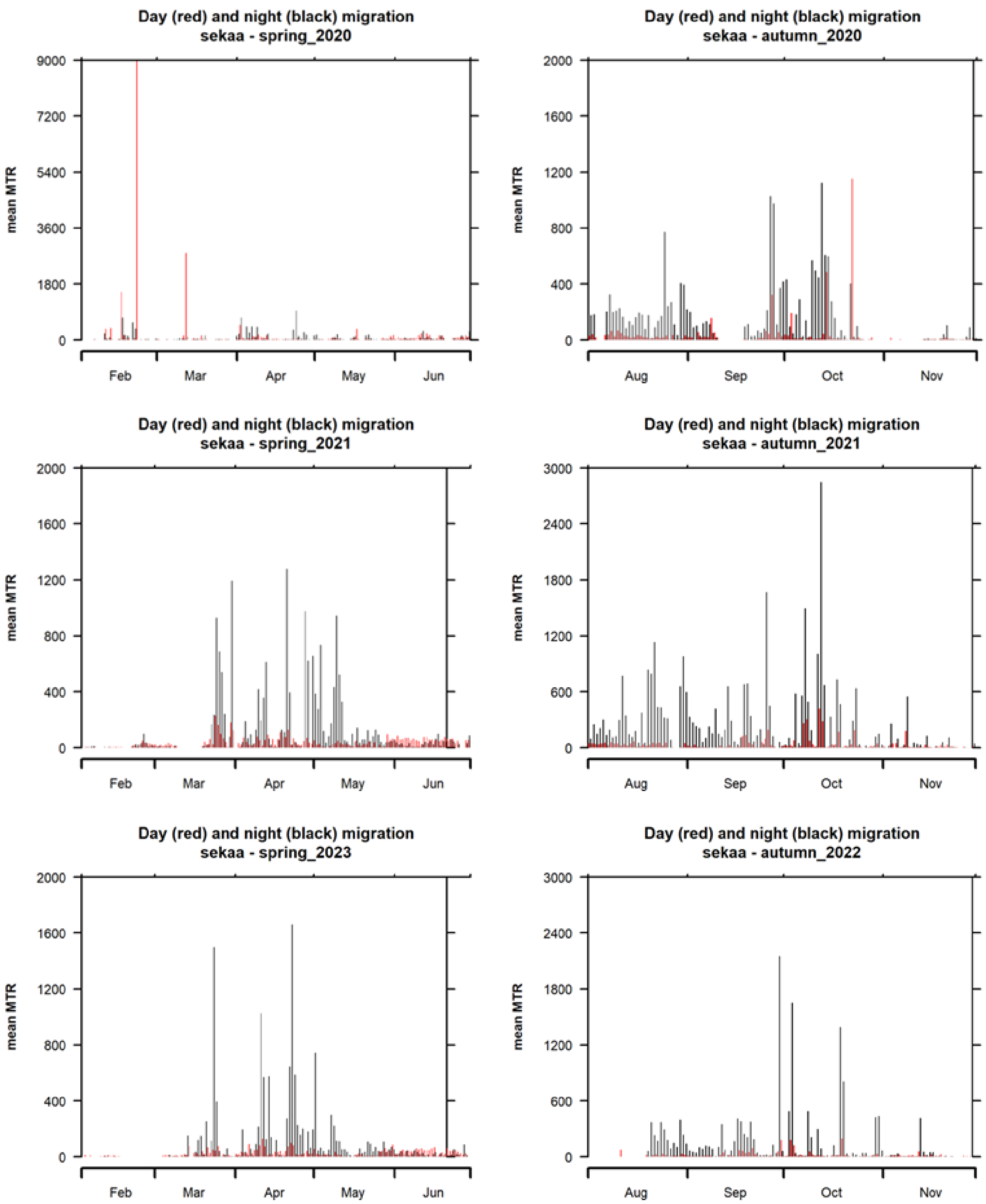


Figure 213. Seasonal dynamics of day (red) and night (black) migration at weather radar station sekaa, Karlskrona, Sweden.

Table 29. Statistics on mean daily traffic rate (MTR) of daytime bird migration in spring at selected weather radar stations. For each year and station MTR values of three days with maximal peaks are listed (starting from highest), followed by the mean MTR value for the season and a number of observations (amount of days/number of radar working cycles per season). In red are values that should be excluded from the analysis.

year	parameter	dkbor	sehem	sekaa
2020	max peaks	24 - 18 - 14	4,057 – 1,072 - 146	8,973 – 2,796 – 1,543
	mean	3.5	56.9	141.6

	n observations	145/25,611	138/7884	145/8,353
2021	max peaks	50 - 45 - 36	192 - 145 - 140	232 - 181 - 161
	mean	8.6	36.6	39.4
	n observations	147/26,366	149/25,091	137/22,234
2023	max peaks		189 - 149 - 148	128 - 100 - 91
	mean		22.8	28.3
	n observations		131/24,486	131/24,431

Table 30. Statistics on mean nightly traffic rate (MTR) of nighttime bird migration in spring at selected weather radar stations. For each year and station MTR values of three days with maximal peaks are listed (starting from highest), followed by the mean MTR value for the season and a number of observations (amount of days/number of radar working cycles per season). In red are values that should be excluded from the analysis.

year	parameter	dkbor	sehem	sekaa
2020	max	235 - 203 - 95	411 - 266 - 240	945 - 718 - 715
	mean	11.8	27.5	80
	n observations	144/14422	134/4301	143/4539
2021	max	235 - 191 - 189	1088 - 969 - 905	1277 - 1194 - 975
	mean	18.5	96.7	129.1
	n observations	146/15102	148/11846	134/10421
2023	max		1423 - 796 - 698	1663 - 1498 - 1028
	mean		72.9	107.7
	n observations		128/11993	127/11876

Table 31. Statistics on mean daily traffic rate (MTR) of daytime bird migration in autumn at selected weather radar stations. For each year and station MTR values of three days with maximal peaks are listed (starting from highest), followed by the mean MTR value for the season and a number of observations (amount of days/number of radar working cycles per season). In red are values that should be excluded from the analysis.

year	parameter	dkbor	sehem	sekaa
2020	max	16 - 15 - 10	1496 - 688 - 203	1153 - 485 - 324
	mean	3.8	54	39.6
	n observations	114/16301	119/5864	102/4890
2021	max	45 - 43 - 42	222 - 151 - 135	420 - 307 - 287
	mean	8.7	45.7	39.9
	n observations	121/16935	98/14754	121/17854
2022	max	78 - 66 - 55	298 - 260 - 160	194 - 177 - 177
	mean	14.4	33.7	21.5
	n observations	103/14657	97/14092	104/15004

Table 32. Statistics on mean nightly traffic rate (MTR) of nighttime bird migration in autumn at selected weather radar stations. For each year and station MTR values of three days with maximal peaks are listed (starting from highest), followed by the mean MTR value for the season and a number of observations (amount of days/number of radar working cycles per season). In red are values that should be excluded from the analysis.

year	parameter	dkbor	sehem	sekaa
2020	max	191 - 137 - 86	774 - 770 - 758	1125 - 1026 - 974
	mean	18.8	93.4	173.3
	n observations	113/14505	118/5074	96/4033
2021	max	331 - 219 - 188	1286 - 1169 - 654	2844 - 1671 - 1491
	mean	35	157.9	259.4
	n observations	120/14129	94/10330	120/14859
2022	max	286 - 168 - 151	1373 - 1156 - 1064	2150 - 1654 - 1389
	mean	28.3	127.9	156.7
	n observations	101/13960	95/12885	103/14317