Ålands landskapsregering

Planläggning och miljöbedömning av generalplan Sunnanvind

Bilaga 7. Underlagsutredning: Radar surveillance and visual observations of bird migration at Åland 2024

05-05-2025

Uppdragsinformation

Project name	Planläggning och miljöbedömning av generalplan Sunnanvind
Project number	10359887
Authors	Mikkel Friborg Mortensen, Rune Skjold Tjørnløv, Liv Sofie Dramshøj
Date	05-05-2025
Reviewed by	Erik Mandrup Jacobsen, Thomas Hultquist
Approved by	Jonas Sahlin

Client

Ålands landskapsregering

Consult

WSP

WSP Sverige AB

Org nr: 556057-4880

wsp.com

Contacts

Ålands landskapsregering
Ralf Häggblom, Energy Coordinator
ralf.haggblom@regeringen.ax
Tel: +358 18 25 000

WSP
Jonas Sahlin, Project Manager WSP
Jonas.sahlin@wsp.com
Tel: +46 010 722 88 09

Image on front page: Mikkel Friborg Mortensen och Rune Skjold Tjørnløv

All maps and photographs are produced by WSP.

Summary

Initiated by the government of Åland in 2021, the Sunnanvind project aims to explore the possibility of establishing a large-scale offshore wind farm consisting of up to 301 wind turbines, each with a maximum tip height of 350 meters, located approximately 15 km north of the Åland archipelago. The establishment of offshore windfarms requires careful consideration of potential impacts on migratory birds, including the risk of collision and barrier effect, potentially causing adjustments in migratory flight routes as well as in flight heights.

WSP has been commissioned to investigate these potential impacts using radar devices and visual observations to monitor bird movements. From March to May and from August to October 2024, six horizontal radar surveys were conducted and a total of 195 tracks of migrating birds were recorded by radar, representing 33 species. Visual observations supplemented these data, with 493 land-based observations and 259 offshore observations. Vertical radar surveys provided continuous data on migration intensity and flight height distribution within these periods.

The surveys revealed that sea ducks, geese, and Cormorants were the most frequently recorded taxonomic groups, whereas Swans, mergansers, divers, waders, Gulls, terns and auks were observed in smaller numbers and less frequently. Even smaller numbers of Birds of Prey and Common Cranes were recorded during the surveys and only from the observation points on land.

Predominant migratory directions were northeast in spring and southwest in autumn and most flocks followed the northern coastline of Åland in a corridor between the pre-investigation area and the coastline. Most flocks migrated at altitudes below 50 meters, particularly within 10 meters from the sea surface. However, up to 46% of the recorded radar tracks could have had an unrecorded flight track that partially intersected of the Sunnanvind project area. Overall, migration intensity over the northern part of Åland was assessed to be at a *low-moderate* level, with peak intensities in the range of 200 – 250 birds/km/hour, occurring during specific nights in autumn.

Overall, the impact of the Sunnanvind offshore wind farm on migrating birds is assessed to be *insignificant to low* for most species' groups and *low to moderate* for sea ducks, mergansers, divers, and terns and primarily during the operational phase.

Efficient mitigation measures to reduce the potential risk of collision for migratory birds with the Sunnanvind offshore wind farm include increasing the clearance height of the rotor blades to 30 m, installation of a bird detection system with an integrated curtailment mechanism, as well as appropriate light mitigation to reduce the collision rate for nocturnal migrants.

Innehåll

Summary **3**

1 Introduction **1**

1.1 Effects on migratory birds 1
1.2 The Baltic Sea 2
1.3 Objective 3

2 Methodology **3**

2.1 Radar Surveys 3
2.2 Horizontal Radar Survey 5
2.3 Vertical Radar Survey 6
2.4 Visual Surveys on land and offshore 8
2.5 Laser Rangefinder 9
2.6 Impact assessment on migrating birds 10

3 Relevant species and species groups **11**

3.1 Swans 11
3.1.1 Whooper Swan (*Cygnus cygnus*) 11
3.1.2 Mute Swan (*Cygnus olor*) 12

3.2 Geese 12
3.2.1 Biology, abundance and distribution 12
3.2.2 Greylag Goose *(Anser anser)* 12
3.2.3 Greater White-fronted Goose *(Anser albifrons)* 13
3.2.4 Barnacle Goose (*Branta leucopsis*) 13
3.2.5 Canada Goose (*Branta canadensis*) 14
3.2.6 Bean Goose (*Anser fabalis/ Anser rossicus*) 14

3.3 Dabbling ducks 15
3.3.1 Eurasian Wigeon (*Mareca penelope*) 15

3.4 Sea ducks 16
3.4.1 Common Eider (*Somateria mollissima*) 16
3.4.2 Common Scoter (*Melanitta nigra*) 16
3.4.3 Velvet Scoter (*Melanitta fusca)* 17
3.4.4 Common Goldeneye (*Bucephala clangula*) 17
3.4.5 Long-tailed Duck (*Clangula hyemalis*) 18

3.5 Divers 18
3.6 Great Cormorant *(Phalacrocorax carbo)* 19
3.7 Common Crane (*Grus grus*) 19
3.8 Birds of Prey 20
3.9 Gulls 20
3.9.1 Herring Gull (*Larus argentatus*) 21
3.9.2 Common Gull (*Larus canus*) 21
3.9.3 Lesser black-backed Gull (*Larus fuscus*) 21
3.9.4 Great Black-backed Gull (*Larus marinus*) 22

3.9.5 Black-headed Gull (*Chroicocephalus ridibundus*) 22
3.10 Mergansers 22
3.10.1 Red-breasted Merganser (*Mergus serrator*) 22
3.10.2 Goosander (*Mergus merganser*) 23
3.11 Terns 23
3.11.1 Biology, distribution and abundance 23
3.12 Auks 24
3.12.1 Biology, distrubution and abundance 24

4 Results 25

4.1 Survey Results 25
4.2 General Species Composition 25
4.3 General Flight Altitude 28
4.3.1 Visual observations 28
4.3.2 Land-based - Spring 28
4.3.3 Land-based – Autumn 28
4.3.4 Offshore - Spring 29
4.3.5 Offshore - Autumn 30
4.3.6 Vertical radar 31
4.4 Migration intensity 32
4.5 General Flight Direction 33
4.5.1 Horizontal radar and land-based visual observations - Spring 33
4.5.2 Offshore visual observations – Spring 34
4.5.3 Land-based visual observations and horizontal radar – Autumn 34
4.5.4 Offshore visual observations – Autumn 34
4.6 Relevant Species and Species groups 34
4.6.1 Swans 34
4.6.2 Geese 35
4.6.3 Dabbling ducks 39
4.6.4 Sea ducks 40
4.6.5 Mergansers 44
4.6.6 Divers 45
4.6.7 Great Cormorant 46
4.6.8 Cranes and Birds of Prey 50
4.6.9 Waders 51
4.6.10 Gulls 52
4.6.11 Terns 53
4.6.12 Auks 53
4.6.13 Other birds 54
4.6.14 Bird sp. 59
4.7 Impact assessment on migrating birds 63
4.7.1 Uncertainties of assessments 65

5 Discussion 66

5.1 Potential impacts on migratory birds 66
5.2 Relevant mitigation measures 67

6 Conclusion 68

7 References 69

1 Introduction

The Sunnanvind project was initiated by the government of Åland 2021 to investigate the possibility of a large-scale offshore wind power construction in the offshore area north of the Åland archipelago.

The pre-investigation area is located in the southern part of the Bay of Bothnia, midway between Sweden and Finland and approximately about 15 km north of the northern coast of the Åland archipelago. The pre-investigation area covers an area of about 1,360 km^2 and the eastern tip of the area is about 35 kilometers from mainland Finland, and the western tip is about 40 kilometers from mainland Sweden (Figure 1) (WSP, 2024).

A maximum of 301 Wind Power Plants with a max tip height of 350 meters has been proposed for the Sunnanvind project as the master plan limitation for the windfarm area.

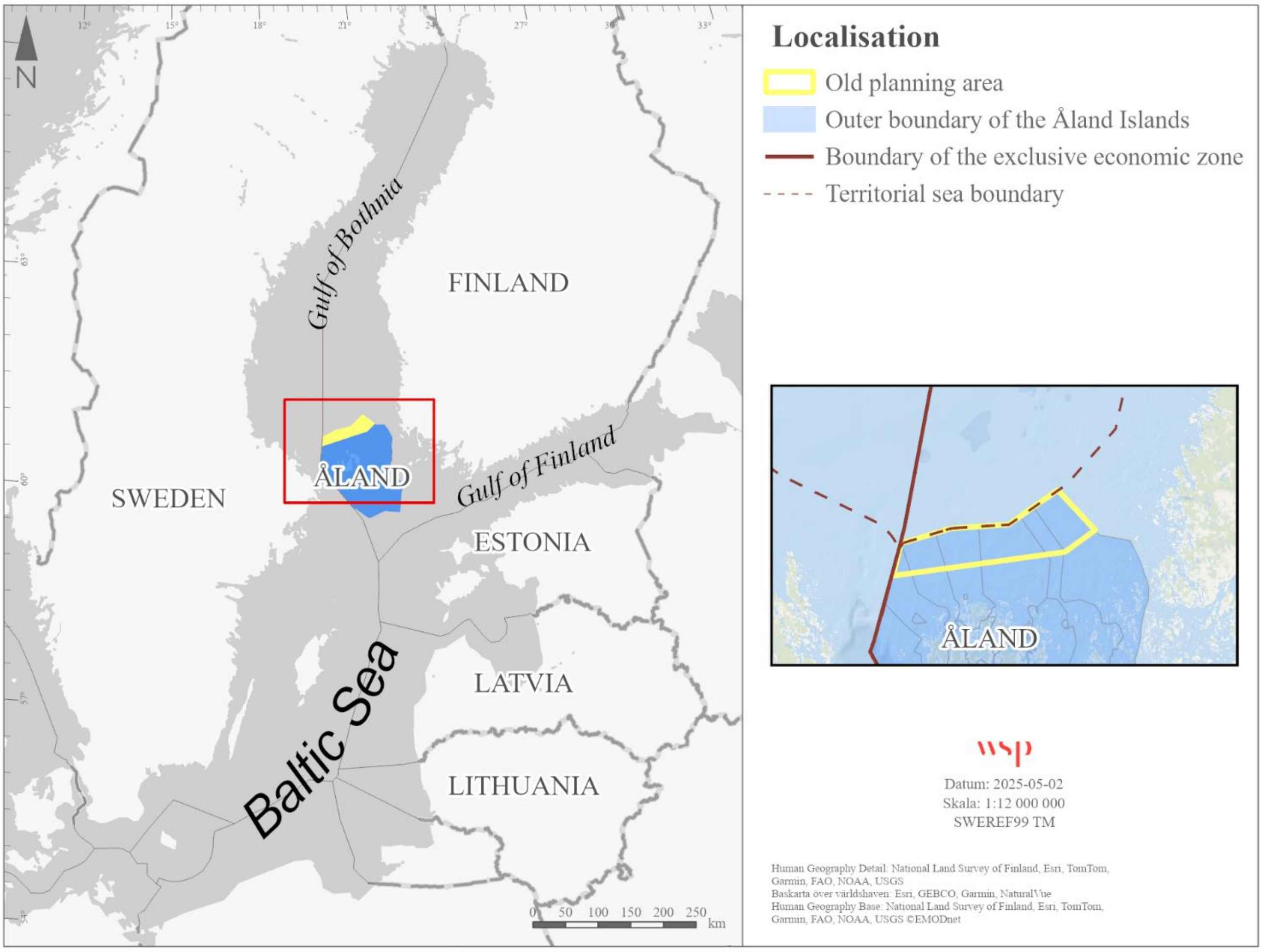


Figure 1. Overview of the investigation area in the Baltic Sea by the Åland Archipelago. The blue marking indicates the outer limit of Åland while the yellow marking indicates the pre-investigation area (WSP, 2024).

1.1 Effects on migratory birds

Increasing demand for sustainable energy sources, such as offshore windfarms, potentially pose a threat to migrating birds. The implications which may affect the birds, are: 1) risk of collision with turbines, which most often result in mortality, 2) displacement of resting birds due to effective loss of habitat, and 3) barrier effects where the windfarm creates an obstacle to migrating birds forcing them to find alternative routes or adjusting their flight altitude, to and from breeding locations.

Migratory birds alternate between breeding and wintering regions bi-annually in the search of feeding resources and more favourable climate conditions. While this is a regular phenomenon, the scale and intensity of migration can vary from year to year.

The distance covered by migratory bird species can vary greatly with some species traveling several hundred or even thousand kilometers, while others fly much shorter distances.

Adding to the complexity, some individuals of a population can migrate, while the rest resides largely in their breeding areas during the non-breeding season.

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 (foraging and resting/wintering) habitats.

Depending on the nature of the migration (e.g. seasonal or local) and the diurnal-nocturnal pattern, the flight altitudes of different species of birds also vary. Daytime waterbird migration typically occurs at relatively low altitudes (<300 meters), while nocturnal migration can occur above 1 kilometer (Kahlert et al. , 2012).

Examination of flight altitudes of birds is of particular interest in regard to various human activities. The risk of bird collisions with anthropogenic obstacles, such as towers, power lines, bridges and wind farms are increasing because of recent developments in infrastructure, especially wind farms (Drewitt & Langston, 2008).

Factors contributing to collision risk are grouped according to species characteristics, site, flight paths, wind farm features, incl. turbine type and design, configuration and lighting regime (Marques et al., 2014).

The degree to which these birds may be affected by any of the potential risks associated with the installation and operation of offshore wind farms vary strongly with respect to the species, and the relevant existing data will be presented accordingly.

1.2 The Baltic Sea

The Baltic Sea is a brackish non-tidal sea containing the Danish strait, the Bay of Bothnia, the Bothnian Sea and the Gulf of Finland. The entire Baltic Sea covers approximately 415,000 km^2 (Skov et al., 2011).

The Baltic Sea has limited connection with the open sea and the salinity spans greatly depending on the area due to freshwater input from river outlets. The salinity can therefore span from approximately 15 – 30 ‰ in the Kattegat (Skov et al., 2011) to around 6-8 ‰ in the Åland Sea (Køie & Kristiansen, 2014).

As salinity declines, the number of species also decreases compared to fully marine systems, such as the North Sea (Køie & Kristiansen, 2014). The species abundance is however also influenced by other factors, such as availability of substrates as well as wave exposure (Køie & Kristiansen, 2014).

In the coastal areas with hard substrates, such as rocky shores, where light is available, the most species-rich areas are found. Here both bivalves, gastropods, crustaceans and fish are present, alongside with macroalgae, attached to the hard surfaces.

At greater depths, where light is limited and algal growth is scarce, the Blue Mussel (Mytilus spp), predominates entirely. In the Baltic proper, the Blue Mussel represent more than 90% of the total animal biomass (Skov et al., 2011).

Many sea ducks, relevant to this report, are reliant of the presence of suitable food items incl. mussels to sustain fitness and build up body reserves for migration.

1.3 Objective

WSP has been commissioned by the government of Åland to investigate the potential impacts on migratory birds in relation to an offshore wind farm area, Sunnanvind, which is currently in a stage of planning (WSP, 2024).

2 Methodology

2.1 Radar Surveys

Radar is originally an acronym 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 that are small and move fast require shorter wavelengths to be detected. Therefore, devices with 25 kW power in the X-band range (9,410 MHz) were used to detect movements of migrating birds effectively. Radar devices were used for tracking of bird targets both vertically and horizontally (Figure 2).

Figure 2. Setup of bird radar station at Dånö, Langnäs on the northern side of Åland. The setup is complete with a horizontal and vertical radar mounted on top of a trailer-wagon. The horizontal radar is used to determine the flight direction of migrating birds, while the vertical radar is used to determine flight height and migration intensity.

Data from the observer-assisted radar surveys provide information on species composition, diurnal activity and seasonal phenology patterns, as well as flight heights and direction of migrating birds.

Both vertical and horizontal radars were used in the surveys. In horizontal surveys, the antenna was simply aligned horizontally. In vertical surveys, the radar had the direction of the vertically rotating antenna adjusted manually to perpendicular align with the assumed migratory direction. The antennas were mounted several meters above sea level, on top of the trailer, for a clearer view. The setup has been assembled on two different sites, an initial site that showed poor conditions for the radar setup, due to nearby cliffs, and the Dånö site which provided the best available conditions for the radar setup. It is this site that data primarily has been collected from. An overview of the two locations of the land-based setup and are given in Figure 3.

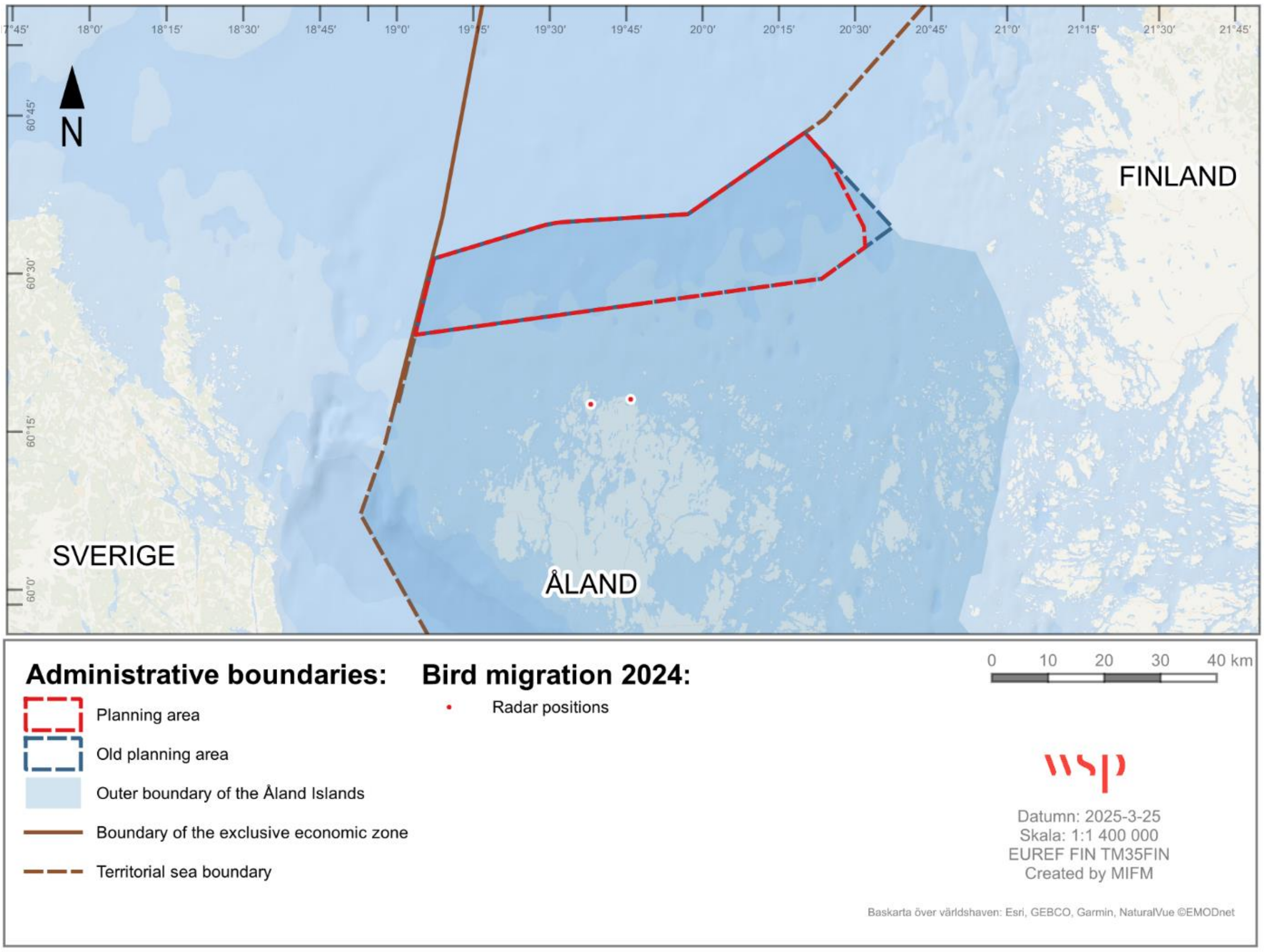


Figure 3. Overview of the two radar setup positions marked by red dots: The Dånö site to the west and the initial site to the east. The pre-investigation area is marked in blue in this figure and in yellow in Figure 1.

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

In general, the observers estimated the flight heights of the visual observations, however, as a supplement on various occasions a laser rangefinder was used. The manufacturer and model: “Safran Vectronix AG - model Vector 21 Aero” was used to attain precise altitude measurements. 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 trigger 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). The purpose of the laser rangefinder was to produce tracks on birds of interest, such as Birds of Prey, that are difficult to detect with the horizontal radar or to get the exact flight heights of bigger flocks of birds within shorter distance.

In the following chapters, the methodology of horizontal and vertical radar surveys on land are described.

2.2 Horizontal Radar Survey

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 radar is approximately 15-20 km under good conditions. The land-based radar setup consists of two radars of the model: FURUNO FAR 2117 ARPA X Band Marine Radar (with a transmission power of 25 kW and 9,410 MHz wavelength), one horizontal and one vertical mounted on the same stand.

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. The antenna gain (i.e. sensitivity) and range was adjusted in relation day-to-day specific conditions from to 70 - 100 % gain and filters for rain and sea clutter were deactivated from 0 – 20% to work around background clutter.

For identification of bird species and counting the 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 eight hours each day, within a period of 3 – 5-day cycles.

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, also to verify if it indeed was bird flock movements on the radar interface or not.

Because the horizontal radar does not have the capability to measure altitude of the returning signals, the observer in charge of the radar tracking also had to apply a rangefinder, when possible. Laser rangefinder measurements were prioritized for focus species, such as Birds of Prey, and only for other species when there was sufficient time to first discover, identify, count the number of individuals and if the flocks were within a shorter range than up to 1.5 km away.

The horizontal radar surveys were carried out during the spring and autumn bird migrating seasons, from March to May & from August to October.

During the period from the start of March 2024 to the end of October 2024, a total of 6 horizontal radar surveys were completed, within that period a total of 195 unique horizontal tracks were produced. An overview of the dates and number of tracks produced are shown in (Table 1).

Unique tracks were produced for a total of 33 different species, including species only identified to group level such as: Goose sp. Or Sea duck sp. However, because the horizontal radar can detect large flocks of birds, returning strong signals up to a 15-20 km distance, it was not possible to identify all tracks to species or group level, therefore a single unidentified group named: Bird sp., which account for flocks identified by the horizontal radar but that remained unidentified by the observer has also been included.

The most numerous species groups were flocks of Sea ducks (n = 77), with Eider accounting for a large proportion of the observed flocks (n= 52), followed by Great Cormorants (n = 34), Bird sp. (n = 27), and Geese (n = 26). For the remaining tracks, only a few tracks per species or species group have been produced, however the species and species groups will be described in the relevant section in the results.

Table 1. Overview of the horizontal radar surveys.

Survey no.	**Date**	**Time**	**Horizontal tracks**
1	21/03/2024:	07:00 - 12:00	1
	23/03/2024:	07:00 - 15:00	19
	24/03/2024:	06:45 - 14:45	0
	26/03/2024:	06:45 - 14:45	27
2	24/04/2024:	06:00 - 14:00	25
	25/04/2024:	06:00 - 14:00	1
	26/04/2024:	06:00 - 14:00	3
	27/04/2024:	06:00 - 14:00	7
	28/04/2024:	06:00 - 14:00	7
	29/04/2024:	06:20 - 14:30	12
	30/04/2024:	06:00 - 11:30	9
3	21/05/2024:	08:00 - 16:00	0
	22/05/2024:	05:00 - 13:00	0
	23/05/2024:	05:00 - 13:00	3
	24/05/2024:	05:00 - 13:00	4
	25/05/2024:	05:00 - 13:00	0
	Part sum – spring		120
4	20/08/2024:	06:00 - 14:00	9
	21/08/2024:	06:00 - 14:00	21
	22/08/2024:	06:00 - 14:00	3
5	30/09/2024:	07:00 - 14:00	09
	01/10/2024:	07:00 - 14:45	11
	02/10/2024:	07:00 - 15:00	12
6	19/10/2024:	08:30 - 15:45	3
	20/10/2024:	08:30 - 15:00	2
	21/10/2024:	08:30 - 14:25	7
	Part sum - autumn		79
	Total sum		**195**

2.3 Vertical Radar Survey

In the vertical radar surveys, the same model: FURUNO FAR 2117 ARPA X Band Marine Radar (with a transmission power of 25 kW and 9,410 MHz wavelength) was used, but in this case, the antenna was deployed vertically and perpendicular on the primary direction of bird migration in Northwest Europe i.e. from south-west to north-east (spring) and from north-east to south-west (autumn). Data from vertical radar surveys provide information on migration intensity and flight height distribution of migrating birds. The data can be used to illustrate phenological variation in migration traffic rates throughout the migration seasons as well as differences in migration intensity and flight height between day and night or at even finer temporal scales such as hours to illustrate the pattern of variation over 24 hours.

The vertical radar scans the airspace in 24-hour cycles in a distance range of 1.5 km. However, a 180 degrees blind sector has been imposed downwards, so that radio waves are exclusively emitted towards the sides and towards the sky. As described above, the radar antenna was aligned perpendicular to the assumed main direction of bird migration to register as many passages of birds as possible. The antenna alignment was only set once at the beginning of the spring and autumn survey periods, respectively.

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 60 seconds which allowed to identify bird signals by the combination of the current signal as well as 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 4).

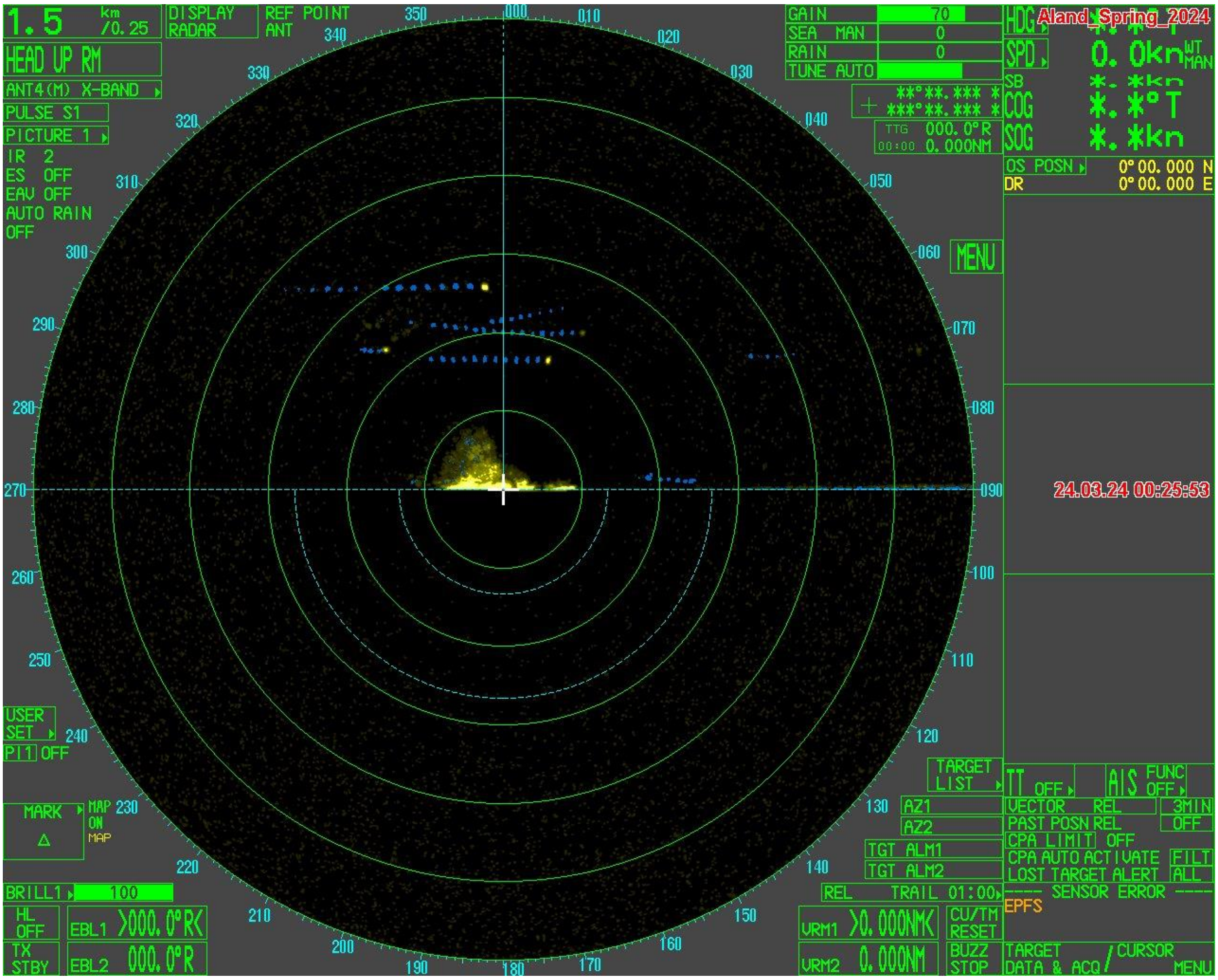


Figure 4. Example of a screenshot from the vertical radar. Bird signals is recognized by the active yellow signal and the blue trails.

The recorded screenshots were scanned for bird signals by a batch-processing detection algorithm, specifically developed to extract bird detections from the images and assign corresponding flight heights. Prior to the image analysis, automatic filtering was applied to reduce the amount of noise and to reject images containing lots of noise. Bird tracks were then automatically identified and marked as polylines through a segmentation approach followed by line detection using the *Probabilistic Hough* lines function in python. To ensure a respectable methodology, a representative dataset of 1006 annotated images was created by selecting every 25 image to cover the entire radar deployment period. This dataset was used to evaluate the algorithms. The dataset was split into 604 photos for training and 402 photos for testing of the algorithm to reduce false detections. Testing and performance evaluation was then followed up by an algorithm optimization procedure resulting in a precision of approximately 43 %, indicating that the algorithm was able to detect 43 % of the bird tracks that could be manually detected in the test sample. To represent the resulting flight height distribution, the detections were aggregated in 100 m height increments up to 1,500 m. and were subsequently corrected for the proportion of false detections occurring in each individual height increment, estimated from the representative sample of images.

