ENERGINET

ENERGY ISLAND BORNHOLM

ENVIRONMENTAL BASELINE NOTE - CRANE AND BIRDS OF PREY AVOIDANCE RESPONSE TO OFFSHORE WIND FARMS

29-09-2023

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Project name	**Energy Island Bornholm**
Project no.	**22000526 - Birds**
Recipient	**Energinet**
Document type	**Note**
Version	**Draft – second update**
Date	**29-09-2023**
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Approved by	**Jan Frydensberg Nicolaisen**
Description	**Environmental Baseline Note - Crane and Birds of prey avoidance response to Offshore wind farms**
Frontpage picture	**Common cranes (*Grus grus*) flying at the GPS marking site, Sweden 2022**

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CONTENTS

Abbreviation	Explanation
AEWA	African-Eurasian Migratory Waterbird Agreement
BSH	Federal Maritime and Hydrographic Agency of Germany (Bundesamt für Seeschifffahrt und Hydrographie)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPUE	Catch per unit effort
CRM	Collision Risk Models
DEA	Danish Energy Agency
EIA	Environmental Impact Assessment
EIB	Energy Island Bornholm
FHD	Flight Height Distribution
GPS	Global positioning System
GW	Gigawatt
IUCN	International Union for Conservation of Nature and Natural Resources
LRF	Laser rangefinder
LT	Local time
MTR	Migration Traffic Rate
OWF	Offshore Wind Farm
Pre-investigation area	Gross area including the two wind farm areas and the area in between in Danish waters

SUMMARY

The Energy Islands mark a new era in offshore wind energy generation, aimed at providing renewable power to Danish and foreign grids. These offshore renewable power plants will help phase out fossil fuels in Denmark and Europe. The establishment of an Offshore Wind Farm (OWF) of this magnitude will most likely have different environmental impacts, but the effect on long-distance migratory birds like cranes and birds of prey is not well-documented.

To prevent or minimize the risk of collision, it is crucial to gain knowledge of species-specific avoidance behaviour in migrating flocks of birds. Avoidance behaviour is divided into three categories: Macro avoidance, that occurs outside the OWF, meso that occurs within the array, and micro which involves last-second manoeuvres to avoid rotor blades. At this point, precise data on avoidance behaviour, especially for migrating common cranes (*Grus grus*) at existing OWFs, is limited. This often results in conservative assumptions in collision risk models during Environmental Impact Assessments (EIAs), due to a precaution principle. This study used radar and laser rangefinder methods from a vessel anchored in front of the existing offshore wind farms Kriegers flak (Denmark) and Baltic 2 (Germany), to estimate avoidance behaviour of cranes and birds of prey at different scales (macro, meso, and micro) as they approach the OWFs.

During the survey period, 4,466 cranes in 84 flocks migrated near two OWFs: Kriegers flak and Baltic 2. In autumn 2022, 3,425 cranes in 47 flocks were observed, with 1,114 cranes exhibiting macro avoidance, and 125 showing meso or micro avoidance. In spring 2023, 1,041 cranes in 37 flocks were observed, with two flocks displaying meso-scale avoidance. Additionally, ten sparrowhawks, one marsh harrier, and one red kite migrated near the OWF, showing avoidance behaviour.

To gather real-time data on cranes' migration across the Baltic Sea, Kattegat, and the Sound during autumn 2022 and spring 2023, common cranes from Sweden were fitted GPS transmitters. In total, 17 juvenile cranes were captured and tagged with GPS transmitters, 11 in the southern Sweden in 2022 and six in northern Sweden in 2023. Data from the tagged cranes during their migration across the Baltic Sea, Kattegat, and the Sound provided real-time insights into migration routes and altitudes. The cranes migrated at varying altitudes from near the sea surface to over one kilometre high. Some cranes exhibited circling behaviour when approaching the coast, potentially to harness thermal updrafts. Circling behaviour was also observed over open water without thermal updrafts.

No collisions between migrating birds and wind turbines were observed throughout the survey period. The results also suggest that, during the survey period, the OWF had no influence on migrating flocks of cranes, that passed the Baltic Sea by routes at a greater distance, either east or west of the OWF.

Further analysis and an extended dataset will be presented in detail in a third draft update of this note, including the statistical analyses to assess the avoidance pattens observed.

1 INTRODUCTION

The Energy Islands mark the beginning of a new era for the generation of energy from offshore wind, aimed at creating a renewable energy supply for Danish and foreign electricity grids. Operating as renewable energy power plants at sea, the islands are expected to play a major role in the phasing-out of fossil fuel energy sources in Denmark and Europe.