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 each day and night, the mean migration intensity was determined from the corresponding hourly results. Flight height distributions and migration intensities were stratified by day and night and spring and autumn, respectively. The R package 'suncalc' (Thieurmel & Elmarhraoui, 2022) was used to extract date-specific times of sunrise and sunset in order to aggregate the vertical data into 'day' and 'night', respectively.

2.4 Visual Surveys on land and offshore

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 March 2024 onwards, a total of 10 observation surveys, consisting of 35 days, were conducted until the end of September 2024 (Table 2). Most of these observations, 25 days, consist of land-based observations close to the radar setup. However, this also include three independent vessel-based surveys, distributed on four days of transect in May, transversing through the entire pre-investigation area, and three days in August and September at selected anchoring positions, combined with transects at specific conditions, within the pre-investigation area. Locations of the different survey positions on land and offshore, are indicated in (Figure 5).

Table 2. Observation effort of 2024. Start and end date/time of surveys including visual observations both land-based and offshore.

Observation Site	Start date/time	End date/time
Initial site	21.03.2024, 07:00 (UTC + 2)	24.03.2024, 14:45 (UTC + 2)
Dånö	26.03.2024, 06:45 (UTC + 2)	26.03.2024, 14:45 (UTC + 2)
Dånö	24.04.2024, 06:00 (UTC + 3)	30.04.2024, 11:30 (UTC + 3)
Dånö	21.05.2024, 08:00 (UTC + 3)	25.05.2024, 13:00 (UTC + 3)
Offshore	21.05.2024, 08:00 (UTC + 3)	24.05.2024, 13:00 (UTC + 3)
Dånö	20.08.2024, 06:00 (UTC + 3)	22.08.2024, 14:00 (UTC + 3)
Offshore	29.08.2024, 07:25 (UTC + 3)	31.08.2024, 12:30 (UTC + 3)
Offshore	22.09.2024, 07:00 (UTC + 3)	24.09.2024, 12:00 (UTC + 3)
Dånö	30.09.2024, 07:00 (UTC + 3)	02.10.2024, 14:25 (UTC + 3)
Dånö	19.10.2024, 08:30 (UTC + 3)	21.10.2024, 14:25 (UTC + 3)

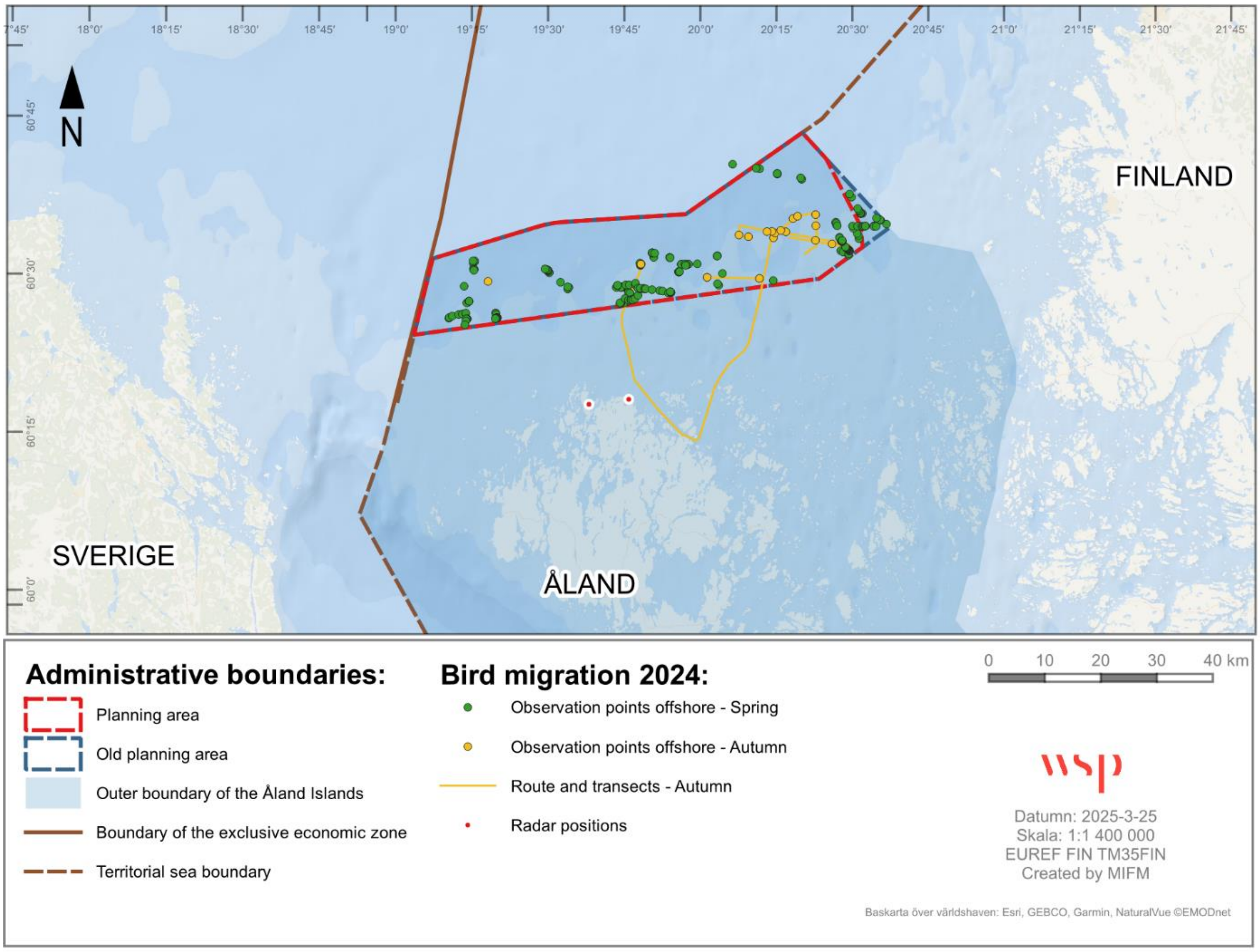


Figure 5. Locations of the different survey positions on land during spring and autumn 2024 and offshore during the surveys in May, spring 2024 (21.05.2024 - 24.05.2024) and in August and September, autumn 2024 (29.08.2024 - 31.08.2024 and 22.09.2024 - 24.09.2024, including transects offshore in autumn.

As a supplement the radar studies, continuous visual observations were conducted during the daylight hours, starting during civil morning twilight and between 5 – 8 hours from then. One observer scanned the surrounding area for flying birds with bare eyes, binoculars and telescope, covering a 360° area. Species and numbers of individuals of flying birds and 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.

2.5 Laser Rangefinder

Laser rangefinder measurements were made in parallel with the visual observations. After using the rangefinder to measure altitudes and distances of the path travelled by a bird or a flock of birds, one of the two observers noted the relevant information in the laser rangefinder interface. 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 can present the flight path in 3D.

Laser rangefinder measurements were primarily used to measure flight directions and altitudes of focus bird species, such as bird of prey or larger flocks of birds, within a shorter range of the setup (< 1.5km). The laser rangefinder delivered information on flight directions of smaller targets that showed difficult to track by the horizontal radar. Also, since information provided by the laser rangefinder is qualitative (providing flight directions of migrating birds), results of laser rangefinder are complementary and partially comparable to that provided by the horizontal radar. Furthermore, laser rangefinder provides additional important information on exact flight altitudes.

The Laser rangefinder was primarily used to attain exact flight heights as a supplement to the estimations made by the visual observer.

Figure 6. Laser rangefinder: Vector 21 Aero, by the company Vectronix.

2.6 Impact assessment on migrating birds

The impact assessment on migrating birds is based on an assessment off the importance of the pre-investigation area in relation to the various selected relevant species groups and their migratory behavior observed during spring and autumn 2024.

The assessment is based on a 3-grade scale called Value of interest (the importance of the pre-investigation area in relation to observed migratory behavior) with three different levels: high, moderate and low level of importance.

The assessments are based on the information attained through radar surveillance and visual observations of migrating flocks of birds during spring and autumn 2024 on Åland.

Furthermore, environmental assessments have been based on a three-graded scale, with respect to uncertainty and environmental impact, see (Table 3) and (Table 4) below:

Table 3. A three- point graded scale used to assess the value of interest for the Sunnanvind offshore wind farm project on migratory birds.

Value of interest	Description
High	High value: the area is of high importance to migratory birds; The area is located on a primary flight route for migratory birds considered of national or international importance
Moderate	Moderate value: the area is of moderate importance to migratory birds; The area is located on a flight route for migratory birds, which is not considered of national or international importance
Low	Low value: the area is of low importance for migratory birds; The area is not located on an important flight route for migratory birds

Table 4. A three- point graded scale used to assess the level of uncertainty in the assessment for migratory birds in relation to the Sunnanvind offshore wind farm.

Uncertainty	Description
High	High uncertainty in assessment: general lack of scientific evidence, including existing literature, and insufficient information on an environmental aspect or its sensitivity in the planning area and lack of data from field surveys.
Moderate	Moderate uncertainty: assessments based on a lack of scientific evidence, including existing literature, on the value of the environmental dimension in the Sunnanvind area, limited timeframe for field surveys, and/- or insufficient amount of data gathered on movements of specific species or species groups.
Low	Low uncertainty: assessment based on extensive scientific evidence, including existing literature, and the presence of the environmental aspect in the Sunnanvind area with good coverage of results from field surveys, with a sufficient amount of data gathered on movements of specific species or species groups.

3 Relevant species and species groups

Description of some of the most relevant species and species groups migrating over the northern parts of Åland.

3.1 Swans

Two species of Swans are relevant for the present study. The two species are described in detail in regard to migration patterns in the following section.

3.1.1 Whooper Swan (*Cygnus cygnus*)

The distribution range of Whooper Swan (*Cygnus cygnus*) is palearctic. The species breed at northern latitudes, from Iceland to the Bering Sea, including Iceland, Norway, Sweden and Finland along with northern Russia (Scott & Rose, 1996). Whooper Swans typically breed by pools and shallow freshwater lakes incapsulated by wooded areas.

The Whooper Swan is almost completely migratory, apart from a minor Icelandic population (Scott & Rose, 1996). Scandinavian and western Russian breeders are thought to mainly winter in Mainland Europe (e.g. Norway, Denmark, Germany and the Netherlands), the Baltic countries and Central Europe (Kear, 2005). Autumn migration takes place during October and November to temperate wintering sites. Whooper Swans return to the breeding grounds from mid-March to early May (Scott & Rose, 1996).

Previous studies suggest that some birds undertake moulting migration, which has been reported for Whooper Swans breeding in Latvia and Estonia and moving to Finland and Arctic Russia for moulting (Boiko & Kampe-Persson, 2012). Numbers wintering in the Baltic Sea fluctuate based on winter conditions (Scott & Rose, 1996).

Whooper Swans are observed both on migration and during winter roost across all of the Åland archipelago, however mainly in the southern and central parts of mainland Åland (Tiira.fi, 2025). During passage, Whooper Swans also make use of Åland as a staging or stop-over ground. Some flocks of migrating Whooper Swans have been reported from the northern archipelago of Åland however, most observations are from the more central, south-western and eastern parts of the mainland (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern)

Annex I of the EU Bird Directive (European-Union, 2010): Listed

3.1.2 Mute Swan (*Cygnus olor*)

The north-west European winter population of Mute Swan (*Cygnus olor*) has increased by 62% from 180,000 in the early 1990's to 292,000 birds in 2006 (Delaney, Veen & Clark, 2006). The current Baltic winter population is estimated at 132,000 birds.

Mute Swans breeding in eastern Europe are mostly migratory or nomadic. Most Swans breeding in Finland, Sweden, the Baltic countries, Poland, northern Germany and Denmark leave inland lakes to winter in archipelagoes and along the coasts of the Baltic Sea (Scott & Rose, 1996).

Mute Swans return to their breeding areas in spring when thaw is setting in, but most birds move inland in February and March (Skov et al., 2011). According to Skov et al., there was an estimated population of 3,820 individuals near the Åland Archipelago between 2007-2009.

Mute Swans are observed throughout the year on Åland, however mainly in the southern and south-eastern parts of the archipelago (LAJI.FI, 2025). During passage, Mute Swans also make use of Åland as a staging or stop-over ground. Some flocks of migrating Mute Swans have been reported from the northern archipelago of Åland however, most observations are from the south-western and south-eastern parts of the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.2 Geese

3.2.1 Biology, abundance and distribution

At least six species of geese migrate annually through the Bay of Bothnia by the Åland archipelago and the Baltic Sea: Greylag Goose (*Anser anser*), Greater White-fronted Goose (*Anser albifrons*), Canada Goose (*Branta canadensis*), Bean Goose (*Anser fabalis/ Anser serrirostris*) and Barnacle Goose (*Branta leucopsis*). Furthermore, a study has found that Pink-footed Goose (*Anser brachyrhynchhus*) has formed a new migration route diverging from the traditional route to Scotland via a new route crossing the Åland archipelago to Russia (Novaya Zemlya) (Madsen et al., 2023).

Most geese breed on lakes, pools, rivers and in a variety of wetland habitats and winter on farmland in open country or in swamps, saltmarshes and coastal lagoons further south than their breeding areas (Scott & Rose 1996). Whereas the specific biology and requirements of each species mentioned here varies, almost all of them follow the same migration pattern. Their migration towards the wintering areas starts by September, and highest densities will be reached in January and February. The migration back to the breeding areas starts again in March (Scott & Rose 1996).

Migratory geese are known to follow their traditional routes between wintering, staging and breeding grounds (Green, 2001).

With regards to the observed migration altitudes, geese often fly at high altitudes. For example, Brent geese (*Branta bernicla)* is known to fly at faster speeds and higher altitudes in spring than in autumn (Green & Alerstam, 2000).

3.2.2 Greylag Goose *(Anser anser)*

The breeding range of Greylag Goose (*Anser anser*) spreads across boreal and temperate latitudes in Europe and Asia. Depending on the winter conditions, they winter in lower latitudes in western and southern Europe and as far as North Africa (Scott & Rose, 1996).

Many Greylag geese breeding in Norway, Sweden, Denmark, Finland and east central Europe migrate south to Spain and Northern Africa through the Netherlands and the Balkans (Delaney, Veen & Clark, 2006; Scott & Rose, 1996).

The spring migration for the Greylag Goose occurs from early February to March. The central European population reach their breeding grounds around this time.

Autumn migration takes place mid to late August and continues until October in Finland and Estonia.

During spring and autumn, migrating Greylag geese are observed across all of the Åland archipelago, in a broad migratory passage (Tiira.fi, 2025). During passage, Greylag geese also make use of Åland as a staging or stop-over ground. Flocks of migrating Greylag geese have been reported from the northern archipelago of Åland, and observations have been reported all the way from outermost north-western parts to the outermost south-eastern parts of the archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.2.3 Greater White-fronted Goose *(Anser albifrons)*

Greater White-fronted Goose (*Anser albifrons*) breeds in open tundra near marshes, lakes, pools and rivers in the arctic and winters in open country, farmland and marshy plains (Scott & Rose, 1996).

Breeders in the Arctic winter from England to the Caspian Sea. Birds wintering in northwest- and central Europe molt in large numbers in Russia (Kear, 2005). Greater White-fronted geese depart from their breeding and molting grounds in September through staging areas along the Gulf of Finland. After staging in the Gulf of Finland, they move towards their breeding grounds.

Greater White-fronted Goose (*Anser albifrons*) migrates over long distances from the Arctic breeding grounds to temperate areas of North America and Eurasia. During both spring and autumn migration, they are heavily reliant of staging areas with abundant resources (Scott & Rose, 1996).

During spring and autumn, migrating Greater White-fronted geese are observed from mainland Åland (Tiira.fi, 2025). During passage, Greater White-fronted geese also make use of Åland as a staging or stop-over ground. Most flocks have been reported in the southern parts of central mainland Åland, however, few flocks of migrating Greater White-fronted geese have been reported from the northern archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.2.4 Barnacle Goose (*Branta leucopsis*)

The Barnacle Goose (*Branta leucopsis*) experienced a decline in population in the middle of the last century. Due to improved protection of the wintering ground in western Europe – and climate change alterations in the Arctic breeding grounds – the distribution of barnacle Goose has taken a southward expansion from the Arctic islands to mainland coastal tundra (Kouvoz, Zagnagutdinova & Kravchuk, 2023). This became evident when breeding centers started to form in migrational stop-overs in the Baltic Sea. Since the last decades, the barnacle Goose, has begun to settle in boreal zones of Northwestern Russia (Kouvoz, Zagnagutdinova & Kravchuk, 2023). Barnacle Goose has bred on islands in the Baltic Sea in Sweden since 1971 and Finland since 1983 (Scott & Rose, 1996).

Barnacle Goose is a moderate to long-distance migrants that annually migrates from their Arctic breeding sites stretching from Greenland to Western Siberia and travel through the Baltic to wintering grounds spanning from Denmark to Belgium (Reeber, 2015). The species can however migrate further south if the winter conditions are harsh.

Barnacle Goose migration is characterized by fast, nonstop flights, or flights with few interruptions, and at higher altitudes (primarily in spring compared to autumn) along relatively direct flight paths.

Mainly during spring, but also in autumn, migrating Barnacle geese are observed from the Åland archipelago (Tiira.fi, 2025). During passage, some Barnacle geese also make use of Åland as a staging or stop-over ground, though most observations are from migrating flocks solely. Most flocks have been reported passing in the southern parts of central mainland Åland, however, flocks of migrating Barnacle geese have been reported from the northern archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Listed.

3.2.5 Canada Goose (*Branta canadensis*)

As the name implies, the Canada Goose (*Branta canadensis*) is native to Canada. The species was introduced in Europe, including Sweden in the 1930's, which provided suitable habitats for the now established European population. In addition, relatively large populations have emerged after release in Norway, Finland, Germany and various other European countries (Bønløkke, Rahbek , & Madsen , 2006).

The geese from the European population (more northernly parts of Sweden and Finland) breeds in Svalbard and Iceland and migrate to wintering grounds in the North Sea and Baltic coasts.

Canada geese are observed throughout the year on Åland, however, with the highest concentration in the southern parts of mainland Åland (LAJI.FI, 2025). During passage, Canada geese also make use of Åland as a staging or stop-over ground. Flocks of migrating Canada geese have been reported from the northern archipelago of Åland, and most observations are from the south-eastern to the north/ - north-western parts mainland Åland (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.2.6 Bean Goose (*Anser fabalis/ Anser rossicus*)

Bean geese are split into the lower-latitude (taiga) and the higher-latitude (tundra) nesting species.

The Taiga Bean Goose (*Anser fabalis fabalis*) breeds on lakes, pools, and rivers in the taiga zone, whereas the Tundra Bean Goose (*Anser fabalis rossicus*) breeds beside lakes, pools, and rivers in the high Arctic or in the taiga zone.

Both species of Bean geese winters in the open country on marshes or agricultural land, including reclaimed areas (Kear, 2005), especially within the western Baltic Sea region, where most of them winter (Heinicke et al., 2018).

The Taiga Bean Goose starts its spring migration in February with the birds arriving in Finland between March and May. The Taiga Bean Goose breeds mostly in north-west Russia, northern Sweden, and central and northern areas of Finland (Piironen et al., 2022a). The autumn migration of the Taiga Bean Goose occurs between late August and October.

The Tundra Bean Goose migrates across Finland one – two weeks later than later than the Taiga Bean Goose both in spring and autumn (Piironen et al., 2022b). The spring migration of Tundra Bean Goose occurs between March and May where the geese migrate towards to their breeding grounds in northern Russia. The autumn migration occurs between late September and November (LAJI.FI, 2025).

Migration routes over Finland may differ slightly between the two species. Where the Taiga Bean Goose migrates across the entire country, though primarily through western Finland, the Tundra Bean Goose pass mainly through the southeast of the country.

During spring and autumn, migrating Bean geese are observed from mainland Åland (Tiira.fi, 2025) Few flocks of migrating Bean geese have been reported from the northern archipelago of Åland however, most observations are from the south-western and north-eastern corner of the mainland (LAJI.FI, 2025). During passage, Bean geese also make use of Åland as a staging or stop-over ground (Tiira.fi, 2025).

In this report however, the two species are regarded as one because of the great similarities between the two and due to uncertainty of identification on great distances or in poor light conditions etc.

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.3 Dabbling ducks

Of dabbling ducks, the most relevant migrant for the present study is Eurasian Wigeon, the species is described in detail in regard to migration patterns in the following section.

3.3.1 Eurasian Wigeon (*Mareca penelope*)

The Eurasian wigeon (*Mareca Penelope)* is a migratory species that is distributed from Iceland and northern Britain across northern Europe and Russia. The Eurasia Wigeon migrates to their wintering grounds in central and southern Europe, and north and central Africa during autumn. Breeding populations in Fennoscandia and north Russia east of Yenisey migrate to western and southwestern Europe, whereas those breeding in west and central Siberia winter on the Caspian and Black Sea (Snow & Perrins, 1998). In Finland there are around 60,000–80,000 pairs, which are probably increasing in numbers, while there is estimated around 170,000–230,000 pairs in European Russia (Kear, 2005), which potentially migrate through the Baltic Sea.

It is essentially a vegetarian duck that primarily feeds on leaves, stems, roots, rhizomes and seeds of grasses, sedges and aquatic vegetation, however in winter it occasionally takes small invertebrates (Larsen, 1996). It resides in shallow, freshwater marshes, lakes and lagoons surrounded by scattered trees or open forest during breeding season, while it moves to coastal marshes, freshwater and brackish lagoons, estuaries, bays and other sheltered marine localities during winter (Kear, 2005).

The migration towards their breeding grounds occur during April – June, depending on latitude, with the first nests initiated during April in Scotland, while their arrival to breeding grounds in Northern Russia may not be reached until the second half of May (Kear, 2005). They are typically present on their wintering grounds between September/October and mid-March to early April in northwest Europe, with departure from their breeding grounds typically occurring earlier during mild winters (Snow & Perrins, 1998).

Post-breeding birds initially migrate to molting grounds, where large gatherings of birds have been observed in countries such as Estonia, Southern Sweden, Denmark and the Netherlands (Snow & Perrins, 1998). In Finland, the timing of these gatherings has been studied and show that the southward migration during autumn tend to have been postponed over a 30-year period since 1979, which might be linked to climate change (Lehikoinen & Jaatinen, 2012).

Eurasian Widgeons are observed in smaller numbers throughout the year, though mainly during migration within the Åland Archipelago (Tiira.fi, 2025). During passage, large flocks of Eurasian Wigeons migrate through the Åland archipelago and make use of the islands as a staging or stop-over grounds. Most observations have been reported from the southern and south-eastern parts of the archipelago and larger islands, while some observations of migrating flocks of Eurasian Wigeons have been reported from the northern parts of mainland Åland (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): EN (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.4 Sea ducks

3.4.1 Common Eider (*Somateria mollissima*)

The common Eider (*Somateria mollissima*) breeds in coastal areas of north-western and northern Europe. The population has increased throughout the 20th century until the 1990's. However, since the mid-1990's, a considerable decline of the breeding population has been observed in the northern Baltic (Finland, Sweden, Estonia). Common Eiders are partially migratory and dispersive and winter mainly in marine or brackish areas (HELCOM, 2013a).

The Common Eider is one of the most numerous breeding sea ducks in northern Europe with a rough estimate of the Baltic population of 515,000 individuals (Skov et al., 2011) and is the most numerous and widespread seaduck in the Baltic archipelagos.

Its distribution is largely dependent on the availability of the Blue Mussel (*Mytilus spp.*), although also other bivalves may serve as a basic food source (HELCOM, 2013a).

The Common Eider has been widespread and common throughout its range in the Baltic and Wadden Sea countries for most of the 20th Century (Desholm et al, 2002). Detailed studies of breeding Eiders have been carried out in the Söderskär bird sanctuary in the Gulf of Finland since the 1950s (Desholm et al, 2002).

Birds breeding in the Baltic region winter mostly in the western parts of the Baltic Sea. Autumn migration from the breeding grounds in the northern and central parts of the Baltic Sea to Danish and German waters begins in late September and lasts throughout December. Some of these birds spend the first part of the winter in the Wadden Sea but return to the Baltic in February and March. Spring migration to the breeding grounds begins in late March (Skov et al., 2011; HELCOM, 2013a).

The common Eider generally flies in compact flocks ranging from only a few individuals to thousands.

In the western part of the Baltic Sea, common Eiders occur preferably in areas of water depths ranging from 5 – 15 meters (Skov et al., 2011; HELCOM, 2013a).

Mainly during spring migration, but throughout the year in smaller numbers Common Eiders are observed throughout the Åland archipelago (Tiira.fi, 2025). During passage, large flocks of Common Eiders also make use of the Åland archipelago as a staging or stop-over ground. Most flocks have been reported from the western, southern and south-eastern parts of central mainland Åland, however, a larger number of migrating flocks of Common Eiders have been reported from the north-western and northern archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): EN (Endangered).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.4.2 Common Scoter (*Melanitta nigra*)

Common Scoters breed in the northern regions of Iceland to northern Eurasia and Eastern Siberia (HELCOM, 2013b).The breeding population in Europe is estimated at 100.000 to 130.000 pairs, with highest numbers in Russia, Norway, Sweden and Finland (HELCOM, 2013b). The European population has been relatively stable since the 1960's. Breeding numbers in Finland and Finland appear to have been stable or increasing slightly since the 1990s (Finland) and 1970's (Sweden) (HELCOM, 2013b). Important wintering areas include the Baltic Sea, the Wadden Sea and along the Atlantic coast stretching to North Africa (HELCOM, 2013b).

Common Scoters are regular and common winter- and migration visitors in the Baltic Sea from October to May (HELCOM, 2013b).

Previous studies from 2007-2009 have shown that the wintering population of Baltic Common Scoters had declined from the late 1980's and early 1990's. It was further observed that there was a slight relocation of the wintering

Common Scoters to the north. Furthermore, it was observed that while the wintering population decreased in Kattegat, Kiel Bay and the Pomeranian Bay, the numbers increased in the Gulf of Riga, the Gulf of Gdansk and parts of Sweden along with other places (Skov et al., 2011).

Common Scoters are observed throughout the year on Åland, however mainly during spring and autumn migration (LAJI.FI, 2025). During passage, Common Scoters also make use of the archipelago as a staging or stop-over ground. Some flocks of migrating Common Scoters have been reported from the northern archipelago of Åland however, most observations are from the south-western, southern and south-eastern parts of the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.4.3 Velvet Scoter (*Melanitta fusca)*

According to previous studies, the estimate of north-west European winter population of Velvet Scoter (*Melanitta fusca*) was updated to approximately 1 million birds. However, since 1993 the Baltic wintering population has declined to 373.000 individuals, equivalent to an annual decline of 3,7% (Skov et al., 2011).

In June, most male velvet Scoters leave the breeding grounds to molt mainly along the north coast of Russia. In autumn, the main migration to the Baltic Sea takes place in September and October. Spring migration begins in March and during May, Velvet Scoters concentrate in the northern part of the Gulf of Riga before they move overland to the breeding areas. By mid-May, only the local breeders remain in the area (Skov et al., 2011).

Velvet Scoters are observed throughout the year on Åland, however mainly during late spring migration and during the breeding season in summer (LAJI.FI, 2025). Both during passage and during breeding, Velvet Scoters also make use of the archipelago as a staging or stop-over ground.

Quite some flocks of migrating Velvet Scoters have been reported from the northern archipelago of Åland however, the vast majority of observations are from the southern and south-eastern parts of the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): VU (Vulnerable).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.4.4 Common Goldeneye (*Bucephala clangula*)

The largest concentration of Common Goldeneye (*Bucephala clangula*) in the Baltic is found in the northern archipelago of Sweden, where a total of 26.800 birds were counted on the Swedish archipelago of Kalmar during survey from 2007-2009 (Skov et al., 2011).

The Common Goldeneye inhabit coastal areas of both fresh- brackish and saltwater, often shallower than 5 meters. Since 1993 a shift in distribution from south to north has been observed (Skov et al., 2011).

During surveys from 2007-2009 (Skov et al., 2011), 4.956 wintering birds were observed on the Åland Archipelago.

Autumn migration to the Baltic begins in late August and peak numbers are observed in November. During harsh winters, Common Goldeneye has been observed relocating to West and Central Europe. The Common Goldeneye returns to the breeding grounds during late February.

Common Goldeneyes are observed throughout the year on Åland, however mainly during late spring migration and during the breeding season in summer (LAJI.FI, 2025). Both during passage and during breeding, Common Goldeneyes also make use of the archipelago as a staging or stop-over ground.

Migrating Common Goldeneyes have been reported from the northern archipelago of Åland however, observations have been reported from the outermost north-western to the south-eastern parts of both mainland Åland and throughout the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.4.5 Long-tailed Duck (*Clangula hyemalis*)

The Long-tailed Duck (*Clangula hyemalis*) breeds in the arctic. In Europe, the breeding range spans from Iceland, Central Norway, Northern Finland, the Finnish Baltic coast to arctic Russia.

Although there has been recorded declines in population numbers for the Long-tailed Duck, there is some debate and discrepancy regarding the population estimations. It is debated whether the populations are in fact declining, or if the birds merely winter in alternative areas. The Long-tailed Duck typically winters in the Baltic due to ice formations in the breeding areas, but it is speculated, that climate change might have caused the ducks to remain further north during winter when there is less – or no – ice (AEWA, 2015). Availability of suitable food sources might also influence the choice of wintering area for the Long-tailed Duck.

The Long-tailed Duck migrate between their breeding grounds in the arctic and wintering sites in temperate areas in the Baltic. They are common winter and migration visitors in the Baltic Sea from October and May (HELCOM, 2013c). During most years, Long-tailed Ducks arrive in the Baltic from their molting grounds in Russia around October to December (Skov et al., 2011). Spring migration occurs in March and in early May.

Long-tailed Ducks are presumed to move frequently among known wintering sites and they migrate both during day- and night time (HELCOM, 2013c).

Long-tailed Ducks are observed throughout the year on Åland, however mainly during migration in spring and autumn and during the non-breeding season in winter (LAJI.FI, 2025). During passage, Long-tailed Ducks also make use of the archipelago as a staging or stop-over ground.

Flocks of migrating Long-tailed Ducks have been reported from the northern archipelago of Åland however, the majority of observations are from the western and south-eastern parts of the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.5 Divers

Divers are hard to quantify as they are primarily offshore species (Skov et al., 2011). Skov et al., (2011) indicated that the population of wintering divers have experienced a decline in the Baltic.

For this study, Red-throated diver (*Gavia Stellata*) and Black-throated diver (*Gavia arctica*) are assessed to be relevant.

Both Red-throated- and Black-throated Diver have circumpolar distributions and many Fenno-Scandinavian breeders winter in the Baltic (Durinck et al. , 1994). Divers breed across northern Eurasia and Red-throated diver furthermore breed in Norway, Greenland and Svalbard, while Black-throated diver breed from northern British Isles and Scandinavia, across Arctic Russia and eastern Siberia (Dorsch et al., 2019).

Very low densities of divers are estimated to winter north of a line between Saaremaa and Stockholm (Skov et al., 2011).

Black-throated and red-throated diver both winter in the Baltic Sea. They start to arrive during September and gradually increase in numbers throughout the following months. Some divers only use the Baltic Sea as a stopover on the way to other wintering quarters in the North Sea, the eastern Atlantic and the Black Sea (Cramp & Simmons, 1977).

Spring migration begin between January and March depending on the harshness of winter. Subsequently, the divers move to the central and eastern Baltic Sea and to the breeding grounds.

By mid-April to mid-May the divers leave the Baltic Sea (Skov et al., 2011).

Mainly Black-throated divers are observed on Åland, and mainly during late spring migration, but also throughout the breeding season and until late autumn (LAJI.FI, 2025). During passage, divers also make use of the archipelago as a staging or stop-over ground.

Migrating divers have been reported from the northern archipelago of Åland however, most observations have been reported from the western and southern islands of the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern), both species.

Annex I of the EU Bird Directive (European-Union, 2010): Listed (both species).

3.6 Great Cormorant *(Phalacrocorax carbo)*

The north-west European breeding populations of two Great Cormorant subpopulations (*P.c.carbo* and *P.c.sinensis*) includes 500,000–525,000 wintering birds (Skov et al., 2011). The current wintering numbers in the Baltic Sea of 54,000 birds constitute 10.3–10.8% of these populations, – a large increase from 19,400 birds recorded during 1988–1993. During the 1980s, the Great Cormorant started to expand its range towards the northern and eastern parts of the Baltic. Currently, the species is present in the whole Baltic Sea area, including the northern parts of the Gulf of Bothnia (HELCOM, 2018). The estimated sizes of the total breeding populations are relatively accurate, and the large increase in the Baltic winter population is undoubtedly a result of the increase of the breeding populations and prolonged periods of mild winters.

The largest concentrations of Great Cormorants in the Baltic Sea were recorded in five regions: Danish waters, the Mecklenburg region of Germany, the southern part of Bohuslän and Gdansk Bay and the Sound. According to previous studies the population of wintering Great Cormorant has increased in the Åland Archipelago by 2,3 %, with a total of 1937 individuals recorded from 2007-2009 (Skov et al., 2011).

The Danish and Swedish breeding population, which belongs to the subspecies *P.c.sinensis* is primarily migratory and migrate to the Mediterranean from August to September.

Great Cormorants are observed throughout the year on Åland, however mainly during late spring migration and during the breeding season in summer (LAJI.FI, 2025). Both during passage and during breeding, Great Cormorants also make use of the archipelago as a staging or stop-over ground.

Migrating Great Cormorants have been reported from the northern archipelago of Åland however, observations have been reported from the outermost north-western to the south-eastern parts of both mainland Åland and throughout the archipelago (Tiira.fi, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.7 Common Crane (*Grus grus*)

The population of Common Cranes breeding in Northwest Europe and Scandinavia increased in size during later years and is estimated to be 350,000 individuals (Wetlands interantional, 2022)

Common Cranes tend to use soaring flight over land, but due to the less frequent thermal updrafts over the open sea they have to maintain altitude by means of powered flight after leaving the coasts (Alerstam, 1990) Studies of flight altitudes of Common Cranes in the Baltic offshore region so far reveal a great deal of variation, with Cranes observed at low altitudes below 200 meters as well as far above (Schulz et al., 2013; Skov et al., 2015) mainly depending on the wind direction relative to the direction of flight.

Especially for Common Cranes from Finland and Sweden, the Southwestern Baltic Sea is an integral part of their migration route to and from wintering quarters in Southwestern Europe.

During spring and autumn, migrating Common Cranes are observed from mainland Åland (Tiira.fi, 2025). During passage, Cranes also make use of Åland as a staging or stop-over ground. Most flocks have been reported in the central parts of mainland Åland, however, few flocks of migrating Common Cranes have been reported from the northern archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Listed.

3.8 Birds of Prey

Birds of Prey, also known as raptors, are all top predators. More than half of the known world species (at least 62% or 183 species) undertake seasonal migrations with many of them performing long-distance migration involving intercontinental flights (Bildstein 2006). Most Birds of Prey perform soaring flight i.e. flight without flapping, making use of the rising air currents thereby reducing energetic costs. Soaring is an efficient form of transport, both during and outside the migration season (Bildstein 2017).

Especially, long-distance migrants are strongly dependent on soaring flight to complete their migration journeys, however, powered flight are also performed by most species and is particularly prominent in species such as ospreys, harriers, most accipiters and falcons. Migrating raptors travel over well-known corridors and often in flocks (Bildstein 2006).

One third of the Finnish White-tailed eagle (*Haliaeetus albicilla*) population breeds on the archipelago of Åland (Saurola, 2008).

During spring and autumn, migrating Birds of Prey, including species such as ospreys, harriers, most accipiters and falcons, are observed from mainland Åland (Tiira.fi, 2025) During passage, Birds of Prey also make use of Åland as a staging or stop-over ground. Some Birds of Prey have been reported migrating from the northern archipelago of Åland however, the Birds of Prey are mainly observed from western, central and southern parts of mainland Åland and from larger islands to the south-east within the archipelago (LAJI.FI, 2025).

White-tailed eagle:

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Listed.

3.9 Gulls

The general term ‘Gulls’ includes different species of small as well as larger Gull species (genus *Larus*). The first include four species that may near the pre-investigation area and additionally also Black-headed Gull (*Chroicocephalus ridibundus)* are included. Many species of Gulls are either unaffected by or even attracted to Offshore Wind Farms (OWF) (Dierschke et al. 2016).

3.9.1 Herring Gull (*Larus argentatus*)

Finnish and other southern Scandinavian breeders move short distances, most remaining in Baltic region, wintering in southern Norway, Kattegat and Skagerrak, but also along western coasts of northern Europe south to Belgium and Britain (Source: Birds of the world). Northeastern populations, in Russia, move south-west either via the Baltic or by following the Norwegian coastline to the North Sea and English Channel.

Herring Gulls arrive to breeding colonies between mid-January and late February. Herring Gulls depart the breeding sites in August, with large concentrations in the Swedish Baltic in September to November (Lyngs 1992).

During spring and autumn, migrating Herring Gulls are observed on all the Åland archipelago, in a broad migratory passage (Tiira.fi, 2025). During passage, Herring Gulls also make use of both mainland Åland, and the islands within the archipelago as a staging or stop-over ground. Flocks of migrating Herring Gulls have been reported from the northern archipelago of Åland, and observations have been reported all the way from outermost north-western parts to the outermost south-eastern parts of the archipelago, with the outermost western and southern islands as accounting for a large majority of observations (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.9.2 Common Gull (*Larus canus*)

The common Gull (*Larus canus*) is primarily migratory and move short- to moderate distances. Birds breeding in Finland and central Russia usually migrate to the Baltic (Burger & Gochfeld , 1996).

In the Baltic Sea, common Gulls (*Larus canus*) breed along Swedish and Finnish coasts. These Gulls are mainly migratory, some birds winter in the northeast and southern Baltic Sea, but most migrate to 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 can be observed in larger flocks containing 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.

During spring and autumn, migrating Common Gulls are observed on all the Åland archipelago, in a broad migratory passage (Tiira.fi, 2025). During passage, Common Gulls also make use of both mainland Åland, and the islands within the archipelago as a staging or stop-over ground. Flocks of migrating Common Gulls have been reported from the northern archipelago of Åland, and observations have been reported all the way from outermost north-western parts to the outermost south-eastern parts of the archipelago, with the outermost western and southern islands as accounting for a large majority of observations (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.9.3 Lesser black-backed Gull (*Larus fuscus*)

Lesser-Black backed Gull (*Larus fuscus*) is a widespread species of Gull in the Baltic Sea.

The largest breeding populations in the Baltic are found in Finland, Sweden and Russia, but the population has suffered a decline since the 1970’s. The population was estimated to approximately 20.000 breeding pairs in the 1960’s, while the population in Finland in 2006-2010 was estimated to around 7.000 breeding pairs (HELCOM, 2013d).

Lesser black-backed Gull is a long-distance migrant that migrates from the Baltic to the African continent.

The spring migration takes place between March and April.

During spring and autumn, migrating Lesser black-backed Gulls are observed from mainland Åland, and the northern placed islands (Tiira.fi, 2025) During passage, Lesser black-backed Gulls also make use of Åland as a staging or stop-over ground.

Several flocks of migrating Lesser black-backed Gulls have been reported from the northern archipelago of Åland however, with most observations are from the south and north-eastern parts of the archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.9.4 Great Black-backed Gull (*Larus marinus*)

Great Black-backed Gulls (*Larus marinus*) occur in the Baltic Sea along coastlines and offshore during winter.

The majority of the Great black-backed Gulls which breed on the Swedish coast are believed to be sedentary, while the Finish and Estonian populations move to the southern part of the Baltic during the winter, especially during harsh winters (Durinck et al. , 1994).

During spring and autumn, migrating Great black-backed Gulls are observed from mainland Åland and from the larger islands of the archipelago (Tiira.fi, 2025). During passage, Great black-backed Gulls also make use of Åland as a staging or stop-over ground. Flocks of migrating Great black-backed Gulls have been reported from the northern archipelago of Åland however, most observations are from the outermost western to the outermost south-eastern parts of the archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.9.5 Black-headed Gull (*Chroicocephalus ridibundus*)

Black-headed Gulls (*Chroicocephalus ridibundus*) are relatively widespread in the Baltic and the northern breeders are primarily migratory, while populations at lower latitudes tend to be resident. Scandinavian breeders migrate to Britain (Olsen & Larsson, 2004) and some birds follow the Atlantic coast down to western Africa.

The migratory populations return to the breeding grounds around February to late March (CornellLab, 2020).

Black-headed Gull is considered of Least Concern (LC) according to the European IUCN Red List category (BirdLife International, 2022).

During spring and autumn, migrating Black-headed Gulls are observed from mainland Åland (Tiira.fi, 2025). During passage, Black-headed Gulls also make use of Åland as a staging or stop-over ground.

Several flocks of migrating Black-headed Gulls have been reported from the northern archipelago of Åland, with most observations from the outermost western, central northern and central southern parts of mainland Åland (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.10 Mergansers

3.10.1 Red-breasted Merganser (*Mergus serrator*)

The Red-breasted Merganser is a regular and common winter and occurs during migration in the Baltic Sea (HELCOM, 2019).

The Red-breasted Merganser (*Mergus serrator*) has a wide breeding range spanning across northern Eurasia, southern Greenland and North America (Robinson, J.A, 1999; Scott & Rose, 1996). According to previous studies, the wintering Baltic population was estimated around 25.700 (2007-2009) (Skov et al., 2011).

The species' migratory behavior varies between regions. Birds breeding in Finland and northwest Russia are highly migratory, wintering mainly in northwest Europe, especially the Baltic Sea, but also in small numbers along the north coast of the Mediterranean (Scott & Rose, 1996). During autumn migration the migrants from northern breeding grounds begin to arrive in the Baltic in September. While some of the mergansers remain in the Baltic during winter, some will continue to the Netherlands and Britain. Spring return depends on thawing, but the majority of Red-breasted Mergansers usually start migration in March and April (Skov et al., 2011).

The most important wintering areas in the Baltic Sea are in the south-western part along the coasts of Denmark, Sweden, Germany and Poland as well as along the coast of Gotland and in the Gulf of Riga.

During spring, mainly, and autumn, migrating Red-breasted Mergansers are observed from mainland Åland and from the larger islands of the archipelago (Tiira.fi, 2025). During passage, Red-breasted Mergansers also make use of the islands within the archipelago as a staging or stop-over ground. Flocks of migrating Red-breasted Mergansers have been reported from the northern archipelago of Åland however, most observations are from the outermost western to the southern and south-eastern parts of mainland Åland (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): NT (Near Threatened).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.10.2 Goosander (*Mergus merganser*)

The Goosander breeds across Eurasia and North America (Scott & Rose, 1996). The Goosander winter in eastern Germany, southern Europe, west Poland and along the Swedish east coast. The main area on the Swedish coastline is around Kalmar Sound (holding 5000 individuals) and the Stockholm Archipelago (holding 3800 individuals).

The current wintering population of Goosander (*Mergus merganser*) has been estimated to 66,000 individuals (Skov et al., 2011).

Migrants from the north starts to arrive in the Baltic Sea around October to December and spring return commences between January and March.

During spring and autumn, migrating Goosanders are observed from mainland Åland and from the larger islands of the archipelago (Tiira.fi, 2025). During passage, Goosanders also make use of the islands within the archipelago as a staging or stop-over ground. Flocks of migrating Goosanders have been reported from the northern archipelago of Åland however, most observations are from the western to the southern and south-eastern parts of mainland Åland and larger islands of the archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed.

3.11 Terns

3.11.1 Biology, distribution and abundance

The most common species of terns in the pre-investigation area are Sandwich Tern (*Thalasseus sandvicensis*), Arctic Tern (*Sterna paradisaea*) and the Common Tern (*Sterna hirundo*).

Sandwich terns were not breeding in the Baltic Sea until the beginning of the 20th century (Hermann et al., 2008). In the Baltic (central Sweden/Estonia), the species reaches its actual northern range limit and in the mid 1970's the northmost breeding place was recorded in the Stockholm Archipelago (HELCOM, 2019).

The Arctic Tern is a regular breeder in Finland (LAJI.FI, 2025) and a long-distance migratory species in Eurasia. It migrates from Finland to winter in Antarctica and is therefore likely present in the pre-investigation area.

All mentioned terns 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). Sandwich tern is not expected to occur abundantly in the pre-investigation area.

During spring and autumn, migrating Terns, mainly Common and Arctic Terns, are observed from mainland Åland and from the larger islands of the archipelago (Tiira.fi, 2025). During passage, Terns also make use of the islands within the archipelago as a staging or stop-over ground. Flocks of migrating Terns, especially Arctic Tern, have been reported from the northern archipelago of Åland however, most observations of both Common and Arctic Terns are from the western to the southern and south-eastern parts of mainland Åland and larger islands of the archipelago (LAJI.FI, 2025).

IUCN Red List (BirdLife International, 2022): LC (Least Concern), all species.

Annex I of the EU Bird Directive (European-Union, 2010): Listed (both species).

3.12 Auks

3.12.1 Biology, distrubution and abundance

The relevant auks for this report include Common guillemot/murre (*Uria aalge*), Black guillemot (*Cepphus grylle*) and Razorbill (*Alca torda*). Occasionally, other auks such as the Atlantic puffin (*Fratercula arctica*) are also observed in the Baltic Sea.

Over two thirds of the population of common guillemots and 30% of the populations of razorbills breed in two small islands (Störa Karlso and Lilla Karlsö), which are located west of the island of Gotland and are famous for large colonies of fish-eating birds in the Baltic Sea (Olsson & Hentati-Sundberg 2017).

The Baltic population of Black guillemot, breeds at the Swedish east coast, in Finland, St. Petersburg region of Russia, and Estonia (HELCOM, 2018). This breeding population covers an extensive range, and the species is very dispersed during the breeding season.

During spring and autumn, migrating Auks, mainly Razorbills, but also Black guillemots, are observed from mainland Åland and from islands within the archipelago (Tiira.fi, 2025). During passage, Auks also make use of the islands within the archipelago as a staging or stop-over ground. Flocks of migrating Razorbills and Black guillemots have been reported from the northern archipelago of Åland, with several observations of both Razorbills and Black guillemots to the north-western and northern parts of mainland Åland. However, a considerable number of observations have also been reported from the western, southern and to the south-eastern parts of the archipelago (LAJI.FI, 2025).

<u>Common- and black guillemot and razorbill</u>

IUCN Red List (BirdLife International, 2022): LC (Least Concern)

Annex I of the EU Bird Directive (European-Union, 2010): Not listed).

<u>Atlantic puffin:</u>

IUCN Red List (BirdLife International, 2022): EN (Endangered).

Annex I of the EU Bird Directive (European-Union, 2010): Not listed).

4 Results

4.1 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:

- **Species composition** to identify the most frequent migratory species in the investigation area.
- **Flight altitudes** to identify the flight height profiles of migrating birds.
- **Migration intensity** to analyse migration intensity patterns across the migration seasons.
- **Flight direction** to analyse migration patterns including certain potential migration corridors or specific routes.
- **Migration patterns** of relevant species and species groups.

4.2 General Species Composition

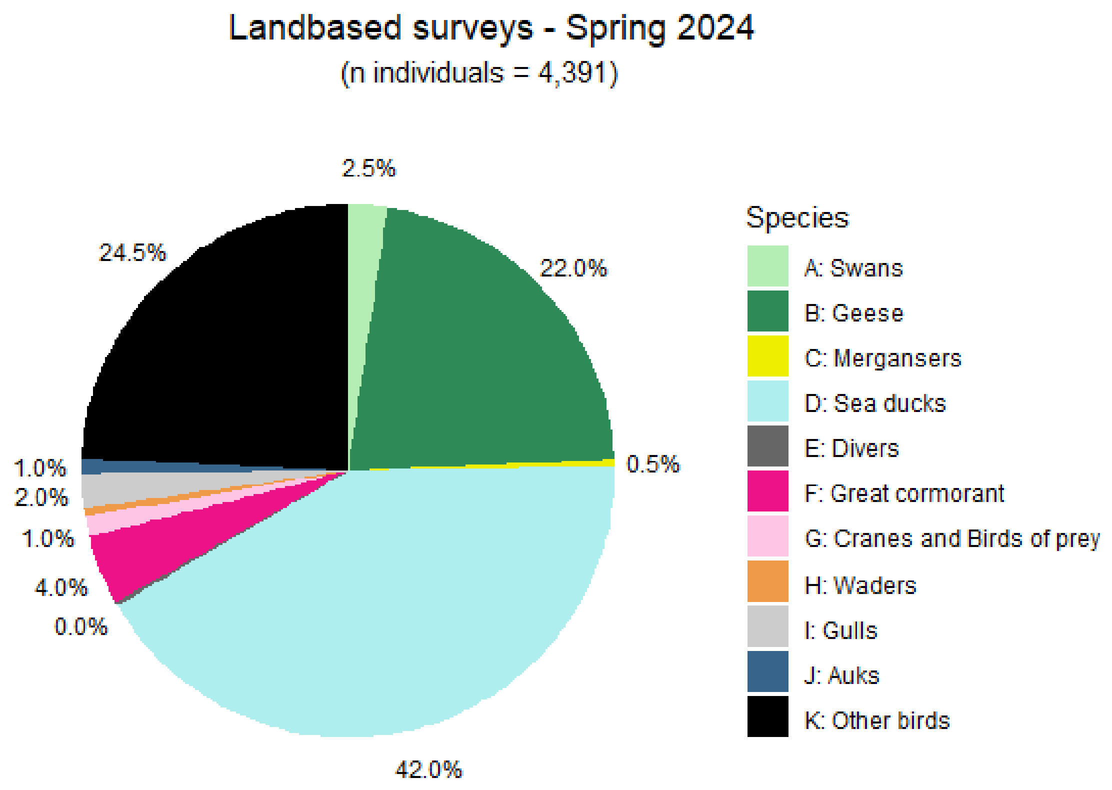
In spring and autumn 2024, diurnal bird migration was recorded from two observation points on land; west of Havsvidden and Dånö, Langnäs as well as offshore from a vessel using a combination of transects and anchoring points. During the inventories, 195 tracks of migrating birds were recorded by the horizontal radar. These records were supplemented by visual observations; a total of 493 observations of either single individuals or flocks of birds were collected from land, whereas 259 observations were collected during the offshore surveys. The observation period usually started from the time of sunrise and continued for approximately eight hours. The surveys were conducted in relation to the migratory tendencies of the relevant species groups, favorable weather conditions for observations and for tracking of bird flocks by the horizontal radar, so that days with good conditions were present, to some degree, throughout the survey period.

In general, bird migration does not only vary between spring (before the breeding season) and autumn (after the breeding season) but also between offshore and onshore locations, between day- and night and across taxa.

Both during spring and autumn migration, the predominant species groups were Sea ducks (mainly Eider, but also Common Scoter and Velvet Scoter), Cormorants (Great Cormorant), Geese (such as Greylag Goose, Greater White-fronted Goose, Canada Goose and Barnacle Goose).

Other regularly occurring groups of migrant species include Swans (Mute Swan and Whooper Swan), Mergansers (Goosander), Dabbling ducks (Eurasian Wigeon, Mallard, Northern Pintail, and Eurasian Teal), Divers (Black-throated Diver), Birds of Prey (Common Buzzard, Hen Harrier, Hobby, Honey Buzzard, Kestrel, Merlin, Osprey, Peregrine Falcon, Rough-legged Buzzard, and Sparrowhawk), Cranes (Common Crane), Waders (Curlew, Dunlin, Golden Plover, Greenshank, Lapwing, and Oystercatcher), Gulls (Black-headed Gull, Common Gull, Great Black-backed Gull, Herring Gull, and Lesser Black-backed Gull), Terns, (Arctic Tern), Auks (Common Guillemot, and Razorbill) and other passerine and non-passerine birds (such as finches, thrushes and pipits, pigeons, corvids, swifts and swallows).

Species composition from the land-based and offshore surveys in spring and autumn are presented as pie charts in Figure 7 and Figure 8.



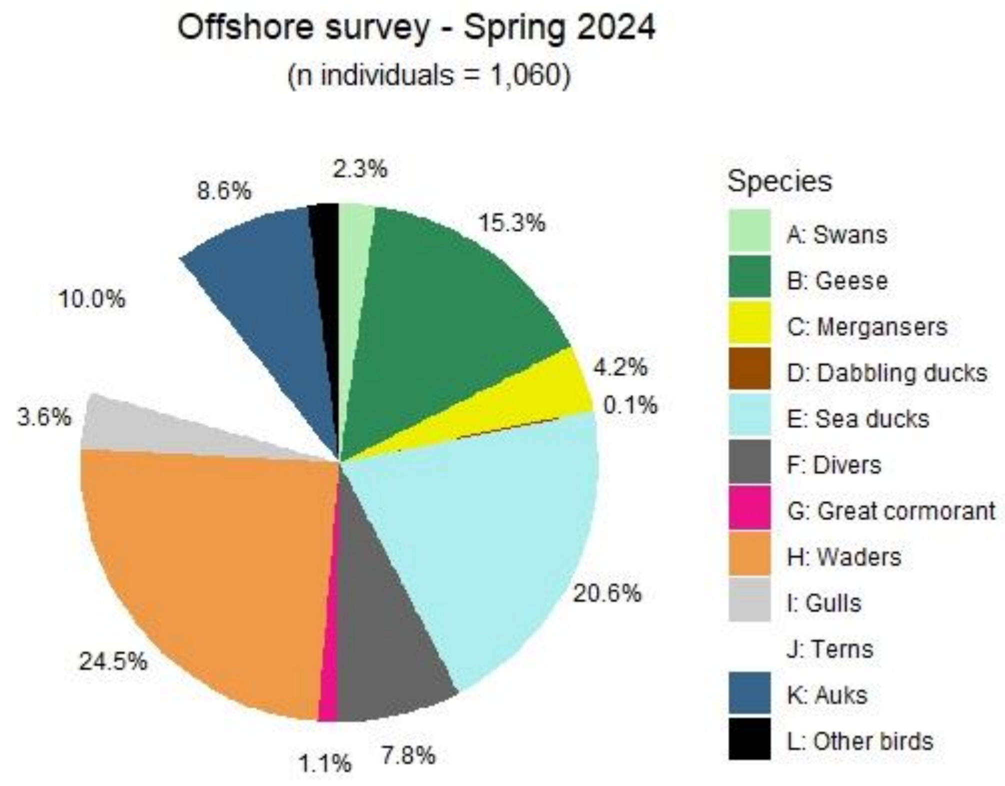


Figure 7. Proportion of diurnal migratory bird species observed during spring 2024. Top: Land-based surveys. bottom: Offshore surveys. The category "other birds" includes all other observed bird taxa. The sample size is provided as n = the number of individuals recorded.

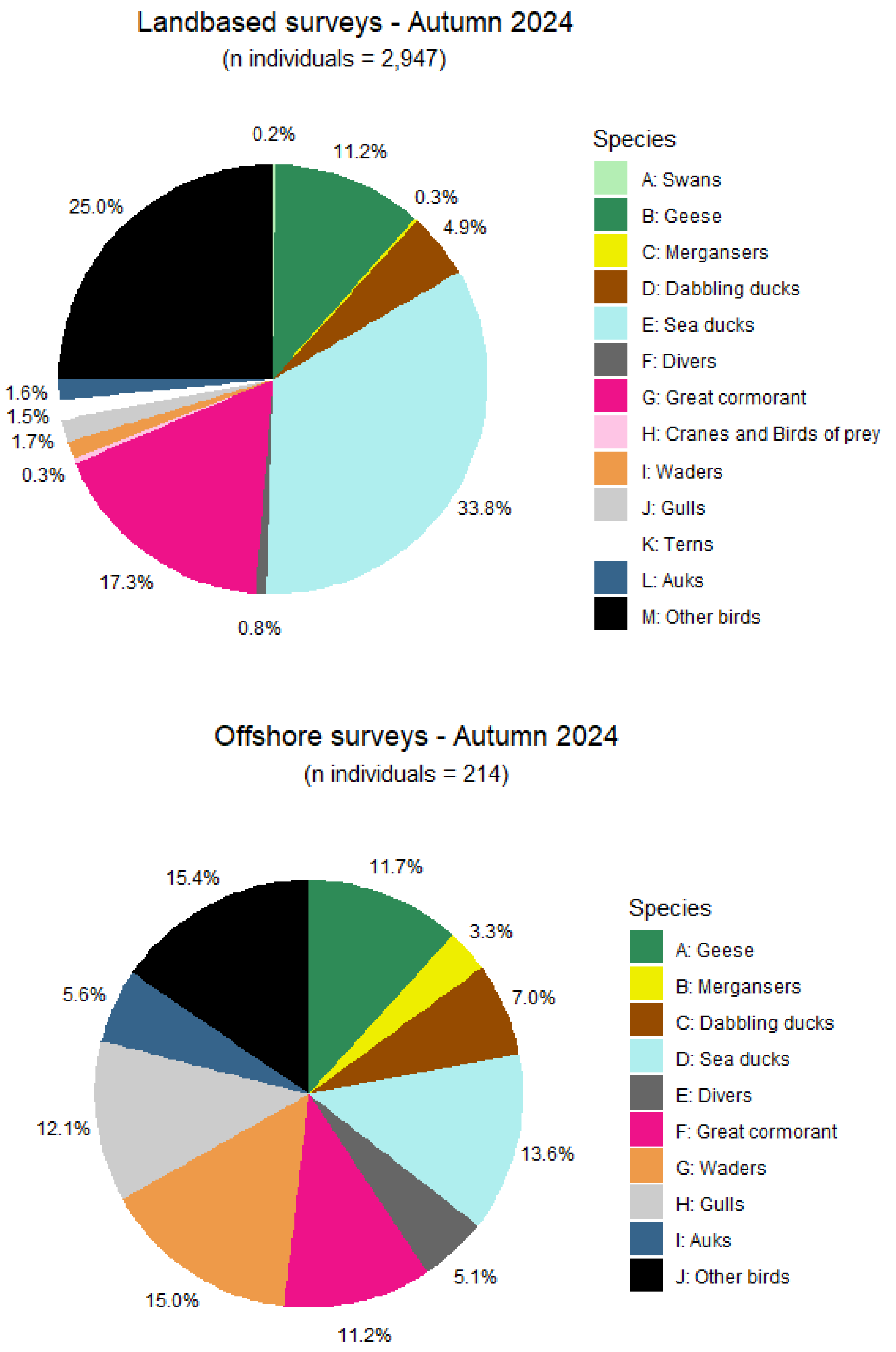


Figure 8. Proportion of diurnal migratory bird species observed during autumn 2024. Top: Land-based surveys. bottom: Offshore surveys. The category "other birds" includes all other observed bird taxa. The sample size is provided as n = the number of individuals recorded.

4.3 General Flight Altitude

The flight altitude of migrating birds can vary from a few centimeters to several thousand meters above sea and ground level, depending mostly on taxon, geography and the ambient weather conditions. Two different methods were applied to collect data flight heights of migrating birds:

- Visual observation of the migrating bird's altitude during observation periods, supplemented by laser-rangefinder measurements (observations up to 330 m), and
- Vertical radar surveys of diurnal and nocturnal migrants flying at altitudes up to 1,500 m.

4.3.1 Visual observations

Results collected from the land-based and offshore visual observations showed in general, during both spring and autumn, that the vast majority of the observed flocks migrated at altitudes below 50 meters and especially within the interval 0 -10 meters above surface (Figure 9) and (Figure 10). This tendency was particularly evident in the offshore surveys where > 98 % of the recorded flight heights were below 50 meters in both spring and autumn. This contrasts with the heights recorded from land with 60 and 79 % flying at altitudes below 50 meters in spring and autumn, respectively.

4.3.2 Land-based - Spring

During the land-based observations of migrating birds in spring 2024, flight heights were observed varying from 1 – 320 meters, based on visual estimates and laser-rangefinder measurements of 283 flocks of birds, distributed within ten different taxonomical groups and a combined group of less relevant or unidentified observations. The majority of the observed flocks, 60 %, migrated at altitudes below 50 meters.