After political agreement on the energy islands has been reached, the Danish Energy Agency (DEA) plays a key role in leading the project that will transform energy island from a vision to reality. The Energy Island projects are pioneer projects that will necessitate the deployment of existing knowledge into an entirely new context.

In the Baltic Sea, the electrotechnical equipment will be placed on the island of Bornholm, where electricity from offshore wind farms will be routed to electricity grids on Zealand and neighbouring countries. The offshore wind farms will be constructed approximately 15 km south-southwest of the coast and will be visible, but not dominate the horizon. The turbines off the coast of Bornholm will have a capacity of 3 GW, corresponding to the electricity consumption of two million households.

The establishment of an Offshore Wind Farm (OWF) of this magnitude will most likely have different environmental impacts, especially on the ecosystem of the area in close proximity to the OWF, but the effect on long distant migrants such as the common crane (*Grus grus*), hereafter crane, is only incompletely described in the literature. The possible risk of collision between larger birds such as cranes and wind turbines are an issue of great importance, since a presumable collision between bird flocks and wind turbines would damage the wings of the wind turbines, resulting in higher maintenance cost, but especially because of the impact collisions could affect the overall status on the protected European populations of migrating larger birds. To prevent or minimize the risk of collision, it is crucial to gain knowledge of species-specific avoidance behaviour in migrating flocks of birds.

1.1.1 OFFSHORE WIND FARMS AND FLIGHT BEHAVIOUR

Since one of the projects main goals is to observe avoidance behaviour when approaching an OWF, investigations of flight behaviour near to existing wind farms can provide crucial information to consider. We are sure that the observed avoidance behaviour can be generalized to other OWF sites if site-specific circumstances are accounted for.

Avoidance behaviour will depend on multiple factors. First, there are site independent factors such as weather conditions in particular wind and visibility. It is therefore expected that avoidance behaviour will be affected by weather independently from the exact location / wind farm site. Secondly, avoidance behaviour will crucially depend on the flight height of birds. Only if birds fly at certain altitudes they are at risk of colliding with the turbine and thus will only show avoidance at specific flight heights and potentially show different avoidance types (macro- versus meso avoidance and vertical versus horizontal movements) depend on the exact flight height.

Flight heights in turn are influenced by location. Depending on season flight height of cranes near to the starting point of migration will be higher and slowly decrease over the course of crossing the sea. Thus, to accurately predict avoidance behaviour we need season- and site-specific flight height distributions (FHDs).

This note will propose methods to investigate the near wind farm flight behaviour of common crane – in particular FHDs and avoidance behaviour. This will be achieved using vessel-based surveys, that will investigate FHD and avoidance behaviour of cranes near OWFs during their migration over the Baltic Sea. By combining radar and laser rangefinder methods, avoidance behaviour can be specified on different scales. Horizontal radar allows tracking of cranes up to 20 km distance and thus to observe large distance (macro-) avoidance. Whereas the usage of rangefinder can obtain three-dimensional data on flying birds close to and even within OWF, if they enter a wind farm, allowing to capture meso- and possible micro avoidance, further explained in section 4 Methodology.

In combination, these methods contribute to determine macro-, meso-, and micro-avoidance of cranes toward OWFs. Avoidance rates are a crucial factor in collision risk models (CRMs; Band 2012; May 2015). For example, a change in assumed avoidance rate from 95 % to 99.5 % can result in a 10-fold change of estimated collisions (compare Chamberlain et al. 2006). Unfortunately, precise, and data-based estimates of avoidance behaviour towards OWFs and FHD of migrating cranes are very limited. This lack of knowledge leads to the practice of assuming rather low avoidance rates in collision risk models during EIAs, due to a precaution principle. Consequently, German authorities are considering demanding wind farms to be shut down if specific threshold of mean migration traffic rates (MTR) are exceeded. However, recent investigations of crane flight behaviour towards onshore wind farms shows significant higher avoidance rates than typically used in CRMs ranging from 99.88 % to 100 % (Drachmann et al. 2021). This stresses the importance of assessing cranes' avoidance behaviour in an offshore setting. Identifying accurate avoidance rates of cranes towards offshore OWFs are therefore of utmost importance to correctly estimated number of collisions using CRMs. The same holds true for FHD (Johnston et al. 2014b) which will be identified in this project as well. This note will help to clarify estimates on realistic, not worst-case, avoidance rates which can be used in collision risk models to assess a realistic impact of OWFs on migrating cranes.