The highest frequency of migratory flight heights was found within the interval 0 – 10 meters with 24 % of the flocks observed migrating at altitudes below 10 meters. While the frequency found within the interval of 0 – 20 meters was 36 % and the frequency found within the interval of 0 – 30 meters was 41 %.

Of the flocks migrating at altitudes higher than 50 meters, which was 40 % of the observed flocks, most of the flocks migrated at altitudes below 110 meters, 90 %, and especially at altitudes within the interval 50 – 60 meters, 12 %, and within the interval 100 – 110 meters, 7 %. For a graphic display see (Figure 9) below.

4.3.3 Land-based – Autumn

During the land-based observations of migrating birds in autumn 2024, flight heights were observed varying from 1 – 230 meters, based on estimations and laser-rangefinder data of 210 flocks of birds, distributed within 12 different taxonomically groups and a combined group of less relevant or unidentified observations. Most of the observed flocks, 79 %, migrated at altitudes below 50 meters.

The highest frequency of migratory flight heights was found within the interval 0 – 10 meters with 32 % of the flocks observed migrating at altitudes below 10 meters. While the frequency found within the interval of 0 – 20 meters was 49 % and the frequency found within the interval of 0 – 30 meters was 61 %.

Of the flocks migrating at altitudes higher than 50 meters, which was 21 % of the observed flocks, most of the flocks migrated at altitudes below 70 meters, 90 %, and especially at altitudes within the interval 50 – 60 meters, 5 %, and within the interval 60 – 70 meters, 5 %. For a graphic display see (Figure 9) below.

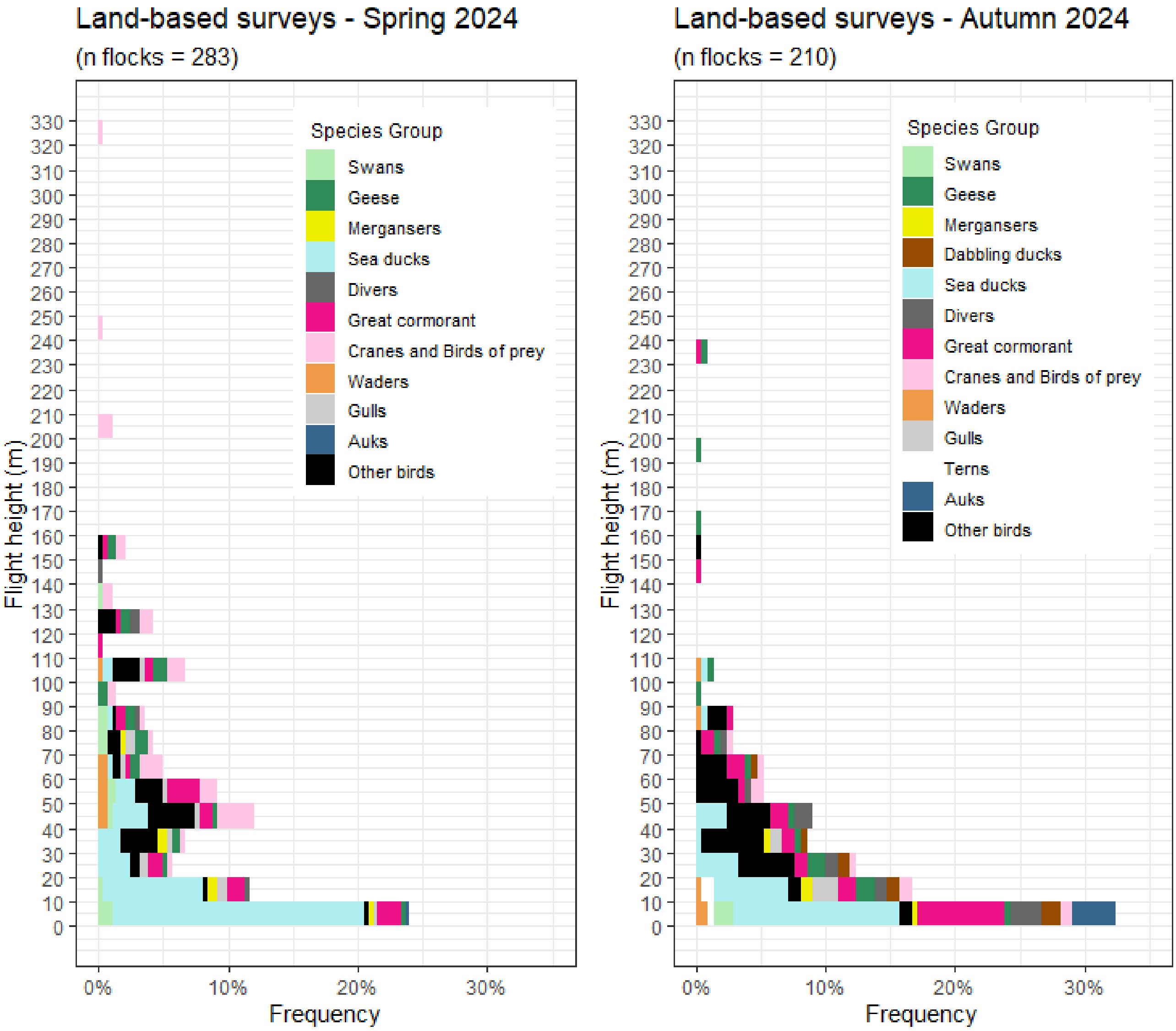


Figure 9. Results of the flight height distribution collected through the land-based observations during spring (to the left) and autumn (to the right). The observed flocks have been sorted into species groups based on their taxonomy and depicted in different colors. The flight height of each flock has been clustered in 10 m intervals and frequency of the number of flocks within each interval are shown in percent.

4.3.4 Offshore - Spring

During the offshore observations of migrating birds in spring 2024, flight heights were observed varying from 1 – 180 meters, based on estimations and laser-rangefinder data of 206 flocks of birds, distributed within 11 different taxonomically groups and a combined group of less relevant or unidentified observations. Most of the observed flocks, 99 %, migrated at altitudes below 50 meters.

The highest frequency of migratory flight heights was found within the interval 0 – 10 meters with 55 % of the flocks observed migrating at altitudes below 10 meters. While the frequency found within the interval of 0 – 20 meters was 90 % and the frequency found within the interval of 0 – 30 meters was 99 %.

Of the flocks migrating at altitudes higher than 50 meters, which was 1 % of the observed flocks, the flocks migrated at altitudes within the interval 100 – 110 meters, 0.5 %, and within the interval 180 – 190 meters, 0.5 %. For a graphic display see (Figure 10) below.

4.3.5 Offshore - Autumn

During the offshore observations of migrating birds in autumn 2024, flight heights were observed varying from 1 – 50 meters, based on estimations and laser-rangefinder data of 53 flocks of birds, distributed within nine different taxonomically groups and a combined group of less relevant or unidentified observations. Most of the observed flocks, 98 %, migrated at altitudes below 50 meters.

The highest frequency of migratory flight heights was found within the interval 0 – 10 meters with 62 % of the flocks observed migrating at altitudes below 10 meters. While the frequency found within the interval of 0 – 20 meters was 75 % and the frequency found within the interval of 0 – 30 meters was 83 %.

Of the flocks migrating at altitudes higher than 50 meters, which was 2 % of the observed flocks, the flocks migrated at altitudes within the interval 50 – 60 meters. For a graphic display see (Figure 10) below.

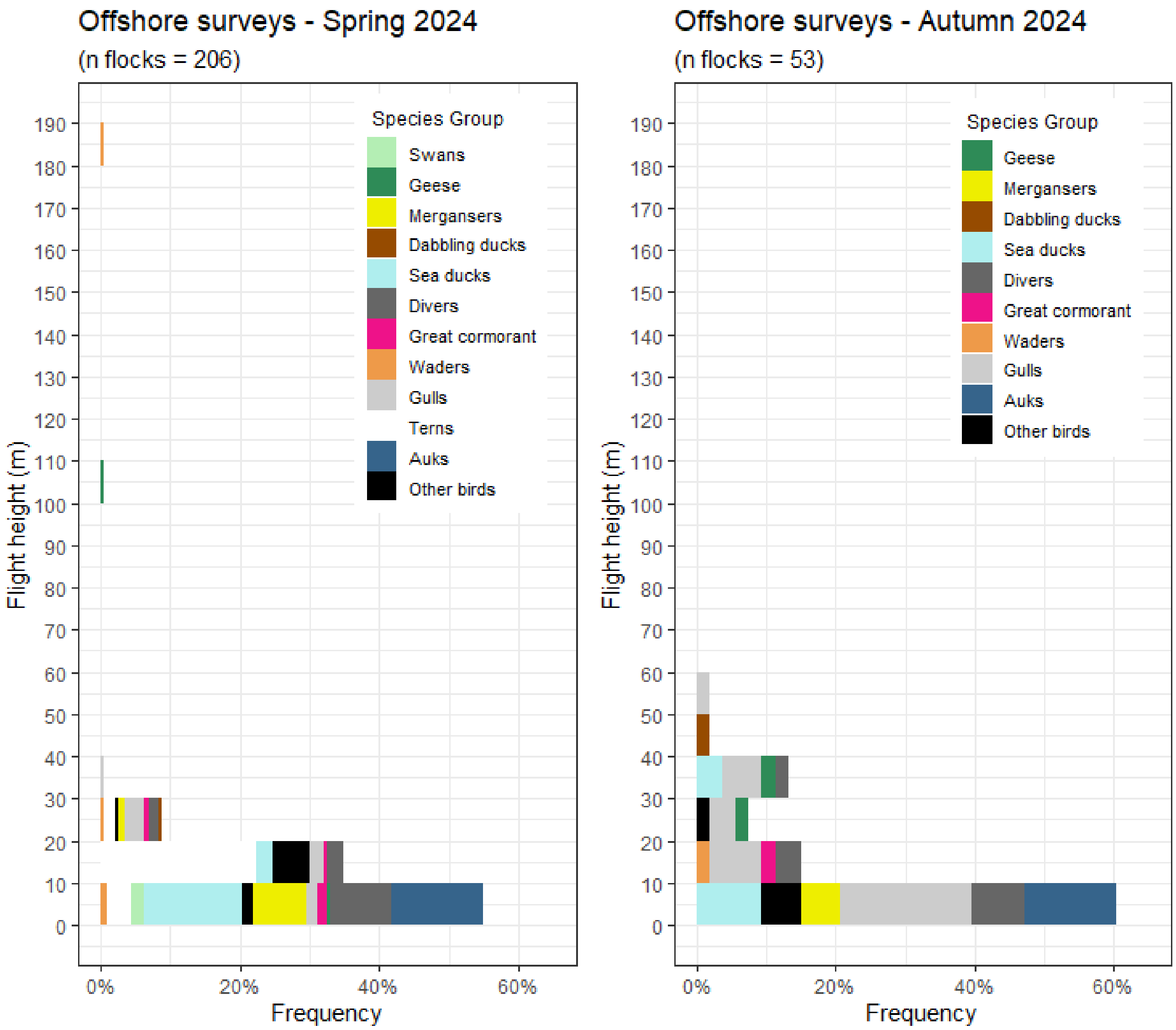


Figure 10. Results of the flight height distribution collected through the offshore observations during spring (to the left) and autumn (to the right). The observed flocks have been sorted into species groups based on their taxonomy and depicted in different colors. The flight height of each flock has been clustered in 10 m intervals and frequency of the number of flocks within each interval are shown in percent.

4.3.6 Vertical radar

Vertical radar data for flight height of migratory birds was available for spring and autumn 2024. Diurnal and nocturnal flight height distribution from vertical radar in spring 2024 were not very different from each other and resembled the height profiles inferred from the visual observations (Figure 9 and Figure 10). In both cases, the majority of the signals were detected in the lowest 100 m above the sea surface (Figure 11). However, a lightly smaller proportion (~ 23 %) of the migrants were detected in the lower 100 m height interval during the night than during daylight (~ 32 %) indicating that nocturnal migration occurs at slightly higher altitudes. In autumn, the majority of the signals during both day and night were detected in the height interval between 100 – 200 m above the sea surface (Figure 12).

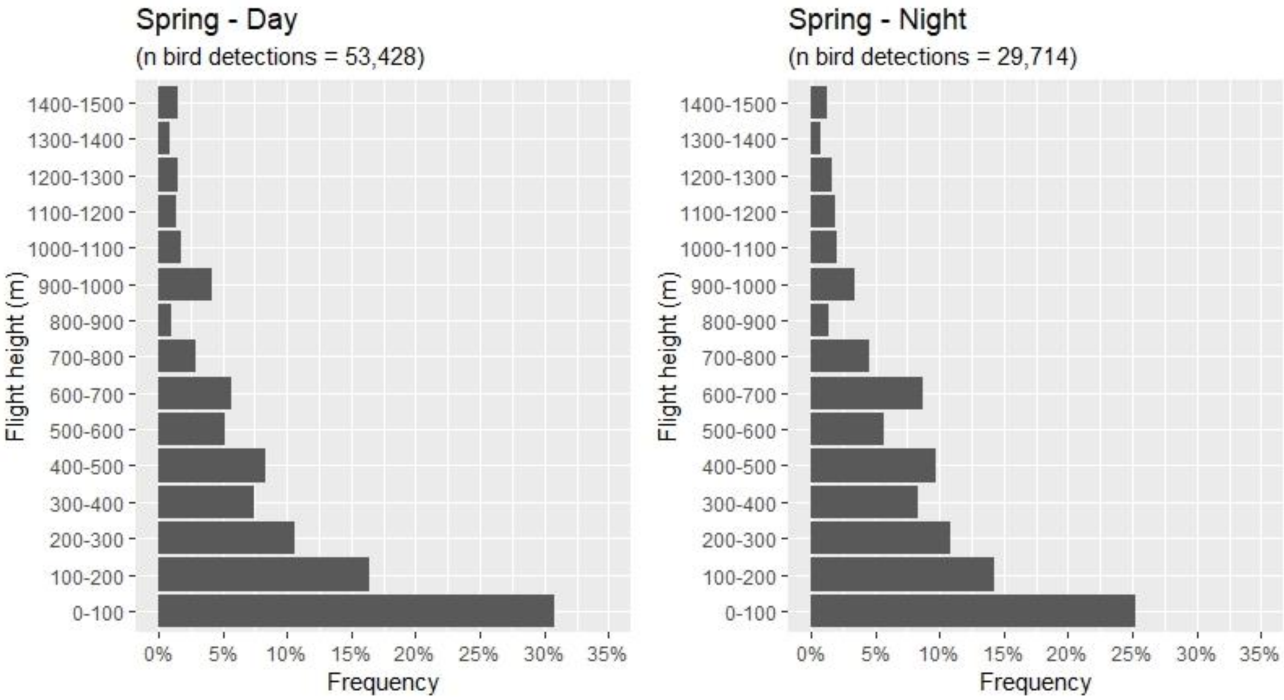


Figure 11. Flight height distribution based on vertical radar data collected from Dånø, Åland in spring 2024. Depicted is the relative frequency of signals up to 1,500 m height presented in 100 m increments. The panel on the left side show the altitude distribution of birds during the daylight phase, right panels during the night. The number of bird track detections is indicated above the plot

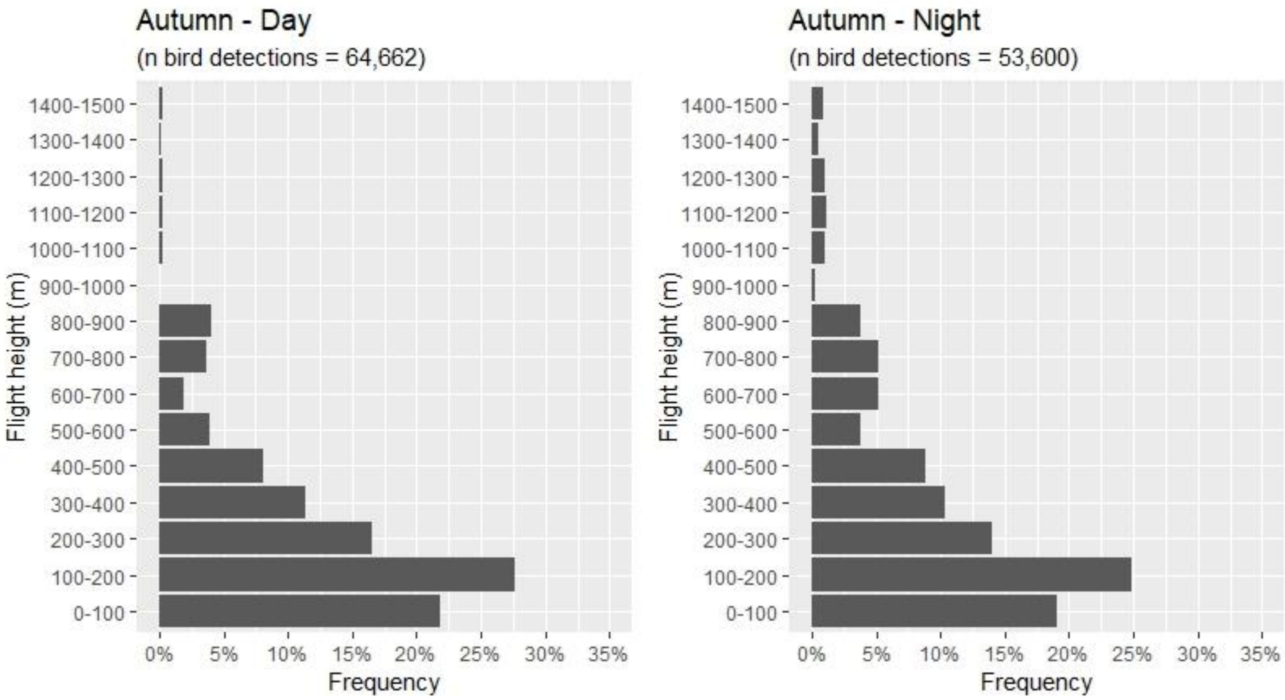


Figure 12. Flight height distribution based on vertical radar data collected from Dånö, Åland in autumn 2024. Depicted is the relative frequency of signals up to 1,500 m height presented in 100 m increments. The panel on the left side show the altitude distribution of birds during the daylight phase, right panels during the night. The number of bird track detections is indicated above the plot.

4.4 Migration intensity

Migration intensity, measured as the mean traffic rate of migratory birds/km/hour, varied considerably between spring and autumn with the highest mean intensities recorded in spring and the highest peak intensities recorded during the night in autumn (Figure 13). Within these peak migration periods, between 200 – 250 birds/km/hour were recorded by the vertical radar, whereas the mean intensity in autumn was below 50 birds/km/hour. Moreover, migration intensity also varied substantially between the two altitude bins considered (0-500 m and 500-1500 m), whereas only slight variation was evident between day and night.

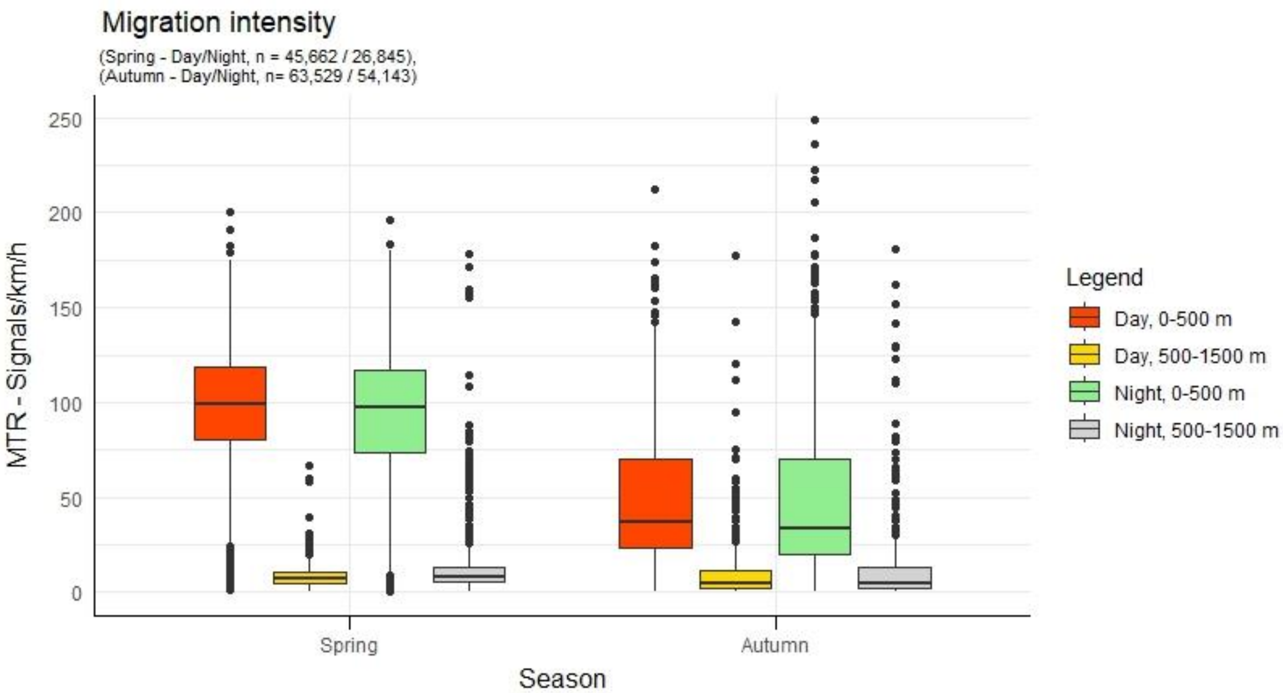


Figure 13. Migration intensity presented as Mean Traffic Rate (MTR) computed from vertical radar data collected during the 2024 field season on Åland. MTR values are presented as boxplots and segregated with respect to season, day/night and altitude (0-500 m and 500-1500 m). The number of bird detections (corrected for detection bias) in spring and autumn and per day and night are indicated above the plot.

4.5 General Flight Direction

The migratory directions observed throughout the survey period varied a lot from day to day, especially in relation to weather conditions such as wind speed and directions, rain etc. However, some patterns and different tendencies was found.

Additionally, it was possible to estimate whether the directions of the produced radar tracks would intervene with the pre-investigation area, by extending the produced tracks from the horizontal radar. Spatial extrapolation of the leading and trailing edge of the recorded radar tracks offered the opportunity to investigate potential intersections with the pre-investigation area by assuming no change in flight direction, which may occur as a result of re-orientation, changes in wind conditions or as an avoidance response towards the planned wind farm. Between the two layouts, “Old planning area” and “Planning area”, less than a 3 % difference in flocks that entered the bounds of the pre-investigation area was found. Most of the observed flight directions, tracked by the horizontal radar, can be explained by three groups divisions: Sea ducks, Great Cormorant and Bird sp.

4.5.1 Horizontal radar and land-based visual observations - Spring

During spring, the tracks obtained by the horizontal radar show patterns with strong tendencies of the main migratory directions, with 76 % of the observed flocks heading in a NNE direction (42 % heading directly NNE, while 17 % heading more NE and another 17 % heading more N).

By the extension of the produced tracks, 35 % of the tracks showed directions that would enter the bounds of the pre-investigation area, with Sea ducks, Great Cormorant and Bird sp. accounting for 28 % of this tendency, elaborated under the species-specific section 5.1.6.

From the land-based visual observations, similar tendencies are found, though less pronounced. The main migratory directions found was northeast and east with 56 % of the flocks observed heading in those directions (36 % heading NE, and 20 % heading E).

The rest of the flocks was observed, migrated in most other directions distributed more or less equally with a percentwise distribution varying from 0.3 – 11 % between every other direction.

4.5.2 Offshore visual observations – Spring

From the offshore visual observations, the main migratory directions found was in northern and eastern directions, with 62 % of the flocks observed heading in those directions (20 % heading N, 17 % heading E, 15 % heading NE, and 10 % heading NW). However, at the same time, 26 % of the observed migration was heading in more southern and western directions (12 % heading S, 6 % heading SE, and 8 % heading W).

The rest of the flocks was observed, migrated in most other directions distributed more or less equally with a percentwise distribution varying from 0.5 – 5 % between every other direction.

4.5.3 Land-based visual observations and horizontal radar – Autumn

During autumn, the tracks obtained by the horizontal radar show patterns with strong tendencies of the main migratory directions, with 74 % of the observed flocks heading in a SSW direction (36 % heading directly SSW, while 24 % heading more SW and another 14 % heading more S).

By the extension of the produced tracks, 46 % of the tracks showed directions that would enter the bounds of the pre-investigation area, with Sea ducks, Bird sp., Great Cormorant, Sea ducks and geese accounting for 38 % of this tendency, elaborated under the species-specific section 5.1.6.

From the land-based visual observations, similar tendencies are found, though slightly less pronounced. The main migratory directions found was west and southwest with 65 % of the flocks observed heading in those directions (34 % heading W, and 31 % heading SW). However, besides the main migratory directions, another 13 % of the observed migration had unspecified directions.

The rest of the flocks was observed, migrated in most other directions distributed more or less equally with a percentwise distribution varying from 0.5 – 8 % between every other direction.

4.5.4 Offshore visual observations – Autumn

From the offshore visual observations, the main migratory directions found was southwest and south with 68 % of the flocks observed heading in those directions (49 % heading SW, and 19 % heading S).

The rest of the flocks was observed, migrated in most other directions distributed more or less equally with a percentwise distribution varying from 4 – 8 % between every other direction.

Furthermore, visualizations of individual tracks for the relevant species groups are presented alongside the elaborated migration tendencies under the species-specific section 5.1.6.

4.6 Relevant Species and 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.

4.6.1 Swans

The total number of Swans observed throughout the survey period was 136 individuals, distributed in 19 flocks (16 flocks during spring and 3 flocks during autumn).

The species composition of the flocks observed consisted of two different species of Swans:

→ Mute Swan (n = 9, distributed in 4 different flocks), and

- Whooper Swan (n = 107, distributed in 11 different flocks),

as well as a sub-group called:

- Swan sp. (n = 20, distributed in 4 different flocks).

The general average flight height for Swans was 31.4 m (ranging from 1 – 130 meters).

The majority of the flocks were observed during the land-based observations (15 flocks, n = 112), while the remaining flocks were observed in spring during the offshore observations (4 flocks, n = 24).

Of the flocks which were observed during the land-based observations in spring, five flocks (n = 45) got detected by the horizontal radar and produced tracks, mainly on flocks of Whooper Swans (n = 41, distributed in 3 flocks), one of the five flocks showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 20 % of the flocks recorded by the horizonal radar.

During spring the main migratory direction was northeast, with 10 flocks heading towards that direction in an average altitude of 40.2 meters.

During autumn no clear tendency on main migratory direction was found.

4.6.2 Geese

The total number of geese observed throughout the survey period were 1482 individuals, distributed in 41 flocks (23 flocks during spring and 18 flocks during autumn).

The species composition of the flocks observed consisted of five different species of geese:

- Barnacle Goose (n = 660, distributed in 5 different flocks),
- Bean Goose (n = 2, distributed in 1 flock),
- Canada Goose (n = 15, distributed in 1 flock),
- Greylag Goose (n = 253, distributed in 11 different flocks), and
- Greater White-fronted Goose (n = 209, distributed in 8 different flocks),

as well as two sub-groups called:

- Anser sp. (n = 108, distributed in 6 different flocks), and
- Goose sp. (n = 235, distributed in 9 different flocks).

The general average flight height for Geese was 70 m (ranging from 1 – 230 meters).

The majority of the flocks were observed during the land-based observations (37 flocks, n = 1295), while the remaining flocks were observed during the offshore observations (4 flocks, n = 187).

Of the flocks that was observed during the land-based observations, 26 flocks (n = 594) got detected by the horizontal radar and produced tracks (13 flocks during spring and 13 flocks during autumn), mainly on flocks of:

- Greater White-fronted Goose (n = 209, distributed on 8 tracks),
- Greylag Goose (n = 156, distributed on 5 tracks), and
- Anser sp. (n = 105, distributed on 5 tracks).

During spring, four of the 13 flocks detected by horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 31 % of the flocks of geese recorded by the horizonal radar within the period.

During autumn, another four of 13 flocks, detected by horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 31 % of the flocks of geese recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions was northeast and east, respectively, with 17 flocks (n = 1031) heading towards those directions in an average altitude of 81.2 meters. The average migration direction found based on the produced radar tracks was 59 ° (n = 13)

During autumn the main migratory direction was southwest with 18 flocks (n = 356) heading towards those directions in an average altitude of 62.5 meters. The average migration direction found based on the produced radar tracks was 241 ° (n = 13).

In the following visualizations, the produced individual tracks and the extended tracks are presented for geese migration during spring (Figure 14-Figure 15) and during autumn (Figure 16-Figure 17).