1.1.2 VESSEL BASED SURVEYS OF MIRGATING CRANES AND BIRDS OF PREY

A vessel, Skoven, anchored in front of the existing offshore wind farms, Kriegers flak (Denmark) and Baltic 2 (Germany), facing the migrating cranes and birds of prey, providing some of the best observation opportunities possible. Since migration directions changes with season, the best observation spots will change accordingly. Using a vessel, it is possible to freely choose where exactly to anchor and observe depending on the season: north or south of a particular wind farm facing the approaching cranes (see Figure 1). Additionally, the anchor site can be changed during an observation trip, if it turns out that on a specific day that cranes mainly cross the Baltic Sea some distance further west or east of the current location. While in general the main migration corridor is known, unpredictable conditions such as weather.

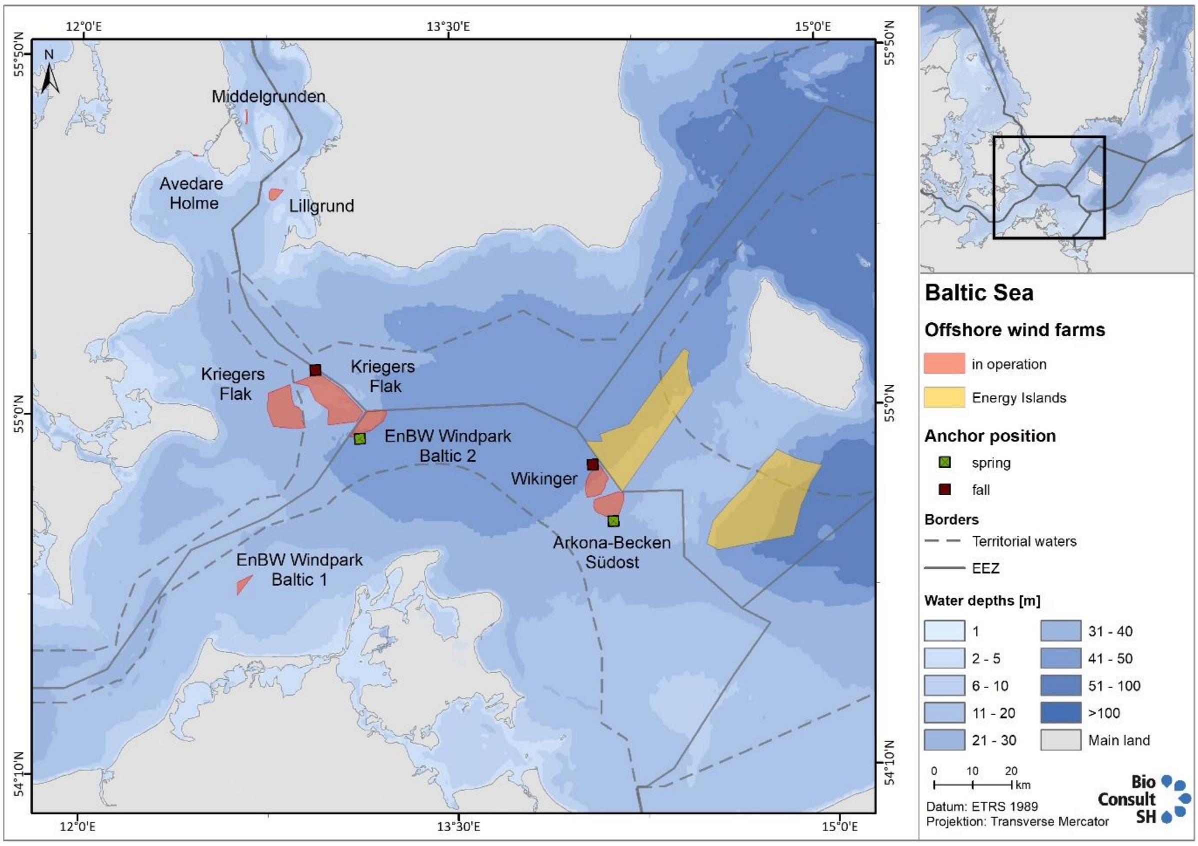


Figure 1. Overview of operational wind farms in the Baltic Sea between Swedish and German land masses. Potential anchor positions are given in green for spring migration and in red during fall migration.

To observe enough migrating cranes and to generate a sufficient database (sample size) for statistical analysis seven observation days were accomplished. To produce enough data, the field trips needed to match with the migration peak. Information from local observers and online bird observation databases helped determine the onset of migration. Together with weather forecasts indicating good migration conditions, this aided narrowing down to the most likely periods of crane migration over the Baltic Sea and when to start field observations accordingly. The vessel used for the observations was available on short notice, which allowed full flexibility and the possibility to mobilise with very short notice. Nevertheless, due to stochastic events and local conditions at migration starting sites, the main days on which cranes will cross the Baltic Sea are not possible to be precisely predicted. Therefore, the risk of spending observation days out at sea without any or just a few sightings of cranes cannot be eliminated completely.

1.1.3 SUPPORTING DATA FROM CRANES WITH SATELLITE TRANSMITTERS

To obtain information on fine scale flight behaviour of cranes, 11 juvenile cranes were marked with GPS transmitter (OrniTrack-R19 3G solar powered GPS-GSM transmitter) during late summer in southern Sweden 2022 and 6 cranes in northern Sweden late summer 2023.

So far, tagging projects on cranes were mostly focused on juveniles, since they can be tagged with a relative low risk for the birds. Young cranes have high survival rates compared to other species and they follow the same migration routes as the adults, as the birds fly in mixed flocks of young and adult birds.

In the final note, flight behaviour data derived from the GPS tracks will be analysed using adequate models incorporating weather data. This will provide new and updated avoidance rates and information on flight behaviour that can be applied in e.g., impact assessments. However, this note will only superficially include the GPS data.

2 BIRDS AND OFFSHORE WIND FARMS

Birds potentially making use of the pre-investigation area can be roughly divided into two groups, those that are typically found within the area most of the time (resting seabirds) and those that alternate between different distant regions and may only cross the area temporarily when migrating (e.g., cranes and birds of prey).

Potentially, offshore windfarms pose a variety of direct and indirect impacts to migrating birds, most notably:

- Risk of collision with turbines, which most often results in direct mortality
- Barrier effects where the wind farm creates an obstacle to migrating birds forcing birds to find alternative routes or different flight altitude
- Attraction to the offshore structures, as possibly of night-migrating passerines to light sources

The degree to which these birds may be affected by any of these 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. Moreover, these effects rarely occur in isolation but are likely additive and may also co-occur with other already existing anthropogenic effects, such as industrial monocultures for agricultural sites regarding biofuels or solar fields (Dwyer et al. 2018).

2.1 BIRD MIGRATION

Migrating birds alternate between breeding and non-breeding regions. They can disperse very long distances twice a year in search of feeding resources and better climate conditions. Although it is a regular yearly repeating phenomenon, the magnitude and timing of migration can vary strongly from year to year and is subject to great variability. Moreover, some species migrate long distances, others only comparatively shorter distances, while for other species, only parts of the populations may migrate, and the rest remain in the area.

Despite the great variability, estimates suggest that about half a billion birds of about 200 species cross the western Baltic Sea during autumn, and half of this number (~ 250 million birds) crosses the area in spring (BSH 2021). The great majority of them (> 95 %) are songbirds. The rest is composed of sea- and waterbirds such as divers, grebes, ducks, geese, waders, gulls, terns and auks and by thermal gliders such as birds of prey and cranes (BSH 2021).

As already mentioned, bird migration is very variable and thus hard to predict. However, birds adapt the timing of their migration to weather conditions such as temperature, precipitation, fog, wind speed and direction, because energetic costs are related to the presence and magnitude of these parameters (BSH 2021). Thus, migration does not occur regularly but most of it takes place during certain days of the migration period.

For many Scandinavian and Siberian breeding bird species, the Baltic Sea is part of their annual migration routes (Figure 2). Numerous night-migrating songbirds are thought to cross the Baltic offshore area in a broad front movement mostly with a south-western orientation, but local aggregations and deviating directions are also possible. Most day-migrating land birds follow landmarks from Falsterbo in Sweden over Danish islands such as Zealand and Lolland and German Fehmarn to the mainland of Europe, but fractions of those populations also directly cross the open water. Waterfowl like geese, ducks or divers mainly move through the area in an east-west direction (Bellebaum et al. 2010a).