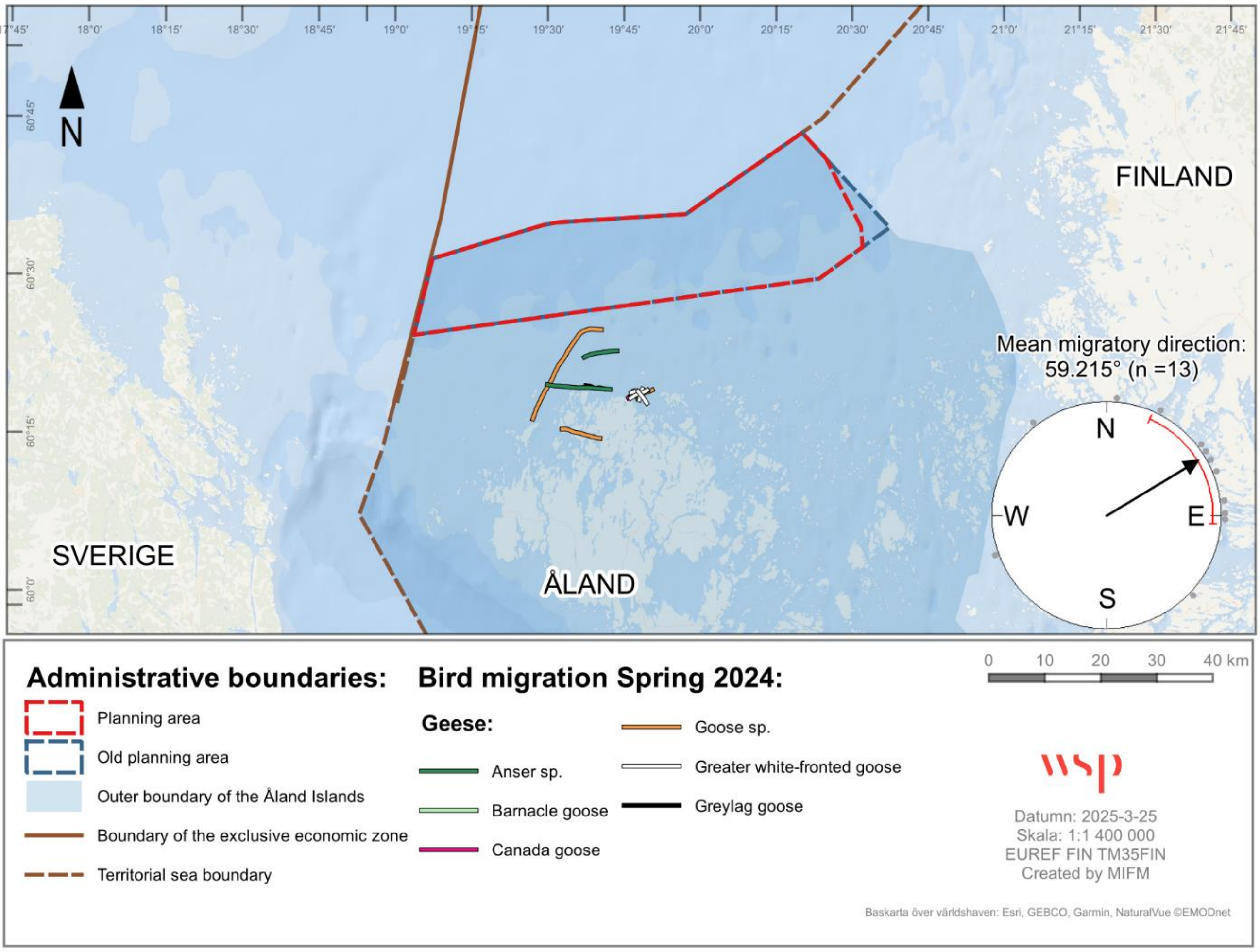


Figure 14. Visualization of the produced radar tracks for geese (n = 13), during spring 2024. The circular plot shows the smoothed migration direction on a 360° axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averages for all tracks (avg = 59.215°).

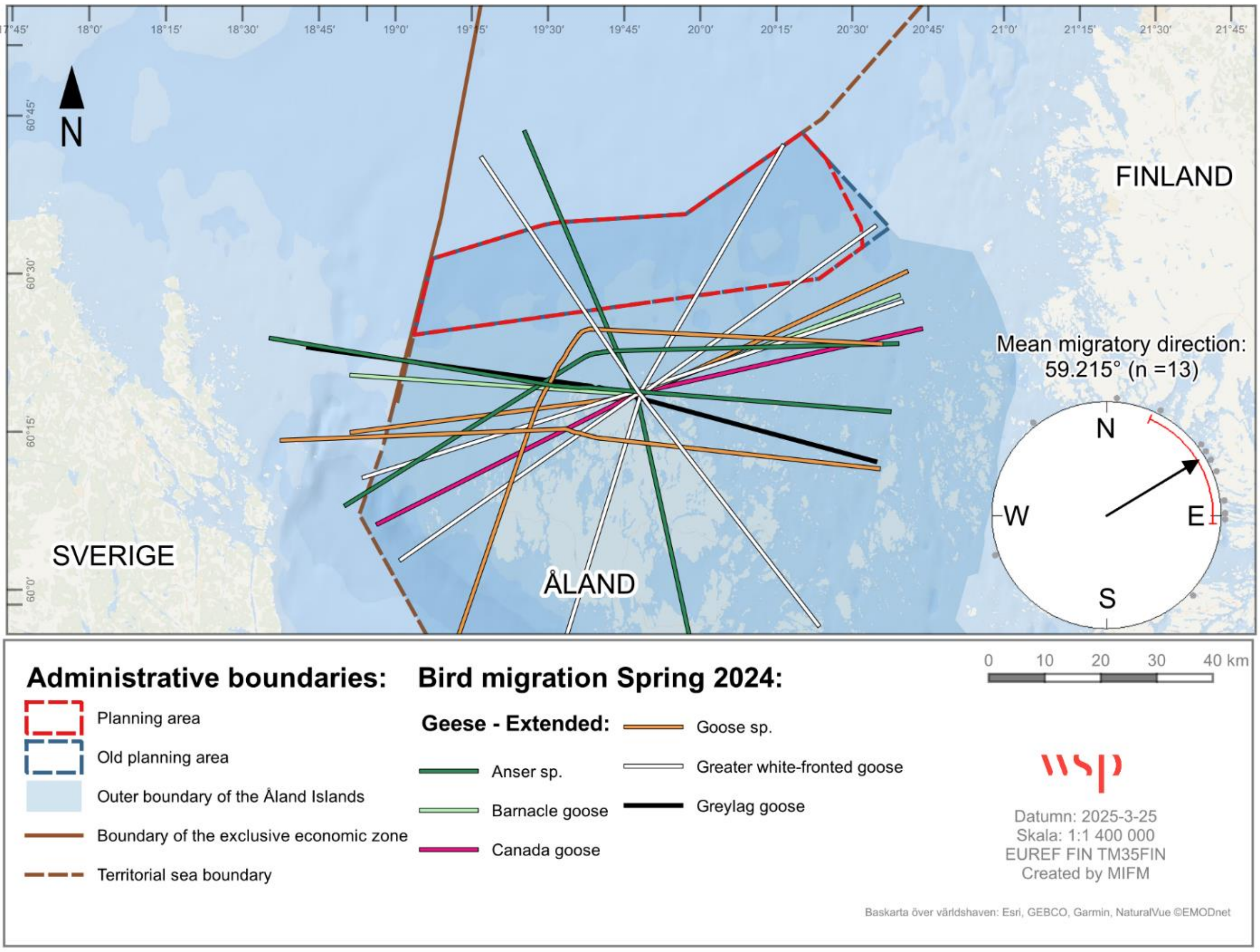


Figure 15. Visualization of the extended produced radar tracks for geese (n= 13), during spring 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all t racks (avg. = 59.215°).

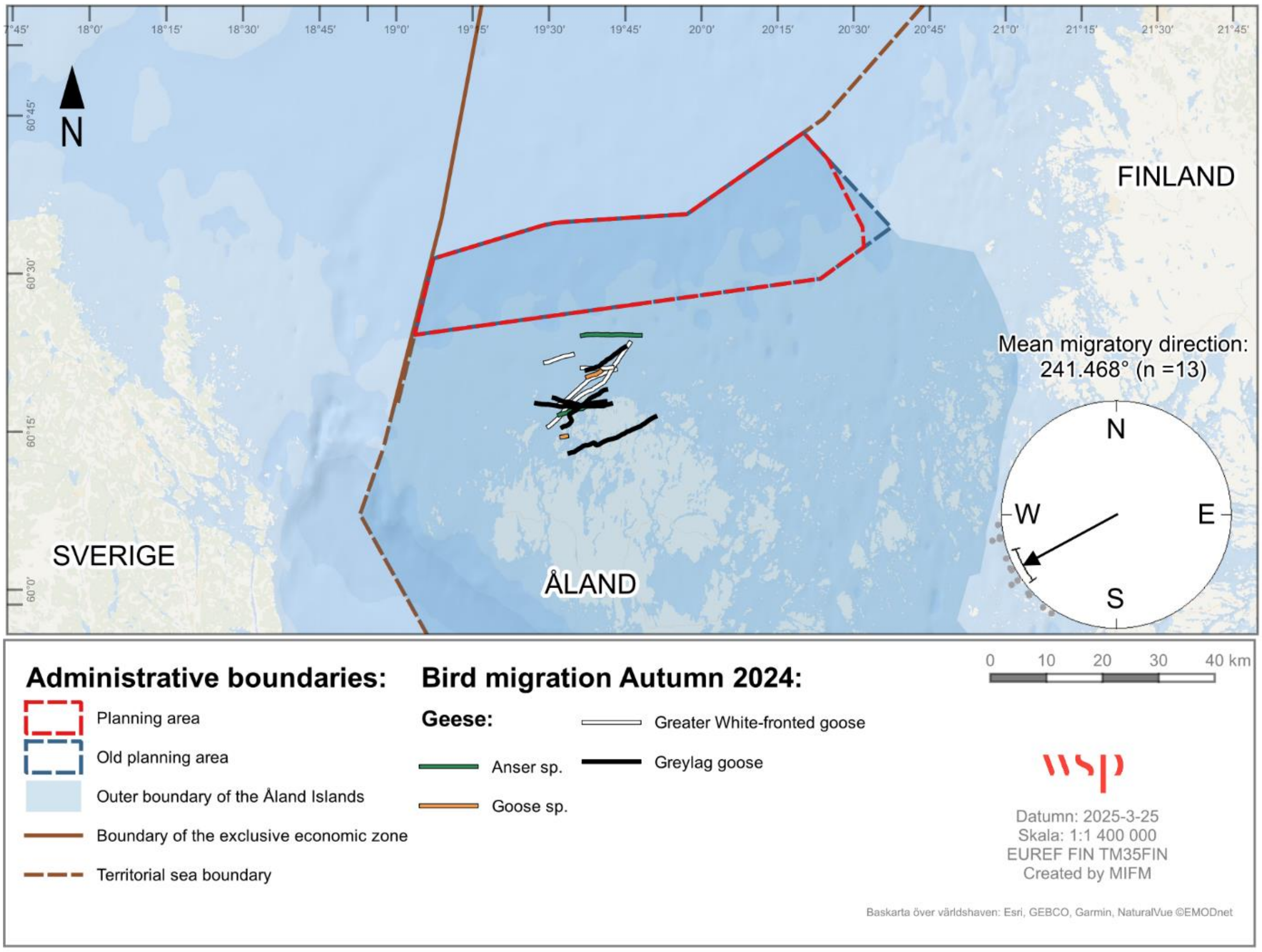


Figure 16. Visualization of the produced radar tracks for geese (n= 13), during autumn 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 241.468°).

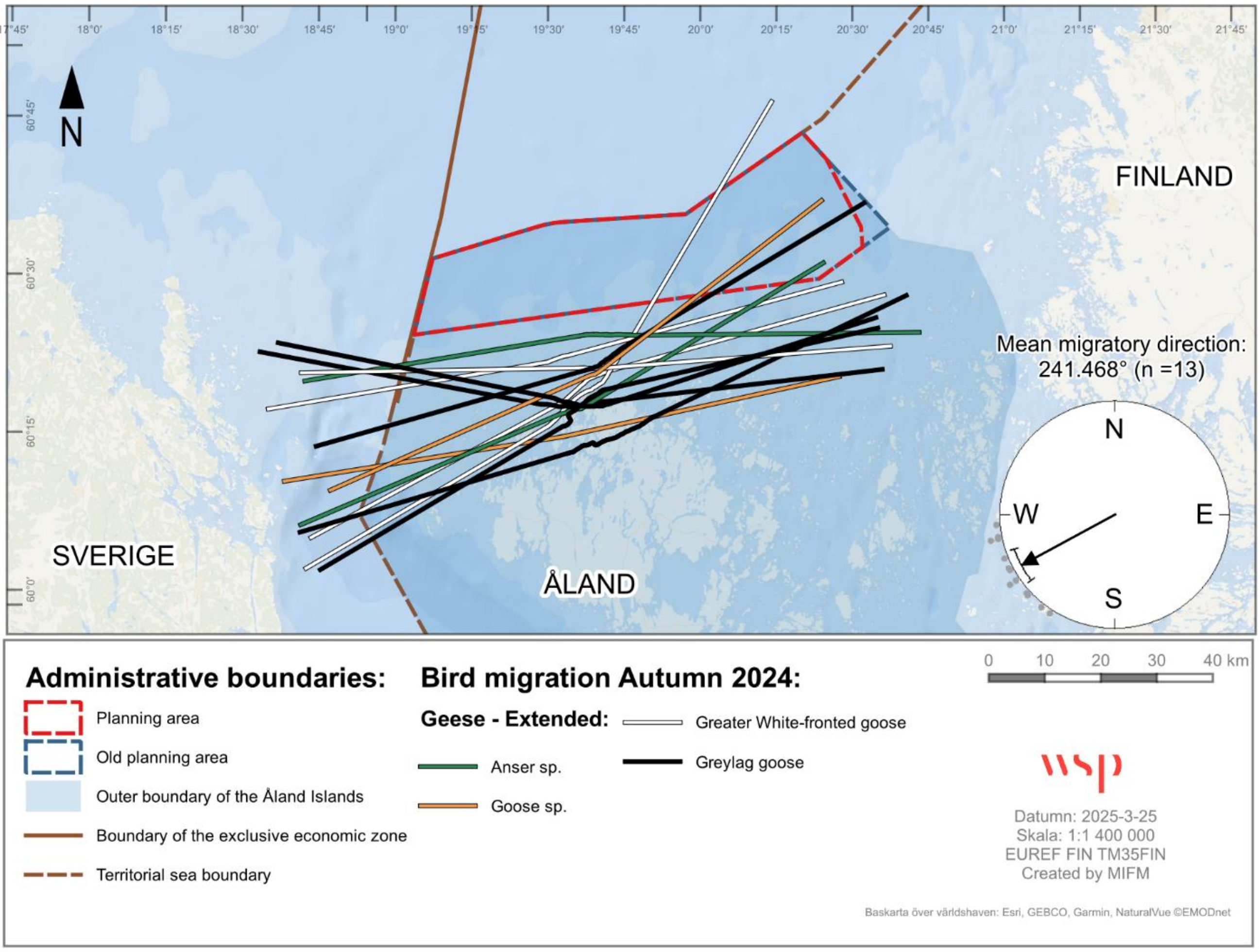


Figure 17. Visualization of the extended produced radar tracks for geese (n= 13), during autumn 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 241.468°).

4.6.3 Dabbling ducks

The total number of dabbling ducks observed throughout the survey period was 160 individuals, distributed in 11 flocks (1 flocks during spring and 10 flocks during autumn).

The species composition of the flocks observed consisted of four different species of dabbling ducks:

- Eurasian Teal (n = 2, distributed in1 flock),
- Eurasian Wigeon (n = 139, distributed in 7 different flocks),
- Mallard (n = 16, distributed in 2 different flocks), and
- Northen Pintail (n = 3, distributed in1 flock).

The general average flight height for dabbling ducks were 20 m (ranging from 1 – 60 meters).

The majority of the flocks were observed during the land-based observations (9 flocks, n = 144), while the remaining flocks were observed during the offshore observations (2 flocks, n = 16).

Of the flocks that was observed during the land-based observations, three flocks (n = 107) got detected by the horizontal radar during autumn and produced tracks, mainly on flocks of:

- Eurasian Wigeon (n = 103, distributed in 2 different flocks), and
- Northen Pintail (n = 3, distributed in1 flock).

During autumn, two of the three flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 67 % of the flocks of dabbling ducks recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring no clear tendency on main migratory direction was found.

During autumn the main migratory directions was southwest and west, respectively, with 10 flocks (n = 159) heading towards those directions in an average altitude of 14 meters. The average migration direction found based on the produced radar tracks was 217 ° (n = 3).

The produced individual tracks and the extended tracks presented for dabbling duck migration during autumn, are visualized in a combined figure (Figure 28-Figure 29) within the section '*Other birds'*.

4.6.4 Sea ducks

The total number of sea ducks observed throughout the survey period was 3080 individuals, distributed in 200 flocks (139 flocks during spring and 61 flocks during autumn).

The species composition of the flocks observed consisted of six different species of sea ducks:

- Common Goldeneye (n = 1, distributed in 1 flock),
- Common Scoter (n = 546, distributed in 43 different flocks),
- Eider (n = 1892, distributed in 115 different flocks),
- Long- tailed Duck (n = 20, distributed in 3 different flocks), and
- Velvet Scoter (n = 147, distributed in 31 different flocks),

as well as two sub-groups called:

- Common/ Velvet Scoter (n = 15, distributed in 1 flock), and
- Sea duck sp. (n = 459, distributed in 16 different flocks).

The general average flight height for sea ducks was 13 m (ranging from 1 – 100 meters).

The majority of the flocks were observed during the land-based observations (159 flocks, n = 2833), while the remaining flocks were observed during the offshore observations (41 flocks, n = 247).

Of the flocks that was observed during the land-based observations, 77 flocks (n = 1776) got detected by the horizontal radar and produced tracks (59 flocks during spring and 18 flocks during autumn), mainly on flocks of:

- Common Scoter (n = 255, distributed on 11 tracks),
- Eider (n = 1313, distributed on 52 tracks), and
- Sea duck sp. (n = 143, distributed on 8 tracks).

During spring, 16 of the 59 flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 27 % of the flocks of sea ducks recorded by the horizonal radar within the period.

During autumn, seven of the 18 flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 39 % of the flocks of sea ducks recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions was northeast and east, respectively, with 111 flocks (n = 1847) heading towards those directions in an average altitude of 11.5 meters. The average migration direction found based on the produced radar tracks was 66.6 ° (n = 59)

During autumn the main migratory directions was west and southwest, respectively, with 52 flocks (n = 957) heading towards those directions in an average altitude of 14 meters. The average migration direction found based on the produced radar tracks was 248 ° (n = 18).

In the following visualizations, the produced individual tracks and the extended tracks are presented for sea duck migration during spring (Figure 18-Figure 19) and during autumn (Figure 20-Figure 21).

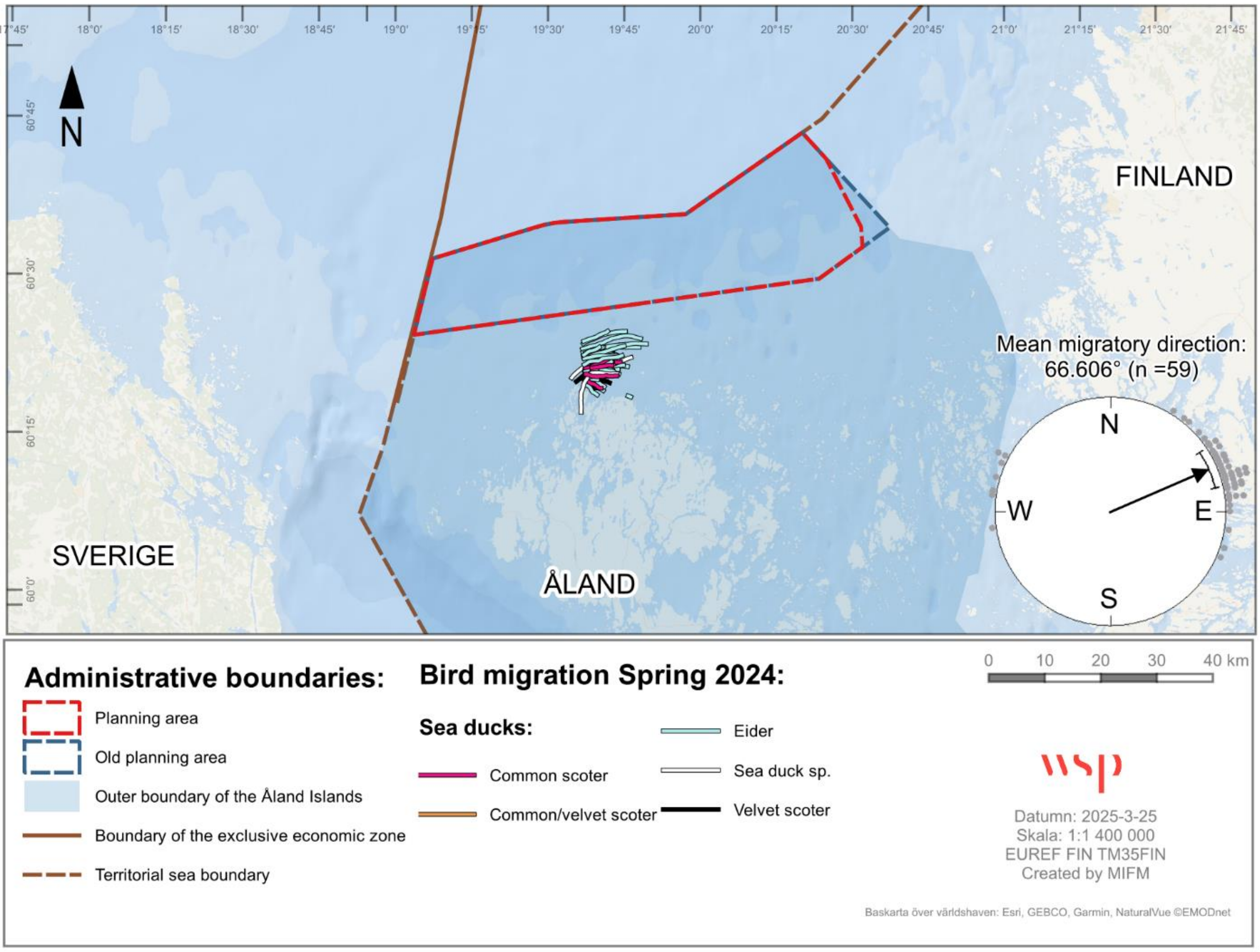


Figure 18. Visualization of the produced radar tracks for sea ducks (n= 59), during spring 2024. The circular plot shows the smoothed migration direction on a 360° axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 66.606°).

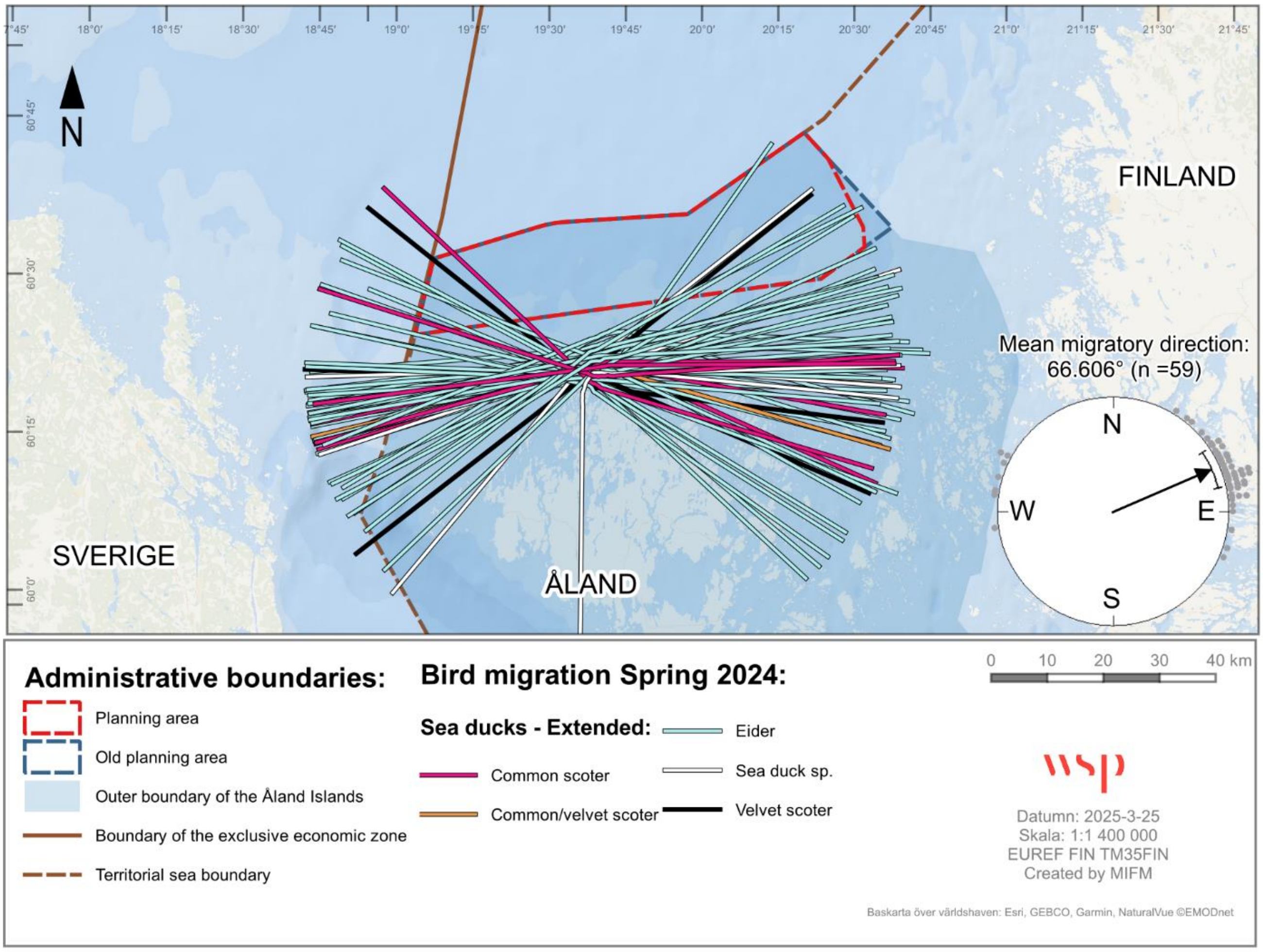


Figure 19. Visualization of the extended produced radar tracks for sea ducks (n= 59), during spring 2024. The circular plot shows the smoothed migration direction on a 360° axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 66.606°).

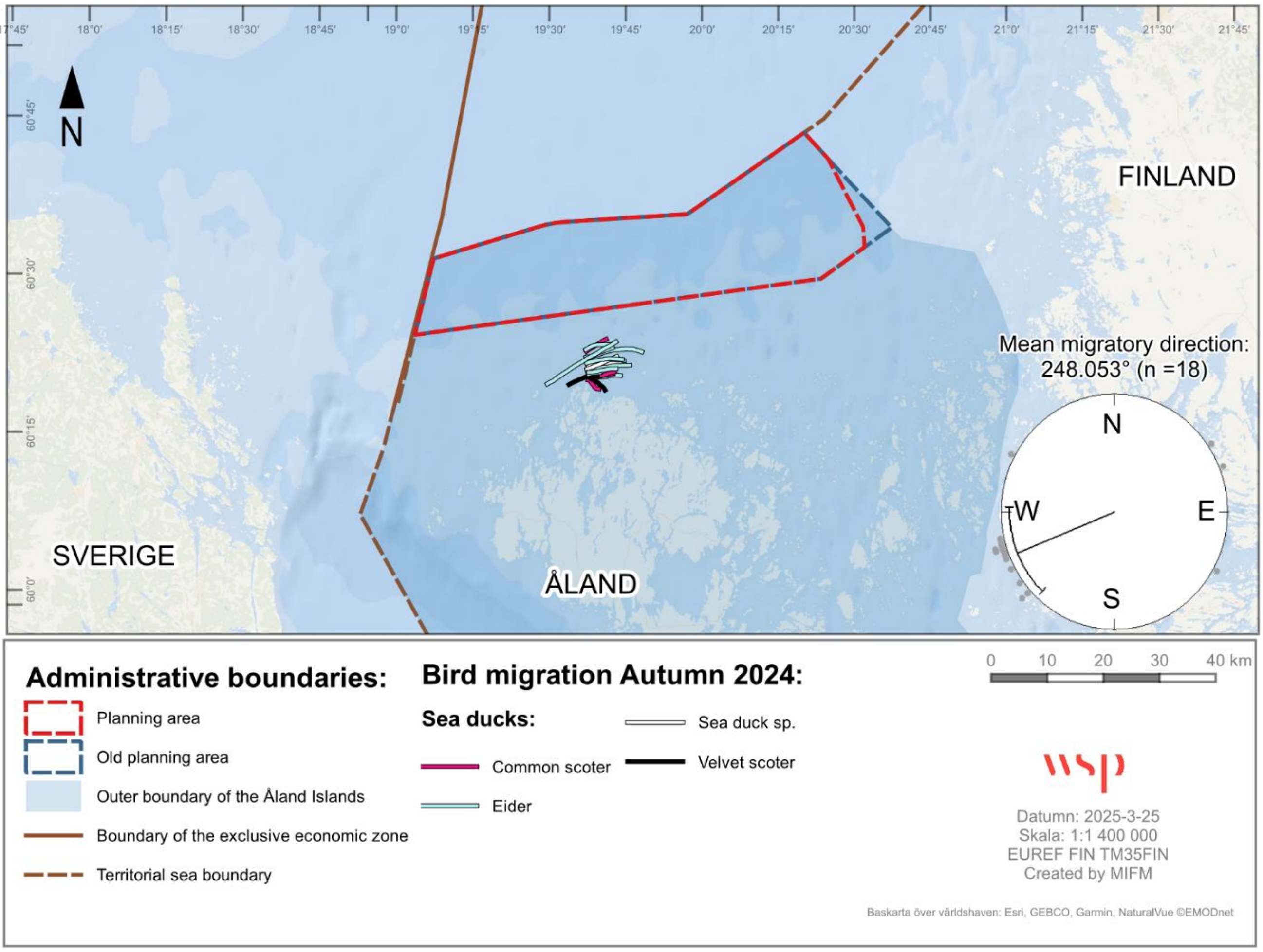


Figure 20. Visualization of the produced radar tracks for sea ducks (n= 18), during autumn 2024. The circular plot shows the smoothed migration direction on a 360° axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 248.053°).

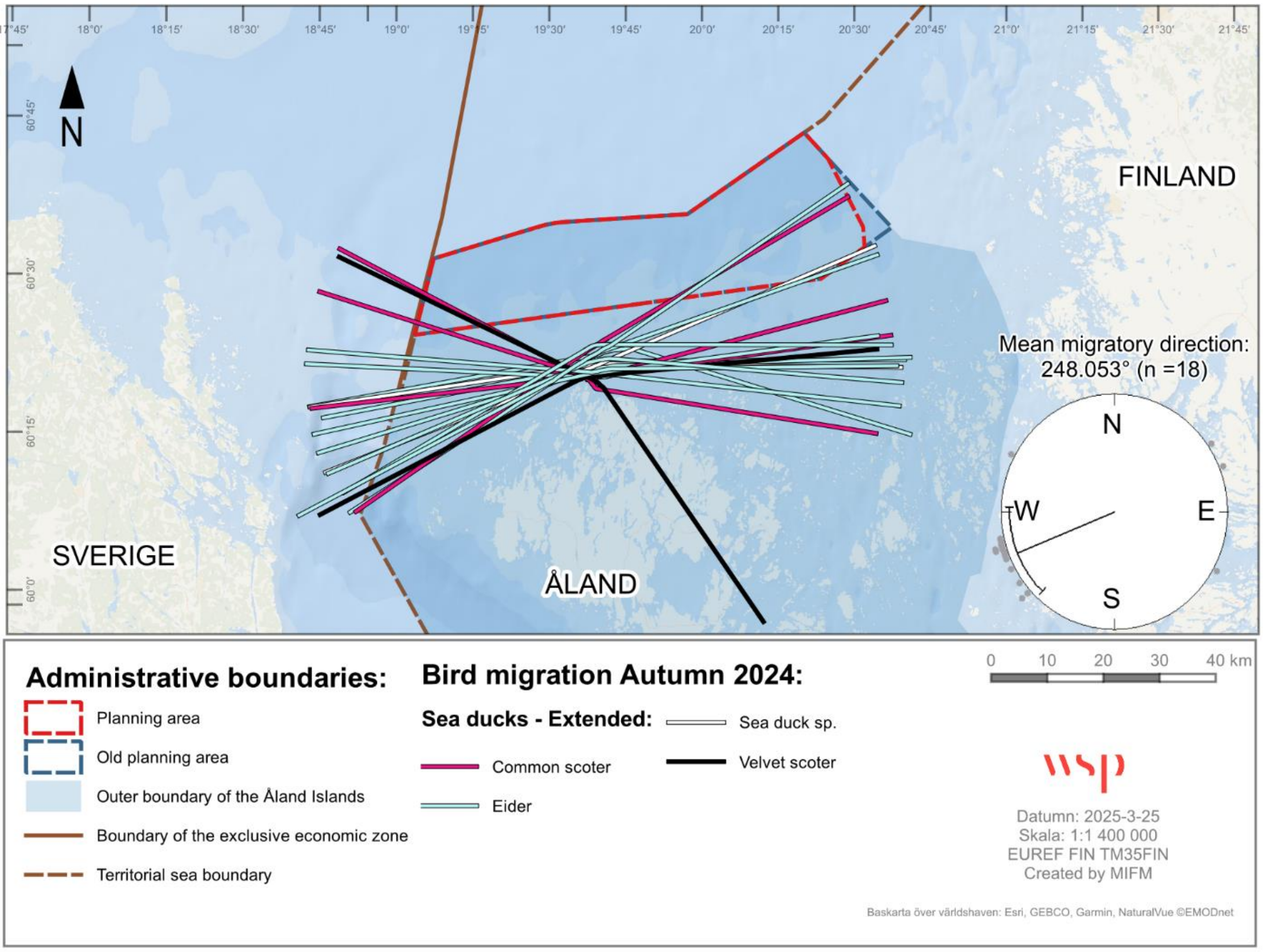


Figure 21. Visualization of the extended produced radar tracks for sea ducks (n= 18), during autumn 2024. The circular plot shows the smoothed migration direction on a 360° axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 248.053°).

4.6.5 Mergansers

The total number of mergansers observed throughout the survey period was 78 individuals, distributed in 31 flocks (24 flocks during spring and 7 flocks during autumn).

The species composition of the flocks observed consisted of two different species of mergansers:

- Goosander (n = 26, distributed in 9 flocks), and
- Red-breasted Merganser (n = 49, distributed in 21 different flocks),

as well as one sub-group called:

- Merganser sp. (n = 3, distributed in 1 flock),

The general average flight height for mergansers was 9.5 m (ranging from 1 – 70 meters).

The majority of the flocks were observed during the offshore observations (21 flocks, n = 51), while the remaining flocks were observed during the land-based observations (10 flocks, n = 27).

Of the flocks that was observed during the land-based observations, 2 flocks (n = 11) got detected by the horizontal radar during spring and produced tracks of one species:

- Goosander (n = 11, distributed on 2 tracks), During spring, both of the two flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 100 % of the flocks of Mergansers recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring no main migratory directions was found, however, 9 flocks (n = 28) headed towards and east and northeast, respectively, in an average altitude of 9.5 meters. The average migration direction found based on the produced radar tracks was 98 ° (n = 2)

During autumn no clear tendency on main migratory direction was found.

The produced individual tracks and the extended tracks presented for merganser migration during autumn, are visualized in a combined figure (Figure 28-Figure 29) within the section '*Other birds'*.

4.6.6 Divers

The total number of divers observed throughout the survey period was 128 individuals, distributed in 52 flocks (31 flocks during spring and 21 flocks during autumn).

The species composition of the flocks observed consisted of two different species of divers:

- Black-throated Diver (n = 102, distributed in 40 different flocks), and
- Red-throated Diver (n = 1, distributed in 1 flock),

as well as one sub-group called:

- Diver sp. (n = 25, distributed in 11 different flocks),

The general average flight height for divers were 19 m (ranging from 1 – 140 meters).

The majority of the flocks were observed during the offshore observations (33 flocks, n = 93), while the remaining flocks were observed during the land-based observations (19 flocks, n = 34).

Of the flocks that was observed during the land-based observations, four flocks (n = 8) got detected by the horizontal radar (1 flock during spring and 3 flocks during autumn), and produced tracks of one species and one sub-group:

- Black-throated Diver (n = 3, distributed in 2 different flocks), and
- Diver sp. (n = 4, distributed in 2 different flocks),

During spring, the one flock detected by the horizontal radar, showed a direction that would not enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 0 % of the flocks of divers recorded by the horizonal radar within the period.

During autumn, one of the three flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 33 % of the flocks of divers recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions was north and northwest, respectively, with 23 flocks (n = 71) heading towards those directions in an average altitude of 19 meters. The migration direction found based on the one produced radar track was 57 ° (n = 1).

During autumn the main migratory directions was west and southwest, respectively, with 17 flocks (n = 30) heading towards those directions in an average altitude of 18 meters. The average migration direction found based on the produced radar tracks was 261 ° (n = 3).

The produced individual tracks and the extended tracks presented for diver migration are visualized in a combined figure (Figure 26-Figure 29) within the section '*Other birds'*.

4.6.7 Great Cormorant

The total number of Great Cormorants observed throughout the survey period were 732 individuals, distributed in 69 flocks (35 flocks during spring and 34 flocks during autumn).

The general average flight height for Great Cormorant was 37 m (ranging from 1 – 230 meters).

The majority of the flocks were observed during the land-based observations (63 flocks, n = 696), while the remaining flocks were observed during the offshore observations (6 flocks, n = 36).

Of the flocks that were observed during the land-based observations, 34 flocks (n = 554) got detected by the horizontal radar and produced tracks (16 flocks during spring and 18 flocks during autumn).

During spring, nine of the 16 flocks showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 56 % of the flocks of Great Cormorants recorded by the horizonal radar within the period.

During autumn, eight of the 18 flocks showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 44 % of the flocks of Great Cormorants recorded by the horizonal radar within the period.

Flight directions and general altitudes

During spring the main migratory directions was northeast and east, respectively, with 21 flocks (n = 138) heading towards those directions in an average altitude of 48 meters. The average migration direction found based on the produced radar tracks was 54 ° (n = 16).

During autumn the main migratory directions was southwest and west, respectively, with 21 flocks (n = 354) heading towards those directions in an average altitude of 42 meters. The average migration direction found based on the produced radar tracks was 236 ° (n = 18).

In the following visualizations, the produced individual tracks and the extended tracks are presented for Great Cormorant migration during spring (Figure 22-Figure 23) and during autumn (Figure 24-Figure 25).

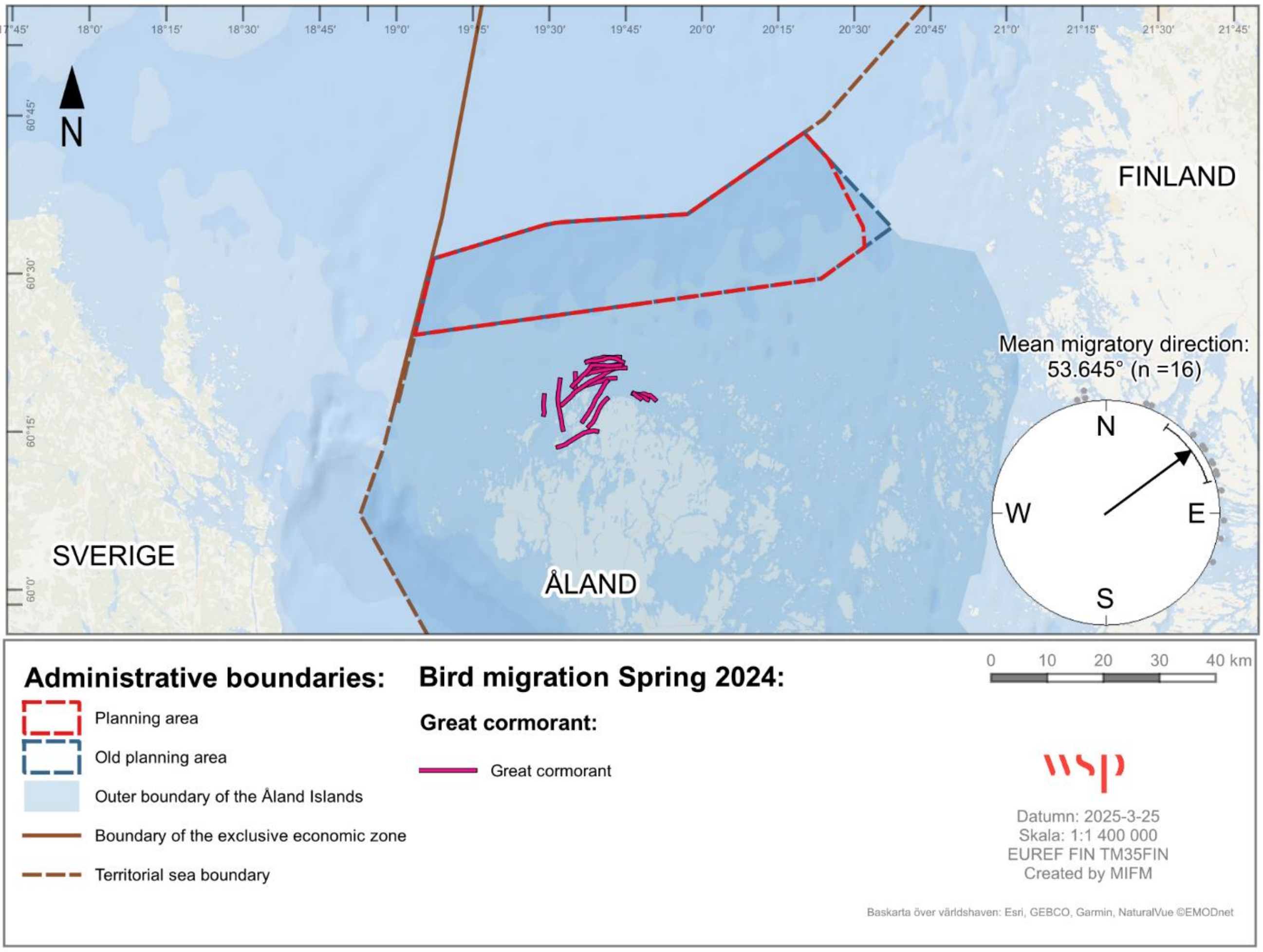


Figure 22. Visualization of the produced radar tracks for Great Cormorants (n= 16), during spring 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 53.645 °).

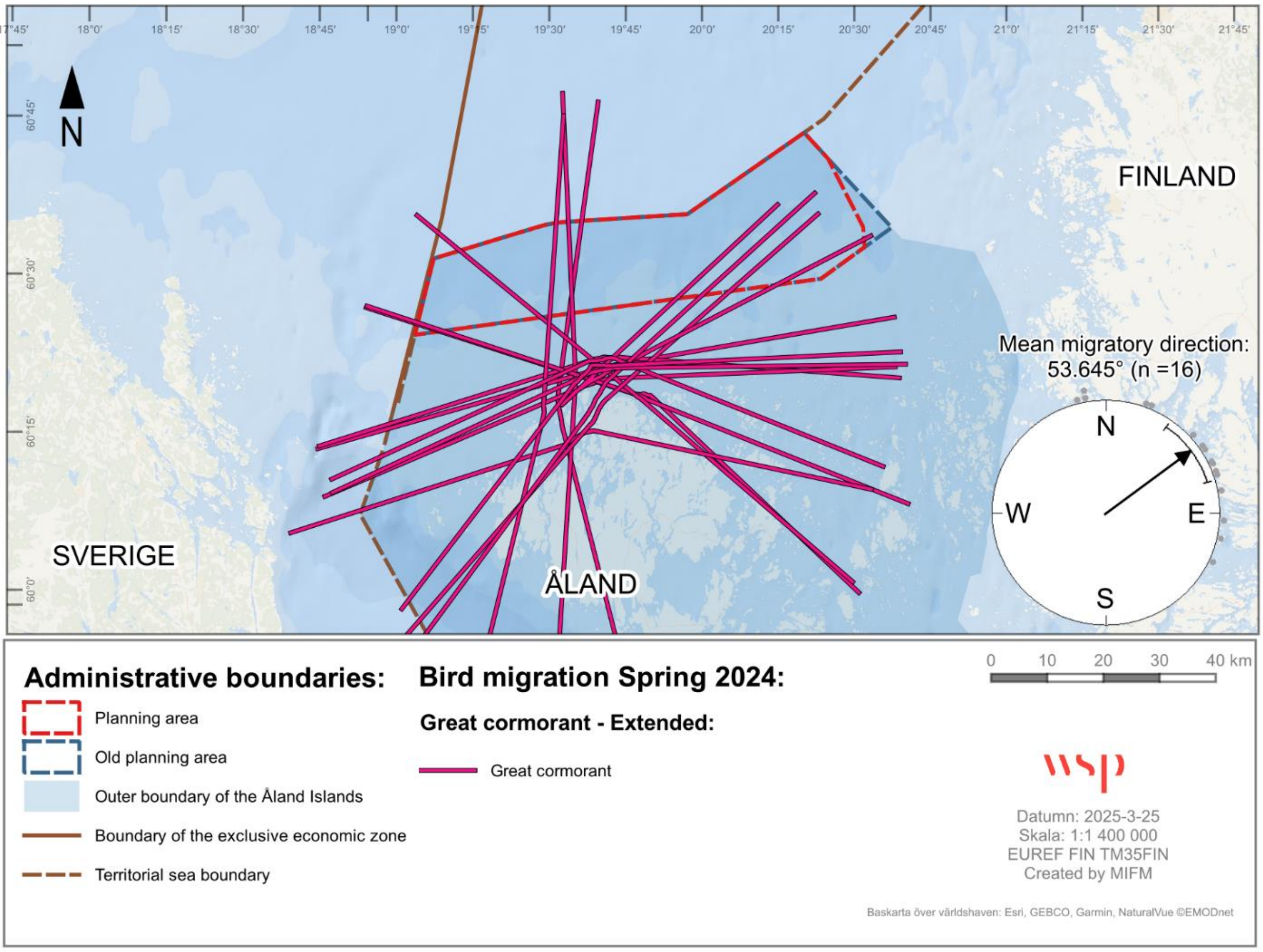


Figure 23. Visualization of the extended produced radar tracks for Great Cormorants (n= 16), during spring 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 53.645 °).

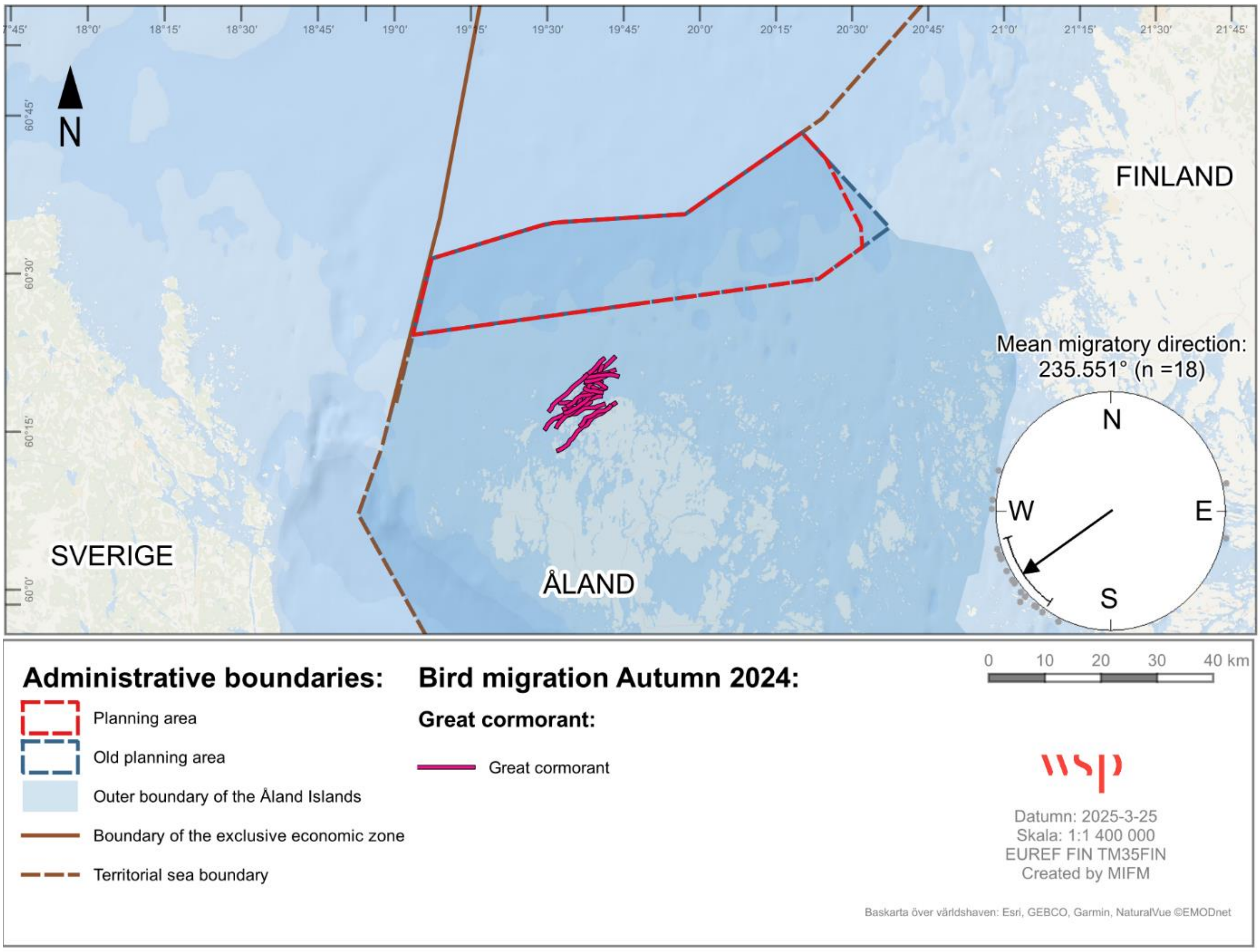


Figure 24. Visualization of the produced radar tracks for Great Cormorants (n= 18), during autumn 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 235.551 °).

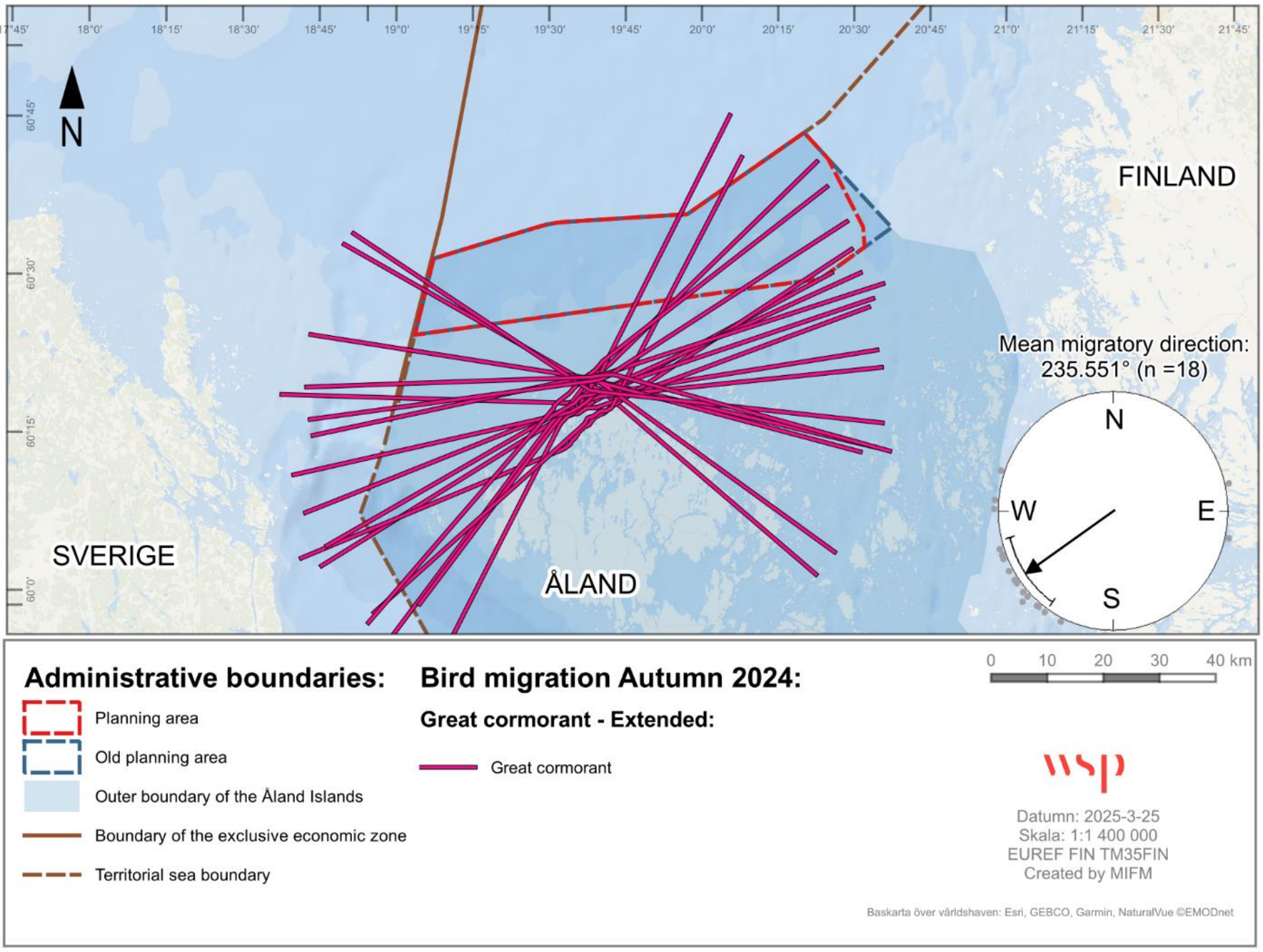


Figure 25. Visualization of the extended produced radar tracks for Great Cormorants (n= 18), during autumn 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 235.551 °).

4.6.8 Cranes and Birds of Prey

The total number of Cranes and Birds of Prey observed throughout the survey period was 64 individuals, distributed in 48 flocks (39 flocks during spring and 9 flocks during autumn).

The species composition of the flocks observed consisted of 11 different species:

- Common Buzzard (n = 2, distributed in 2 different flocks),
- Common Crane (n = 22, distributed in 8 different flocks),
- Hen Harrier (n = 7, distributed in 7 different flocks),
- Hobby (n = 6, distributed in 5 different flocks),
- Honey Buzzard (n = 1, distributed in 1 flock),
- Kestrel (n = 4, distributed in 4 different flocks),
- Merlin (n = 1, distributed in 1 flock),
- Osprey (n = 2, distributed in 2 different flocks),
- Peregrine Falcon (n = 1, distributed in 1 flock),
- Rough-legged Buzzard (n = 1, distributed in 1 flock), and
- Sparrowhawk (n = 16, distributed in 15 different flocks),

as well as one sub-group called:

- Harrier sp. (n = 1, distributed in 1 flock),

The general average flight height for Common Crane was 127 m (ranging from 40 – 318 meters), while the average flight height for Birds of Prey was 74 m (ranging from 2 – 240 meters).

All of the flocks were observed during the land-based observations.

Of the flocks that was observed during the land-based observations, one flock of Common Cranes (n = 7) got detected by the horizontal radar during spring and produced a track.

The one flock of Cranes, detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 100 % of the flocks of Cranes recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions of Cranes and Birds of Prey were east and northeast, respectively, with 39 flocks (n = 54) heading towards those directions in an average altitude of 95 meters. The migration direction found, based on the one produced radar track of Common Cranes, were 43 ° (n = 1).

During autumn the main migratory directions was southwest, with four flocks (n = 4) heading towards that direction in an average altitude of 32 meters.

The produced individual track and the extended track presented of the Common Crane migration are visualized in a combined figure (Figure 26-Figure 29) within the section '*Other birds'*.

4.6.9 Waders

The total number of waders observed throughout the survey period was 353 individuals, distributed in 17 flocks (11 flocks during spring and 6 flocks during autumn).

The species composition of the flocks observed consisted of seven different species of waders:

- Common Sandpiper (n = 1, distributed in 1 flock),
- Eurasian Curlew (n = 1, distributed in 1 flock),
- Dunlin (n = 12, distributed in 1 flock),
- Golden Plover (n = 59, distributed in 5 different flocks),
- Greenshank (n = 4, distributed in 2 different flocks),
- Lapwing (n = 6, distributed in 2 different flocks), and
- Oystercatcher (n = 11, distributed in 2 different flocks),

as well as two sub-groups called:

- Calidris sp. (n = 9, distributed in 2 different flocks), and
- Wader sp. (n = 250, distributed in 1 flock),

The general average flight height for waders were 48 m (ranging from 1 – 180 meters).

The majority of the flocks were observed during the land-based observations (12 flocks, n = 61), while the majority of individuals were observed during the offshore observations (n = 292, distributed in 5 flocks).

Of the flocks that was observed during the land-based observations, one flock of Dunlins (n = 12) got detected by the horizontal radar during autumn and produced a track.

The one flock of Dunlins, detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 100 % of the flocks of Waders recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring, the main migratory directions was northeast and north, respectively, with seven flocks (n = 273) heading towards those directions in an average altitude of 63 meters.

During autumn, the main migratory direction was southwest, with 4 flocks (n = 44) heading towards that direction in an average altitude of 40 meters. The migration direction found, based on the one produced radar track of Dunlins, were 299 ° (n = 1).

The produced individual track and the extended track presented of the Dunlin migration are visualized in a combined figure (Figure 26-Figure 29) within the section '*Other birds'*.

4.6.10 Gulls

The total number of Gulls observed throughout the survey period was 203 individuals, distributed in 52 flocks (26 flocks during spring and 26 flocks during autumn).

The species composition of the flocks observed consisted of five different species of Gulls:

- Black-headed Gull (n = 29, distributed in 6 different flocks),
- Common Gull (n = 31, distributed in 8 different flocks),
- Great Black-backed Gull (n = 2, distributed in 2 different flocks),
- Herring Gull (n = 99, distributed in 15 different flocks), and
- Lesser Black-backed Gull (n = 42, distributed in 21 different flocks),

The general average flight height for Gulls were 20 m (ranging from 1 – 100 meters).

The flocks observed, were equally distributed between the offshore observations (26 flocks, n = 64), and the land-based observations (26 flocks, n = 139), however the majority of individuals were observed during the land-based observations.

Of the flocks that was observed during the land-based observations, four flocks (n = 48) got detected by the horizontal radar (1 flock during spring and 3 flocks during autumn), and produced tracks of three different species:

- Black-headed Gull (n = 23, distributed in 2 different flocks),
- Common Gull (n = 18, distributed in 1 flock), and
- Herring Gull (n = 7, distributed in 1 flock),

During spring, the one flock of Black-headed Gulls detected by the horizontal radar, showed a direction that would not enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 0 % of the flocks of Gulls recorded by the horizonal radar within the period.

During autumn, two of the three flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 67 % of the flocks of Gulls recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions was north and east, respectively, with 16 flocks (n = 73) heading towards those directions in an average altitude of 31 meters. The migration direction found based on the one produced radar track was 263 ° (n = 1).

During autumn the main migratory directions was southwest and west, respectively, with 17 flocks (n = 62) heading towards those directions in an average altitude of 14 meters. The average migration direction found based on the produced radar tracks was 288 ° (n = 3).

The produced individual tracks and the extended tracks presented for Gull migration are visualized in a combined figure (Figure 26-Figure 29) within the section '*Other birds'*.

4.6.11 Terns

The total number of terns observed throughout the survey period was 149 individuals, distributed in 59 flocks (56 flocks during spring and 3 flocks during autumn).

The species composition of the flocks observed consisted of two different species of terns:

- Arctic Tern (n = 100, distributed in 54 different flocks), and
- Common Tern (n = 1, distributed in 1 flocks),

as well as two sub-groups called:

- Tern sp. (n = 48, distributed in 4 different flocks).

The general average flight height for terns were 10 m (ranging from 3 – 20 meters).

The majority of the flocks were observed during the offshore observations (56 flocks, n = 106), while the remaining flocks were observed during the land-based observations in autumn (3 flocks, n = 43).

All three flocks that was observed during the land-based observations in autumn got detected by the horizontal radar and produced tracks of flocks of Tern sp.

During autumn, zero of the three flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 0 % of the flocks of terns recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions was north and east, respectively, with 31 flocks (n = 51) heading towards those directions in an average altitude of 10 meters.

During autumn the main migratory direction was west, respectively, with three flocks (n = 43) heading towards that direction in an average altitude of 9 meters. The average migration direction found based on the produced radar tracks of was 237 ° (n = 3).

The produced individual tracks and the extended tracks presented for tern migration are visualized in a combined figure (Figure 26-
Figure 29 29) within the section '*Other birds'*.

4.6.12 Auks

The total number of auks observed throughout the survey period was 190 individuals, distributed in 42 flocks (28 flocks during spring and 14 flocks during autumn).

The species composition of the flocks observed consisted of three different species of auks:

- Black Guillemot (n = 9, distributed in 6 different flocks),
- Common Guillemot (n = 1, distributed in 1 flock), and
- Razorbill (n = 52, distributed in 24 different flocks),

as well as one sub-group called:

- Auk sp. (n = 128, distributed in 11 different flocks).

The general average flight height for auks were 1 m (ranging from 1 – 5 meters).

The majority of the flocks were observed during the offshore observations (34 flocks, n = 103), while the remaining flocks were observed during the land-based observations (8 flocks, n = 87).

Of the flocks that was observed during the land-based observations, two flocks of Auk sp. (n = 48) got detected by the horizontal radar (1 flock during spring and 1 flock during autumn).

During spring, the one flock of Auk sp. (n = 40) detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 100 % of the flocks of auks recorded by the horizontal radar within the period.

During autumn, the one flock of Auk sp. (n = 8) detected by the horizontal radar, showed a direction that would not enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 0 % of the flocks of auks recorded by the horizontal radar within the period.

Flight directions and average altitudes

During spring the main migratory direction was east, with seven flocks (n = 50) heading towards that direction in an average altitude of 1.5 meters. The migration direction found, based on the one produced radar track of auks, were 91 ° (n = 1).

During autumn the main migratory direction was west, with seven flocks (n = 47) heading towards that direction in an average altitude of 1.5 meters. The migration direction found, based on the one produced radar track of auks, were 271 ° (n = 1).

The produced individual tracks and the extended tracks presented for auk migration during autumn, are visualized in a combined (Figure 28-Figure 29) within the section '*Other birds'*.

4.6.13 Other birds

Besides the observations and recordings of migratory movements within the selected relevant species and species groups, migratory movements were also recorded for species within several different taxon. However, the recorded migratory movements for species within these taxa, have been grouped into the 'Other birds' either due to few observations, irrelevance to offshore pre-investigation, unidentified observations etc.

The visual presentation of the produced tracks for the relevant species groups: swans, dabbling ducks, mergansers, divers, cranes, waders, gulls, terns, and auks, have been included in in this section due to few produced tracks on the horizontal radar, and visualized together with tracks of the remaining recorded flocks of species, not included in the relevant species and species groups, which migratory movements still got picked up by the horizontal radar (Figure 26-Figure 29).

The total number of 'other birds' observed throughout the survey period was 1857 individuals, distributed in 111 flocks (60 flocks during spring and 51 flocks during autumn).

The species composition of the flocks observed consisted of 32 different species:

- Barn Swallow (n = 7, distributed in 6 different flocks),
- Bearded Tit (n = 15, distributed in 2 different flocks),
- Blue Tit (n = 18, distributed in 2 different flocks),
- Brambling (n = 239, distributed in 5 different flocks),
- Chaffinch (n = 8, distributed in 1 flock),
- Common Chiffchaff (n = 1, distributed in 1 flock),
- Common Crossbill (n = 47, distributed in 8 different flocks),
- Common Pochard (n = 30, distributed in 1 flock),
- Common Redpoll (n = 45, distributed in 6 different flocks),
- Common Swift (n = 7, distributed in 4 different flocks),
- Fieldfare (n = 2, distributed in 2 different flocks),
- Goldfinch (n = 3, distributed in 2 different flocks),
- Great-spotted Woodpecker (n = 1, distributed in 1 flock),
- Hooded Crow (n = 49, distributed in 5 different flocks),
- Jackdaw (n = 90, distributed in 2 different flocks),
- Meadow Pipit (n = 201, distributed in 3 different flocks),

- Mistle Thrush (n = 48, distributed in 6 different flocks),
- Raven (n = 31, distributed in 2 different flocks),
- Reed Bunting (n = 1, distributed in 1 flock),
- Rock Pipit (n = 1, distributed in 1 flock),
- Siskin (n = 246, distributed in 9 different flocks),
- Skylark (n = 11, distributed in 3 different flocks),
- Stock Dove (n = 1, distributed in 1 flock),
- Tree Pipit (n = 13, distributed in 7 different flocks),
- Tufted Duck (n = 1, distributed in 1 flock),
- Twite (n = 6, distributed in 1 flock),
- Waxwing (n = 12, distributed in 2 different flocks),
- White Wagtail (n = 1, distributed in 1 flock),
- Wood Lark (n = 4, distributed in 4 different flocks),
- Wood Pigeon (n = 279, distributed in 5 different flocks),
- Yellow Wagtail (n = 1, distributed in 1 flock),
- Yellowhammer (n = 7, distributed in 4 different flocks),

as well as four sub-groups called:

- Duck sp. (n = 47, distributed in 2 different flocks),
- Finch sp. (n = 59, distributed in 3 different flocks),
- Goose sp. or Great Cormorant (n = 70, distributed in 1 flock), and
- Passerine sp. (n = 255, distributed in 4 different flocks),

The general average flight height for the different taxa within ‘other birds’ were 43 m (ranging from 1 – 150 meters)

The majority of the flocks were observed during the land-based observations (92 flocks, n = 1803), while the remaining flocks were observed during the land-based observations (19 flocks, n = 54).

Of the flocks that was observed during the land-based observations, five flocks (n = 424) got detected by the horizontal radar (4 flocks during spring and 1 flock during autumn), and produced tracks of two different species:

- Hooded Crow (n = 14, distributed in 1 flock), and
- Wood pigeon (n = 170, distributed in 2 different flocks),

as well as two sub-groups called:

- Duck sp. (n = 200, distributed in 1 flock), and
- Great Cormorant or Goose sp. (n = 40, distributed in 1 flock).

Zero of the flocks detected by the horizontal radar, showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 0 % of the flocks of ‘other birds’ recorded by the horizonal radar within the period.

Flight directions and average altitudes

During spring the main migratory directions of ‘other birds’ were northwest and west, respectively, with 26 flocks (n = 518) heading towards those directions in an average altitude of 39 meters. Additionally, 8 flocks (n = 147) were recorded migrating in unspecified directions. The average migration direction found based on the produced radar tracks was 64 ° (n = 4).

During autumn the main migratory directions of ‘other birds’ were southwest and south, respectively, with 23 flocks (n = 168) heading towards those directions in an average altitude of 36 meters. Additionally, 19 flocks (n = 419) were recorded migrating in unspecified directions. The migration direction found, based on the one produced radar track of ‘other birds’, were 263 ° (n = 1).

The produced individual tracks and the extended tracks presented of ‘other birds’ as well as the relevant species groups: Swan, dabbling duck, merganser, diver, Crane, wader, Gull, tern, and auk migration are visualized in a combined figure, during spring (Figure 26-Figure 27) and during autumn (Figure 28-Figure 29).

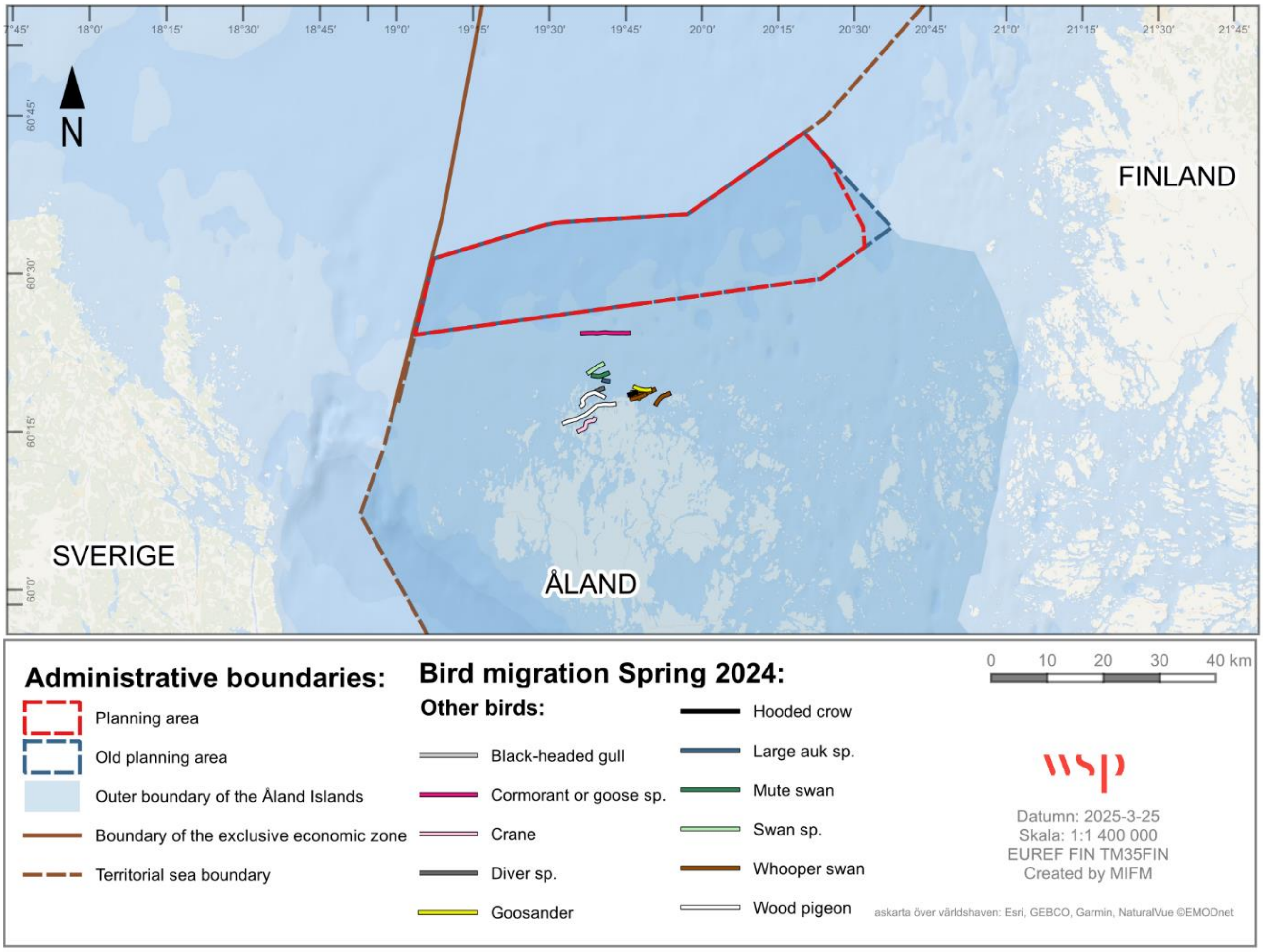


Figure 26. Visualization of the produced radar tracks for of ‘other birds’ as well as the relevant species groups: Swans, dabbling ducks, mergansers, divers, Cranes, waders, Gulls, terns, and auks (n= 15), during spring 2024.

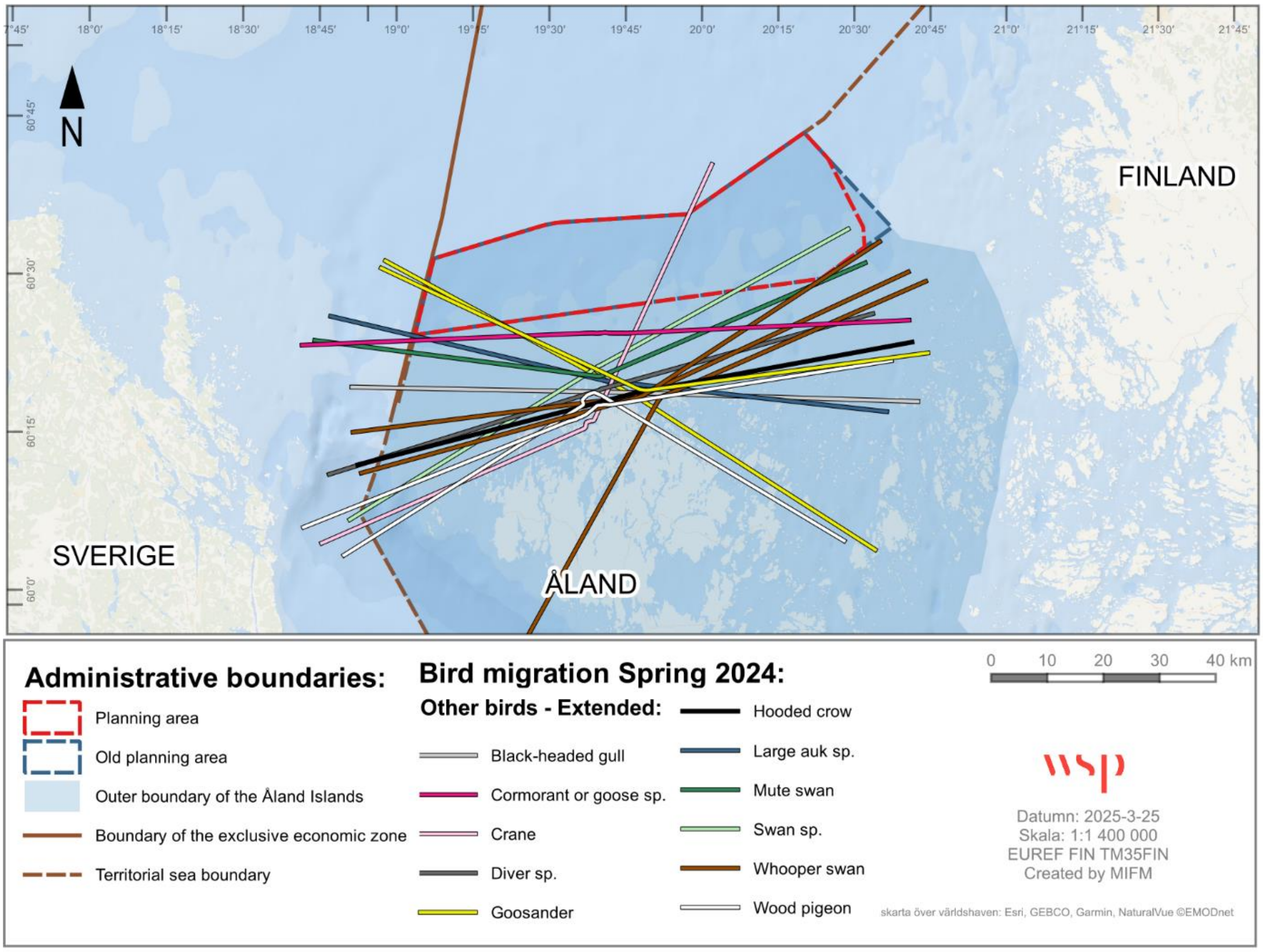


Figure 27. Visualization of the extended produced radar tracks for of 'other birds' as well as the relevant species groups: Swans, dabbling ducks, mergansers, divers, Cranes, waders, Gulls, terns, and auks (n= 15), during spring 2024.

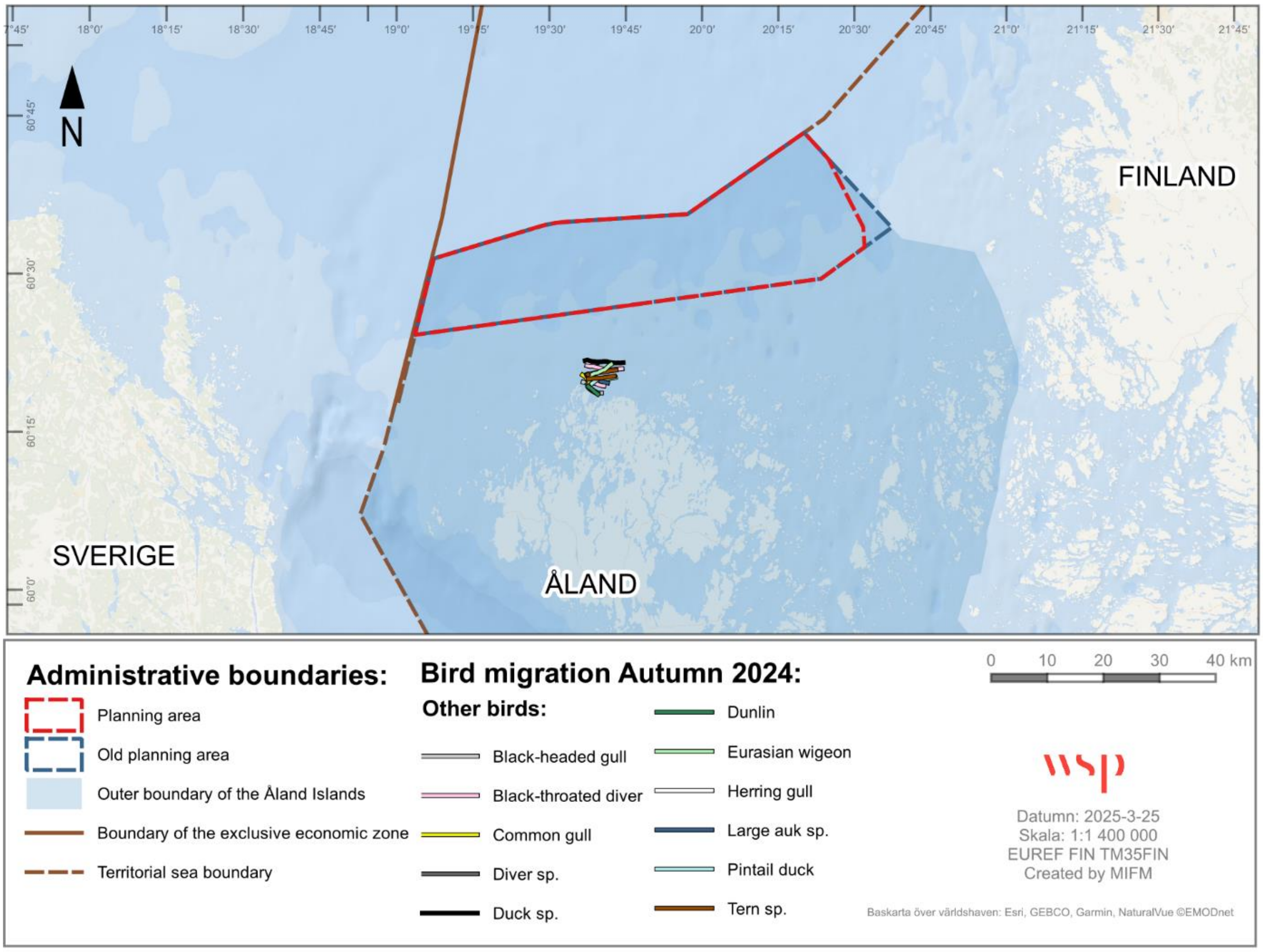


Figure 28. Visualization of the produced radar tracks for of 'other birds' as well as the relevant species groups: dabbling ducks, divers, waders, Gulls, terns, and auks (n= 15), during autumn 2024.

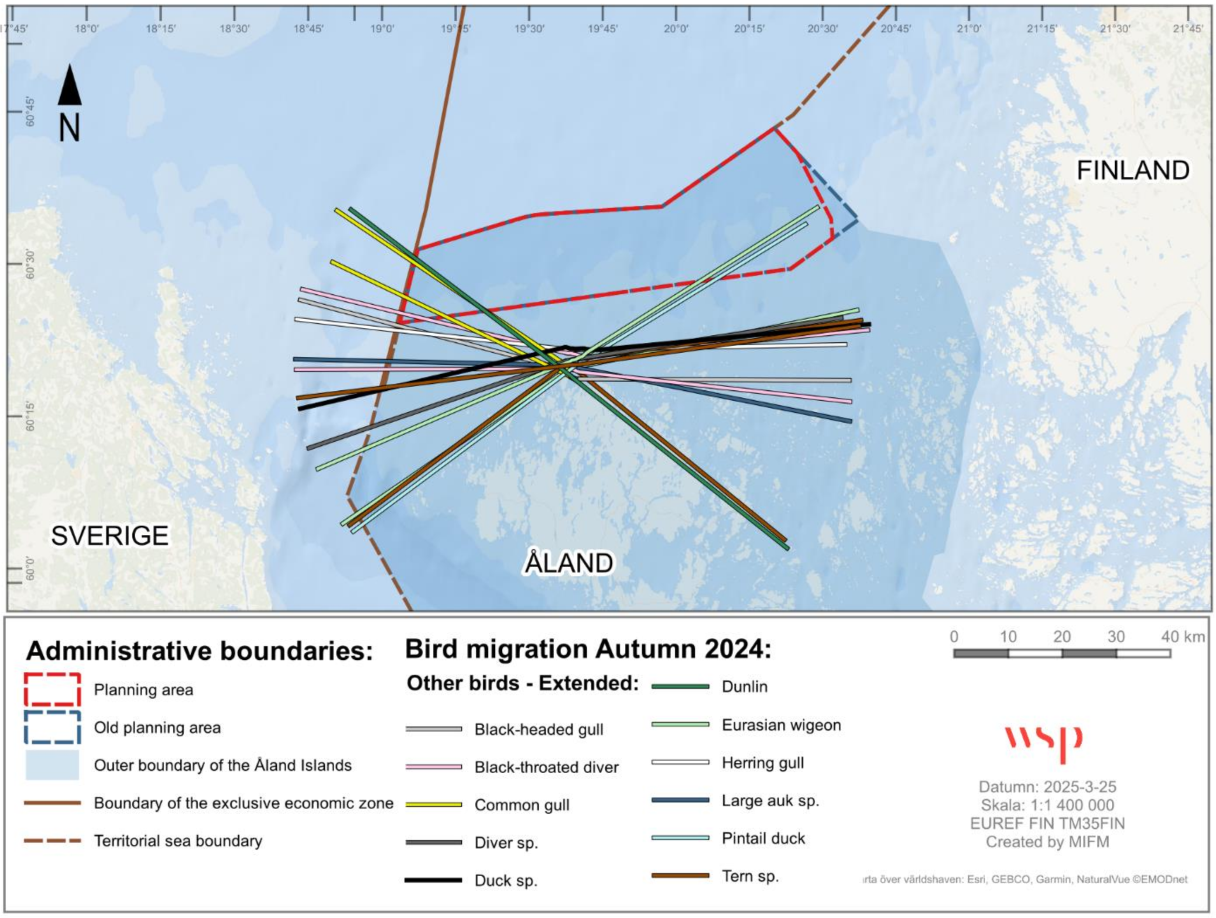


Figure 29.Visualization of the extended produced radar tracks for of 'other birds' as well as the relevant species groups: dabbling ducks, divers, waders, Gulls, terns, and auks (n= 15), during autumn 2024.

4.6.14 Bird sp.

An additional number of bird movements was picked up by the horizontal radar and produced tracks of unidentified flocks called Bird sp. The total number of Bird sp. Tracks produced throughout the survey period was 27 individual tracks (14 tracks during spring and 13 tracks during autumn).

During spring, ten of the 14 tracks showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 71 % of the flocks of unidentified birds recorded by the horizonal radar within the period.

During autumn, 11 of the 13 tracks showed a direction that would enter the bounds of the pre-investigation area, when extending the direction of the produced track, equivalent to 85 % of the flocks of unidentified birds recorded by the horizonal radar within the period.

During spring the average migration direction found based on the produced radar tracks was 30 ° (n = 14)

During autumn the average migration direction found based on the produced radar tracks was 250 ° (n = 13)

In the following visualizations, the produced individual tracks and the extended tracks are presented for the unidentified flocks of birds called Bird sp. During spring (Figure 30-Figure 31) and during autumn (Figure 32-Figure 33).

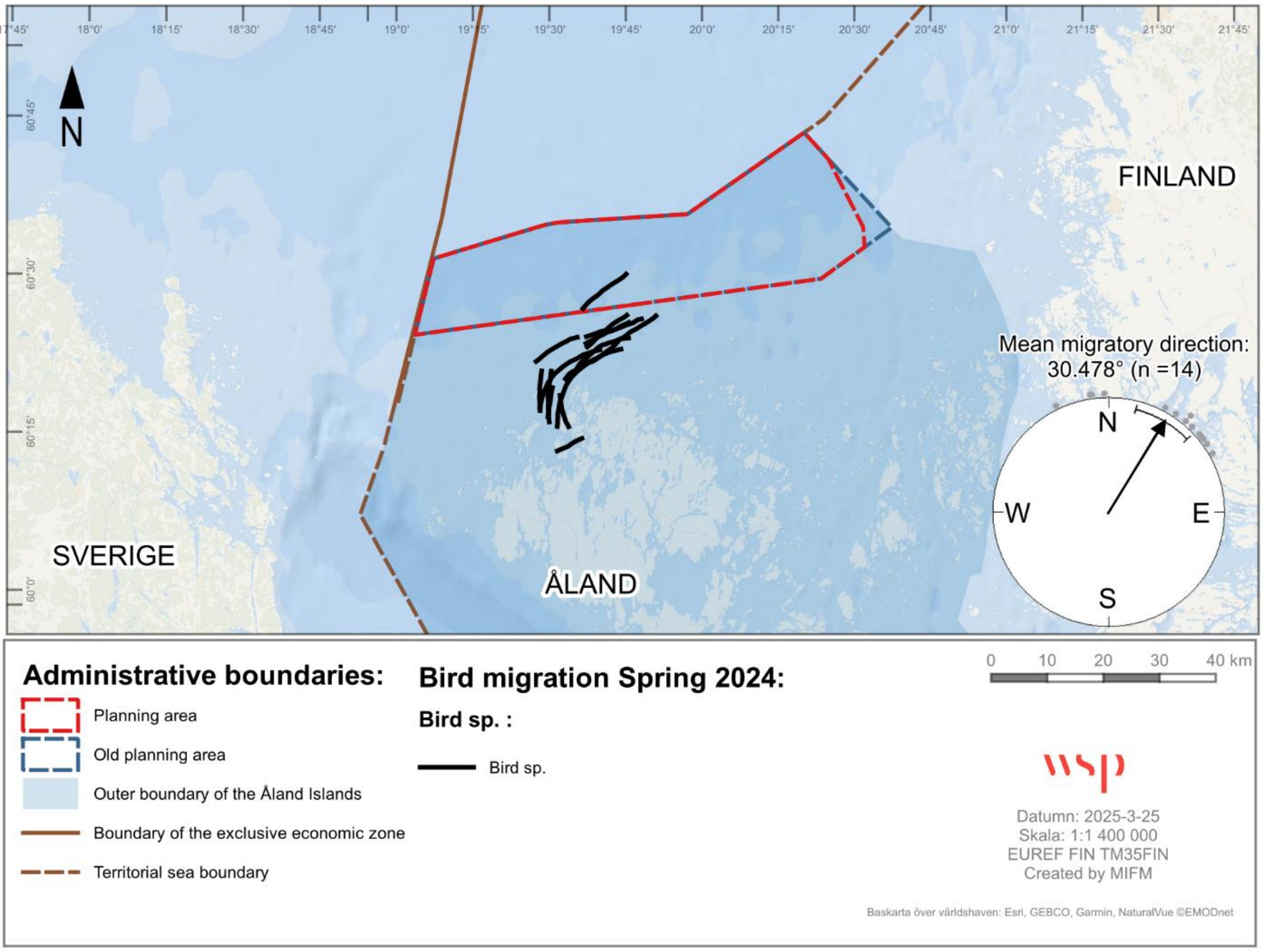


Figure 30. Visualization of the produced radar tracks for Bird sp. (n= 14), during spring 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 30.478 °).

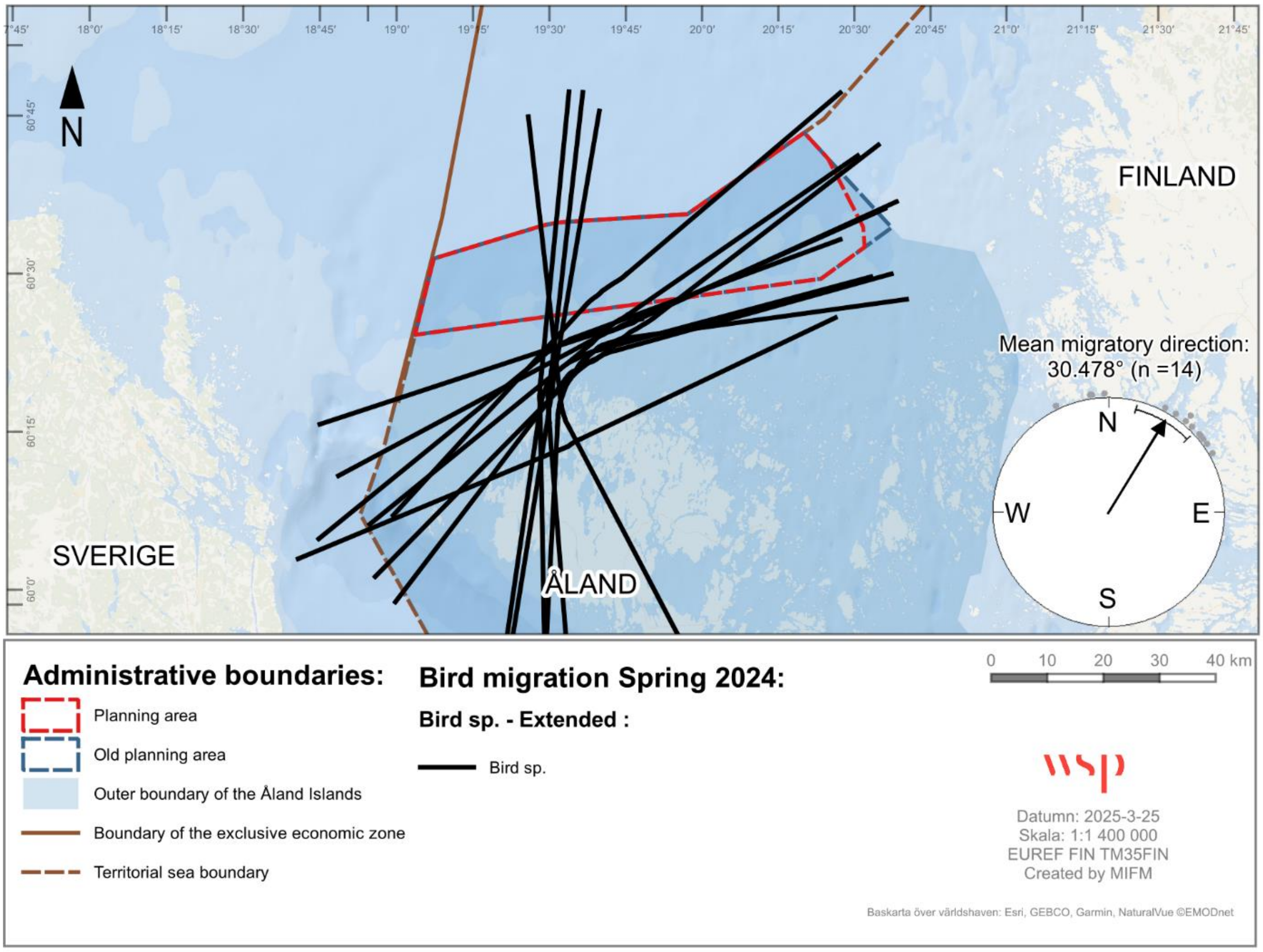


Figure 31. Visualization of the extended produced radar tracks for Bird sp. (n= 14), during spring 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black arrow represents the smoothed migration direction averaged for all tracks (avg. = 30.478 °).

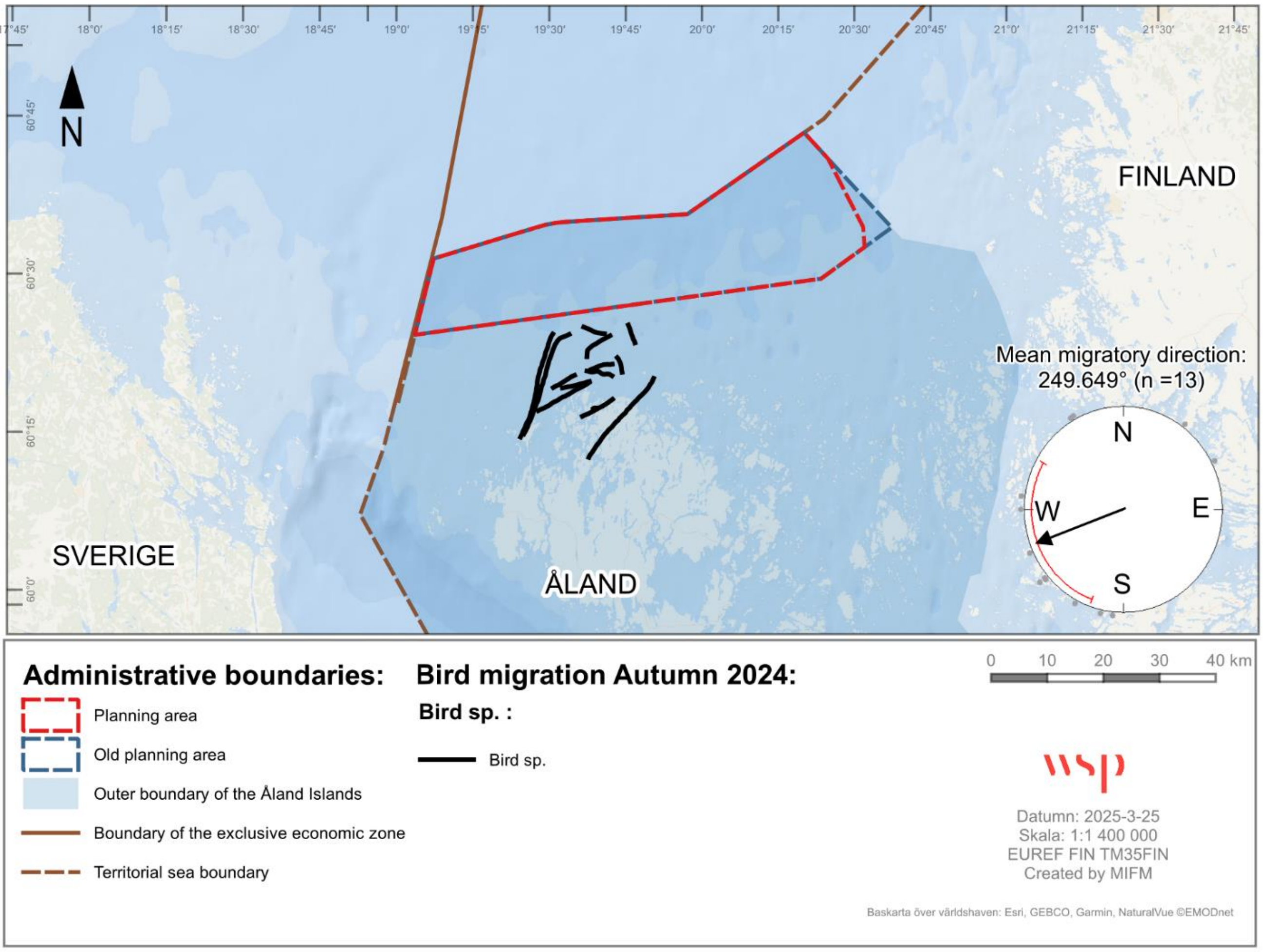


Figure 32. Visualization of the produced radar tracks for Bird sp. (n= 13), during autumn 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black line represents the smoothed migration direction averaged for all tracks (avg. = 249.649 °).

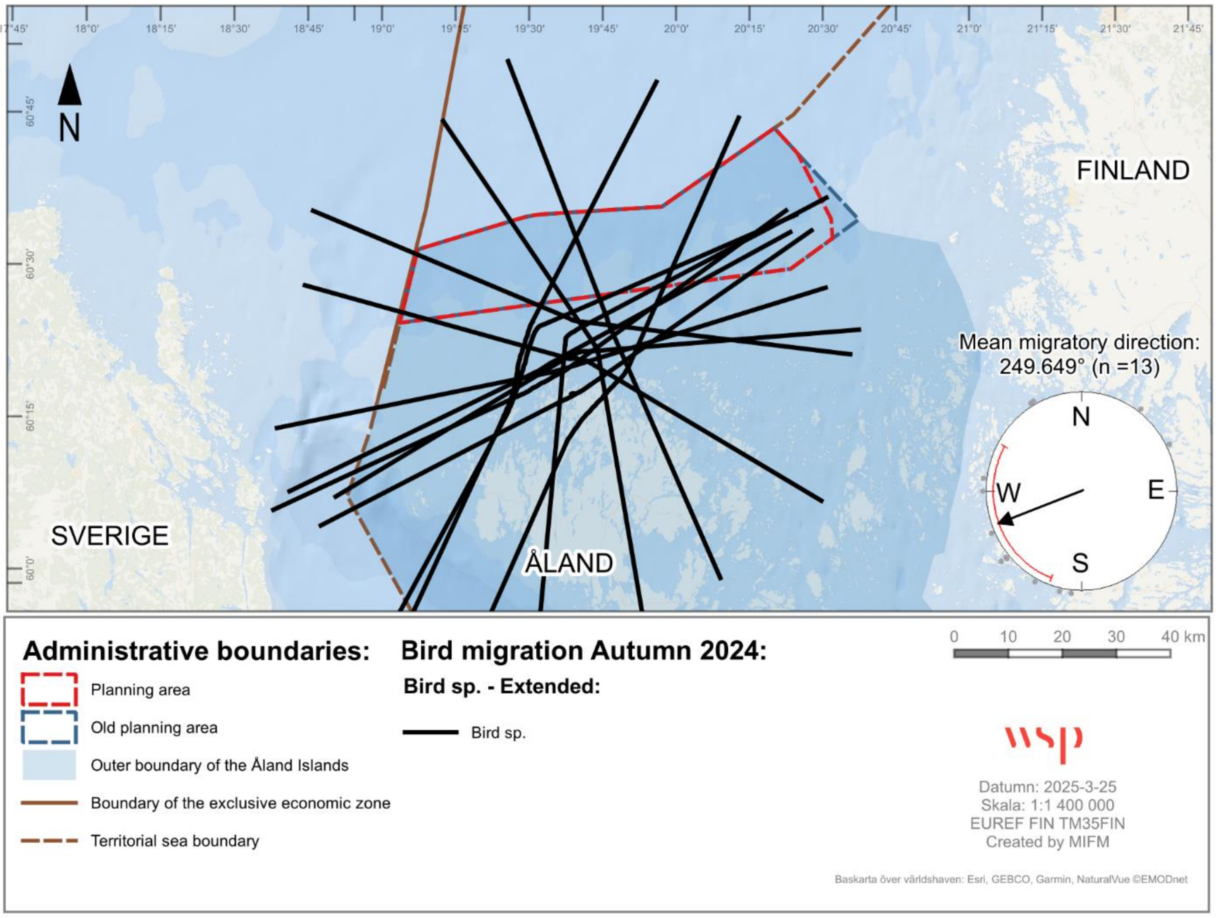


Figure 33. Visualization of the extended produced radar tracks for Bird sp. (n= 13), during autumn 2024. The circular plot shows the smoothed migration direction on a 360°axis. Each grey dot represents the direction of one track, and the black line represents the smoothed migration direction averaged for all tracks (avg. = 249.649 °).

4.7 Impact assessment on migrating birds

Assessments are likely to vary between the considered species groups. Therefore, assessments are presented per group based on the information collected during the surveys. The overall assessment on the influence of the pre-investigation area on bird migration, within the selected species groups, vary between low – moderate for all groups. Some species groups have not been well documented throughout the surveys and hence, assessments are associated with a higher level of uncertainty. The assessments are primarily based on the directions, abundances and flight hights found for the different species groups during the radar surveys in both spring and autumn 2024.

All assessments related to migratory birds are compiled in (Table 5).

Table 5. The assessed impact and importance of the pre-investigation area on relevant species groups of migrating birds, based on the matrix in section 2.1.6. The categorization has been further divided into three phases Anläggningsskede (construction phase), Driftskede (operation phase), and Avvecklingsskede (demolition phase).

Environmental aspect: **Migrating birds** **Value / Interest**	**Assessed impact**	**Potential environmental impact**	**Assessment value:**	
			The value of interest	**Uncertainty in the assessment**
Construction phase				
All species groups	Increased ship traffic and noise between Åland and the pre-investigation area	Avoidance of work vessels, especially within 0 – 20 m altitude resulting in higher energy expenditure	**Low**	**Moderate**
Operation phase				
Swans	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Geese	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Dabbling ducks	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Sea ducks	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Moderate**	**Low**
Mergansers	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Moderate**	**Low**
Divers	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Moderate**	**Low**
Great Cormorant	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Moderate**	**Low**
Birds of Prey	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Cranes	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**

Environmental aspect: Migrating birds Value / Interest	Assessed impact	Potential environmental impact	Assessment value:	
			The value of interest	**Uncertainty in the assessment**
Waders	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Gulls	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Low**
Terns	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Moderate**	**Moderate**
Auks	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Other birds	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**
Bird sp.*	Rotating blades of wind turbines (in varying speeds), attraction of lights during nighttime, barrier effect of wind farm	Risk of collision with wind turbines and increased energy expenditure due to prolonged migratory flights	**Moderate**	**Low**
Demolition phase				
All species groups	Increased ship traffic and noise between Åland and the remaining physical structures of the wind farm, and possible attraction of lights during nighttime, barrier effect of existing wind farm	Avoidance of work vessels, especially within 0 – 20 m altitude. Risk of collision with remaining physical structures and increased energy expenditure due to prolonged migratory flights	**Low**	**Moderate**

** The categorization "Bird sp." Refers to the unidentified tracks recorded by the horizontal radar during the surveys, described in detail under the species-specific section in section 4.1.6.*

4.7.1 Uncertainties of assessments

Environmental assessments are always associated with uncertainties. From an environmental assessment perspective, these are most easily divided between those related to knowledge of the current situation (description of the value of the interest) and environmental impact (description of the impact of the planned activity on the interest). An uncertainty linked to the current situation can be a lack of knowledge about how a particular species group migrate through the Sunnanvind planning area. For instance, some relevant species groups and species have only been recorded scarcely such as Swans and Bean geese, therefore they receive a higher uncertainty than species groups, or species, with a greater coverage of their migratory behavior throughout the bird migration surveys. Moreover, on days with low visibility or with bird movements at great distances or in angles impossible to visually confirm, some tracks named: “Bird sp.” show migratory tendencies that potentially could intervene with a wind farm within the pre-investigation area to an unknown degree.

Furthermore, the pre-investigation area has only been partially covered by the surveys for migratory birds.

5 Discussion

All the primary taxonomic groups that were expected to pass the area north of Åland on migration were recorded during the migratory birds’ surveys. The most commonly recorded taxonomic groups in both spring and autumn included Sea ducks, Geese and Cormorants, whereas Swans, Mergansers, Divers, Waders, Gulls, Terns and Auks were observed in smaller numbers and less frequently. The remaining relevant species groups either showed migratory patterns of less relevance to the pre-investigation area or an insufficient amount of data were collected throughout the surveys. Not surprisingly, the composition of species groups recorded from land and offshore varied considerably in both spring and autumn, with more seabirds, such as Divers, Waders, Terns and Auks, recorded from the offshore observation points compared to the land-based station on mainland Åland. Small numbers of Birds of Prey and Common Cranes were also observed migrating from the observation points on land, whereas none were recorded inside the Sunnanvind project area during the offshore surveys.

Flight heights of migratory birds, either visually assessed or measured with laser rangefinder, were primarily concentrated at lower altitudes ranging from the ground or sea surface and up to 30 m. Within this interval, most migratory birds passed in altitudes below 20 m. Assessed on a coarser scale, the flight height distribution recorded by the vertical radar confirmed that migratory birds pre-dominantly passed at heights below 200 m.

In spring, migration was concentrated in the 0-100 m altitude interval, whereas in autumn, migration was concentrated at slightly higher altitudes, in the 100-200 m interval. This rather small seasonal difference in the distribution of flight heights can possibly be explained by seasonal differences in species composition. For instance, migration of passerines such as thrushes can potentially be much more intense in autumn than in spring, partly due to the addition of migrating first-year individuals. This taxonomic group is known to be able to migrate at low altitudes during the night, especially in adverse weather conditions (WSP Denmark’s own observations and recordings of nocturnal migrants at offshore locations in Danish waters, similar to that of the project area).

Overall, approximately 70 % of the migrating individuals passed below 400 m and thus inside the potential risk zone for collisions with spinning turbine blades or turbine towers in the planned Sunnanvind area.

As expected, the predominant directions of migratory flights (app. 70%) revealed from the horizontal radar tracks, were towards the north-east in spring and towards the south-west in autumn. In most cases, the recorded migratory flights followed the northern coastline of Åland and did not intersect the Sunnanvind project area. However, an extension of the collected bird tracks in both directions showed that up to 35% and 46% in spring and autumn, respectively, might have partially intersected the Sunnanvind project area. These proportions are of course based on the false assumption of complete non-avoidance behaviour. In reality, several studies have demonstrated that avoidance behavior at the macro scale is clear and evident in many taxonomic groups of migrating birds, including sea ducks and geese (Desholm & Kahlert, 2005; Drachmann, 2021).

5.1 Potential impacts on migratory birds

Results from the offshore observations indicate that migratory movements of birds do occur within the pre-investigation area but with a different species composition than the one observed from land. Due to the increasing challenges of detecting flocks of birds at larger distances than 15 km from the radar setup, it seems plausible that similar migratory movements, as observed from the radar setup, also occur at some frequency further from shore e.g. through the Sunnanvind project area, however, the majority of the directional results from the migrating birds’ survey indicate that most movements of migratory birds north of Åland, occur within a flight corridor between the archipelago and the Sunnanvind project area.

For migrating birds, the most considerable potential impact caused by the Sunnanvind project is the apparent risk of collision during passage. Flocks of migrating birds entering the large array may encounter several turbines if they continue their migratory path in a southwest-to-northeasterly direction and may therefore be exposed to the risk of collision during transit. Moreover, nocturnal migrants may collide with the turbines during passage, attracted towards the array, but unable to detect the rotor blades in the darkness. The low-light conditions during the night in combination with the obstruction light regime of the wind farm, implemented to ensure safety of both aviation and maritime navigation, may attract migrating passerines resulting in an elevated risk of collision (Blew, 2012). The impact of a large-scale wind farm array on nocturnal migrants can be assessed by a measure of the potential migration intensity within the pre-investigation area. Based on the collected data, migration intensity (expressed as MTR i.e. the number of bird transits/km/hour) over the northern part of Åland appears overall to be at a low-moderate level, with peak intensities in the range of 200 – 250 birds/km/hour occurring during specific nights in autumn. This level of intensity is well below the 500 birds/km/hour criteria, considered for curtailment in Dutch and Belgian offshore wind farm projects (Rijkswaterstaat, 2019; Degraer, Rumes, & Vigin, 2022), originally calculated by (Krijgsveld, Fijn, & Lensink, 2015) based on similar migration intensity data.

The overall impact of the Sunnanvind project on migratory birds is assessed as insignificant – low on the majority of the relevant species groups. Furthermore, it has been assessed that a low impact is only present during the operational phase of the wind farm, whereas the construction and decommissioning phases are assessed to have an insignificant impact on migrating birds, due to the relatively short time span of the two phases and the potential impacts, such as noise and increased ship traffic, between the pre-investigation area and the Åland archipelago.

Overall, the environmental impact on migratory birds is assessed as low - moderate with a low level of uncertainty for the following species groups: Sea ducks, Merganser, Divers and Terns, due to the presence, abundance, and migratory behavior of these species groups within the pre-investigation area. Assessments for remaining groups of migratory birds are associated with a higher degree of uncertainty due to more scarce information and fewer observations collected during the surveys.

5.2 Relevant mitigation measures

Given the recorded flight height patterns, it is evident that most taxonomic groups of diurnal migrants pass the Sunnanvind investigation area below 30 meters. Therefore, an efficient mitigation measure to reduce the potential risk of collision, would be to increase the clearance height of the turbines to 30 m. This would allow the majority of sea ducks and other low-flying birds to pass the area below the reach of the rotors, and hence outside the risk zone.

It is assessed that the risk of collision for migratory birds can be considerably reduced by installing a bird detection system, capable of detecting migrating birds approaching the wind farm at long range and subsequently performing a risk evaluation for shut-down-on-demand of specific turbines if birds fail to avoid flying into the high-risk airspace. Ideally, such a system should cover all the turbines in the array, and not be limited to just the outer ones, because birds entering the wind farm are likely to either continue along their migratory flight path or get confused due to the presence of the turbines and therefore may have to pass several turbines before they are able to exit.

Birds migrating during the night might become attracted to the Sunnanvind wind farm due to the mandatory obstruction light regime, potentially causing disorientation, exhaustion and collision (Blew, 2012). Light mitigation can be considered a way to avoid attraction of nocturnal migrants to the wind farm and in that way reduce the number of annual collisions. Possible solutions for effective light mitigation do exist (see (Blew, 2012) however, these must take ship and air safety as well as specific requirements of energy providers and legal authorities into account.

6 Conclusion

All primary taxonomic groups expected to migrate through the area north of Åland were recorded during the surveys. Sea ducks, Geese, and Cormorants were the most commonly observed species in both spring and autumn, while Swans, Mergansers, Divers, Waders, Gulls, terns, and Auks were less frequent.

During offshore observations more seabirds were recorded compared to the surveys from land, while Birds of Prey and Common Cranes were only noted from land far away from the Sunnanvind project area.

Migratory birds were primarily recorded at lower altitudes, with most flocks flying below 20 m. Vertical radar confirmed that most birds passed below 200 m, with spring migration concentrated at 0-100 m and autumn migration at 100-200 m.

Predominant migration directions were north-east in spring and south-west in autumn, with most flocks following the northern coastline of Åland, avoiding the Sunnanvind project area. However, up to 35% in spring and 46% in autumn could potentially have intersected the project area.

Migration intensity over the northern part of Åland was assessed to be at a low-moderate level, with peak intensities in the range of 200 – 250 birds/km/hour, occurring during specific nights in autumn.

The overall environmental impact on migratory birds is assessed as insignificant – low on the majority of the assessed species groups. Moreover, it has been assessed that an impact is only present during the operational phase of the wind farm, whereas the construction and decommissioning phases are assessed to have an insignificant impact on migrating birds. However, depending on the final layout of the wind farm array as well as the clearance height of the turbines, the potential impact is assessed to be low - moderate for the following species groups: Sea ducks, Mergansers, Divers and Terns.

The main negative impact of the Sunnanvind offshore wind farm project on migratory birds is the potential risk of collision. Minor impacts include the barrier effect potentially causing adjustments in migratory directions as well as in flight heights resulting in higher energy expenditure.

Based on the analyzed flight height patterns, most migrants pass the Sunnanvind pre-investigation area below 30 meters. An efficient mitigation measure to reduce the potential risk of collision, would therefore be to increase the clearance height of the rotor blades to 30 m.

Additionally, the risk of collision could be considerably reduced by installing a bird detection system with an integrated curtailment mechanism, which ideally cover all turbines within the array, to be able to shut-down specific turbines on-demand. Furthermore, a reduction of light emission from the array could prevent attraction of nocturnal migrants to the wind farm, reducing the number of annual collisions.

The presented monitoring results serve as an input to the strategic environmental assessment for the implementation of the Sunnanvind project. Once the extent and location of the final wind farm area has been decided, additional surveys can provide a more thorough baseline with respect to migratory birds in the area.

7 References

AEWA, 2015. *International Single Species Action Plan for the Conservation of the Long-tailed Duck (Clangula hyemalis).* Agreement of the Conservation of African-Eurasian Migratory Waterbirds (AEWA) - Technical Series no. 57 .

Alerstam, 1990*. Bird migration.* Cambrigde University Press.

BirdLife International, 2022. *European Red List of Birds 2021*. [Online] <https://datazone.birdlife.org/userfiles/file/Species/erlob/BirdLife-European-Red-List-of-Birds-2021_web.pdf>.

Blew, J., 2012. *Night-time obstruction lighting of offshore wind farms and birds.* BioConsult SH. Husum, Germany.

Boiko & Kampe-Persson, 2012. *Moult Migration of Latvian Whooper Swans Cygnus cygnus.* Ornis Fennica, 89: 273 - 280.

Burger & Gochfeld, 1996. *Family Laridae (gulls*). Handbook of the Birds of the World - Hoatzin to Auks.

Bønløkke, J. , Rahbek , C., & Madsen , J. J, 2006. *Dansk Trækfugleatlas .* Statens Naturhistoriske Museum.

CornellLab, 2020. *Birds of the World. Chroicocephalus ridibundus*. [Online] <https://birdsoftheworld-org.proxy.birdsoftheworld.org/bow/species/bkhgul/cur/introduction#mig>.

Cramp & Simmons, 1977. *The Birds of the Western Palearctic*. Volume 1. Ostrich to Ducks - Oxford University Press, Oxford, England.

Degraer, S. B., Rumes, B., & Vigin, L, 2022. *Occurence of intense bird migration events at rotor height in Belgian offshore wind farms and curtailment as possible mitigation to reduce collision risk* Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Attraction, avoidance and habitat use at various spatial scales, 45-58.

Delaney, Veen & Clark, 2006. *Urgent preliminary assessment of ornithological data relevant to the spread og Avian Influenza in Europe.* Report to the European Commission.

Desholm et al, 2002. *Status of the Baltic/Wadden Sea Population of the Common Eider (Somateria m. mollissima).* Wildfowl & Wetlands Trust.

Desholm, M., & Kahlert, J., 2005. *Avian collision risk at an offshore wind farm.* Biology Letters, pp. 1 (3) 296-298.

Dorsch et al., 2019. *DIVER - German tracking study of seabirds in areas of planned Offshore Wind Farms at the example of divers*. Federal Ministry of Economics and Energy (BMWi).

Drachmann, J. W., 2021. *Pink-footed Goose and Common Crane exhibit high levels of collision avoidance at a Danish onshore wind farm.* Dansk Orn. Foren. Tidsskr., 253-271.

Drewitt & Langston, 2008. *Collision Effects of Wind-power Generators and Other Obstacles on Birds*. DOI: https://doi.org/10.1196/annals.1439.015.

Durinck et al., 1994. *Important Marine Areas for Wintering Birds in the Baltic*. Report to the European Commission. (EU DG XI research contract no. 2242/90-09-01).

European-Union, 2010. *Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds* (codified version).

Green & Alerstam, 2000. *Flight speeds and climb rates of Brent Geese: Mass-dependent differences between spring and autumn migration*. Journal of Avian Biology (2, vol. 31).

Green, 2001. *Is wind drift in migrating barnacle and brent geese, Branta leucopsis and Branta bernicla, adaptive or non-adaptiv*e? doi: 10.1007/s002650100333.

Heinicke et al., 2018. *A1 Western Taiga Bean Goose Anser fabalis fabalis.* In A global audit of the status and trends of Arctic and northern hemisphere goose populations . Conservation of Arctic FLora and Fauna International Secretariat, Akureyri, Iceland.

HELCOM, 2013a. *Species information sheet - Somateria mollissima.* [Online] <www.https://helcom.fi/baltic-sea-trends/biodiversity/red-list-of-baltic-species/red-list-of-birds>.

HELCOM, 2013b. *Red List Species Information Sheet - Melanitta Nigra*.

HELCOM, 2013c. *Red List species information sheet (Clangula hyemali*s).

HELCOM, 2013d*. Red List species information sheet (Larus fuscus).*

HELCOM, 2018. *Population development of Baltic Bird Species: Great Cormorant (Phalacrocorax carbo sinensis)* - Update. [Online] <https://helcom.fi/wp-content/uploads/2020/06/BSEFS-Population-development-of-the-Great-Cormorant.pdf>.

HELCOM, 2019. *Red List species information sheet (Mergus serrator - wintering).*

Hermann et al., 2008. *Distribution and population trends of the Sandwich Tern (Sterna sandvicensis) in the Baltic Sea.*

Kahlert et al., 2012. *Factors affecting the flight altitude of migrating waterbirds in Western Estonia*.

Kear, 2005. *Ducks, Geese and Swans.* Volume 1: General chapters, and Species Accounts (anhima to Salvadorina). Oxford University Press, Oxford, England.

Kouvoz, Zagnagutdinova & Kravchuk, 2023. *Baltic Population of the Barnacle Goose (Branta leucopsis) in the Boreal Zone of the Northwestern Russia.* [Online] <https://doi.org/10.1134/S1062359023080137>.

Krijgsveld, K., Fijn, R., & Lensink, R., 2015. *Occurrence of peaks in songbird migration at rotor heights of offshore wind farms in the southern North Sea*. Bureau Waardenburg report, 15-119.

Køie & Kristiansen, 2014. *Havets dyr og planter. 2. udgave*.

LAJI.FI., 2025. *Finnish Biodiversity Info Facility.* [Online] <https://laji.fi>.

Larsen, 1996. *Wigeon Anas penelope offsetting dependence on water by feeding in mixed-species flocks: a natural experiment*. Ibis. 138(3): 555-557.

Lehikoinen & Jaatinen, 2012. *Delayed autumn migration in northern European waterfowl.* Journal of Ornithology 153(2):563–570.

Madsen et al., 2023. *Rapid formation of new migration route and breeding area by Arctic geese.* [Online] <https://www.cell.com/action/showPdf?pii=S0960-9822%2823%2900134-3>.

Marques et al., 2014. *Understanding bird collisions at wind farms: An updated review on the causes and possible mitigation strategies.* [Online] <https://doi.org/10.1016/j.biocon.2014.08.017>.

Olsen & Larsson, 2004. *Gulls of Europe, Asia and North America.* Helm Identification Guide, London.

Piironen et al., 2022a. *When and where to count? Implications of migratory connectivity and nonbreeding distribution to population censuses in a migratory bird population.* Population Ecology 1-12.

Piironen et al., 2022b. *Predicting spatio-temporal distributions of migratory populations using Gaussian process modelling.* Journal of Applied Ecology 59: 1146–1156.

Reeber, 2015. *Waterfowl of North America, Europe and Asia: An Identification Guide.* Princeton University Press, Princeton.

Rijkswaterstaat, 2019. *Kavelbesluit V windenergiegebied Hollandse Kust (noord).* p. 113.

Robinson, J.A., 1999. *Migration and morphometrics of the Red-breasted Merganser (Mergus serrator) in northern Eurasia and the implications for conservation of this species in Britain and Ireland.* The Wildfowl & Wetlands Trust - Wildfowl (1999) 50: 139-148.

Saurola, 2008. *Monitoring birds of prey in Finland: A summary of methods, trends and statistical power.* Royal Swedish Academy of Sciences - Ambio Vol. 37, no. 6, September 2008.

Schulz et al., 2013. *Weiterentwicklung der Technik für Langzeituntersuchungen der Vögel mittels Radars und automatischer Kamerabeobachtung am Standort FINO 2 und Durchfühung von Langzeitmessungen am Standort für den Zeitraum 2010 bis 2012.* Abschlussbericht, Neu Brodersdorf (DEU), Teilprojekt Vogelzug. Bestandteil des Forschungsvorhabens "Betrieb für Forschungsplattform FINO 2" (BMU; FKZ 0329905D), p. 103.

Scott & Rose., 1996. *Atlas of Antidae Populations in Africa and Western Eurasia.* ISBN: 1900442108.

Skov et al., 2011. *Waterbird Populations and Pressures in the Baltic Sea.* [Online] <http://norden.diva-portal.org/smash/get/diva2:701707/FULLTEXT01.pdf>.

Skov et al., 2015. *Kriegers Flak Offshore Wind Farm Environmental Impact Assessment.* Technical background report Birds and bats .Prepared for Energinet.dk.

Snow & Perrins, 1998. *The Birds of the Western Palearctic.* Concise Edition. Volume 1. Non-passerines. Oxford University Press, Oxford, UK. Oxford University Press, Oxford, UK.

Thieurmel, B., & Elmarhraoui, A, 2022. *suncalc: Compute Sun Position, Sunlight Phases, Moon Position and Lunar Phase (Version 0.5.1)* [R package]. [Online] <https://CRAN.R-project.org/package=suncalc>.

Tiira.fi, 2025. *Tiira.fi: Birdlife Finland observation database:* [Online] <https://www.tiira.fi/>.

Wetlands international, 2022. *Waterbirds populations Portal*. [Online] <wpp.wetlands.org>.

WSP, 2024. Yrkesfiske Underlagsutredning. *Analys av möjliga effekter på fiske inom planläggningsområdet Sunnanvind.*

wsp.com