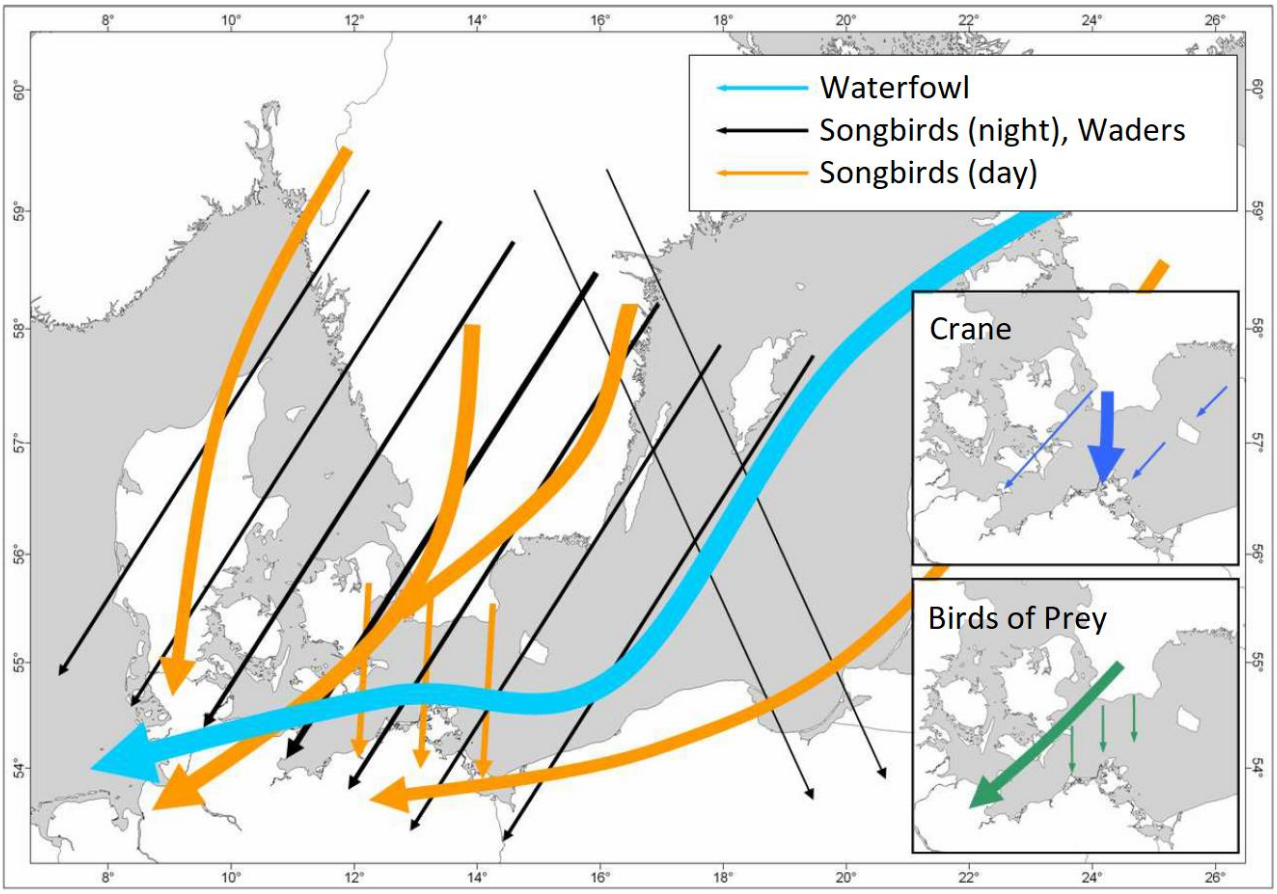


Figure 2. Most important migration routes in the Baltic Sea during autumn. From Bellebaum et al. (2010a).

3 RELEVANT SPECIES AND SPECIES GROUPS

In this section, existing data on the most relevant species groups of migrating and staging birds potentially present in the pre-investigation area is provided.

3.1 CRANES

3.1.1 BIOLOGY, DISTRIBUTION AND ABUNDANCE

The population of cranes breeding in Northwest Europe and Scandinavia increased in size and is estimated to be 350,000 individuals (Wetlands International 2022, AEWA CSR 8, retrieved on 25.02.2022). Especially for cranes of Finland and Sweden, the Southwestern Baltic Sea is an integral part of their migration route to and from wintering quarters in Southwestern Europe. The Rügen-Bock region in Germany is an important resting area, hosting temporarily up to 40,000 cranes (BSH 2021). A huge part of these birds cross the Arkona basin in an 1–2-hour flight. Especially in autumn, a proportion of cranes will also move in a southwestern direction over the area of Bornholm (Figure 3). The exact number of birds crossing the pre-investigation area is not known and will be highly dependent on the weather conditions each year.

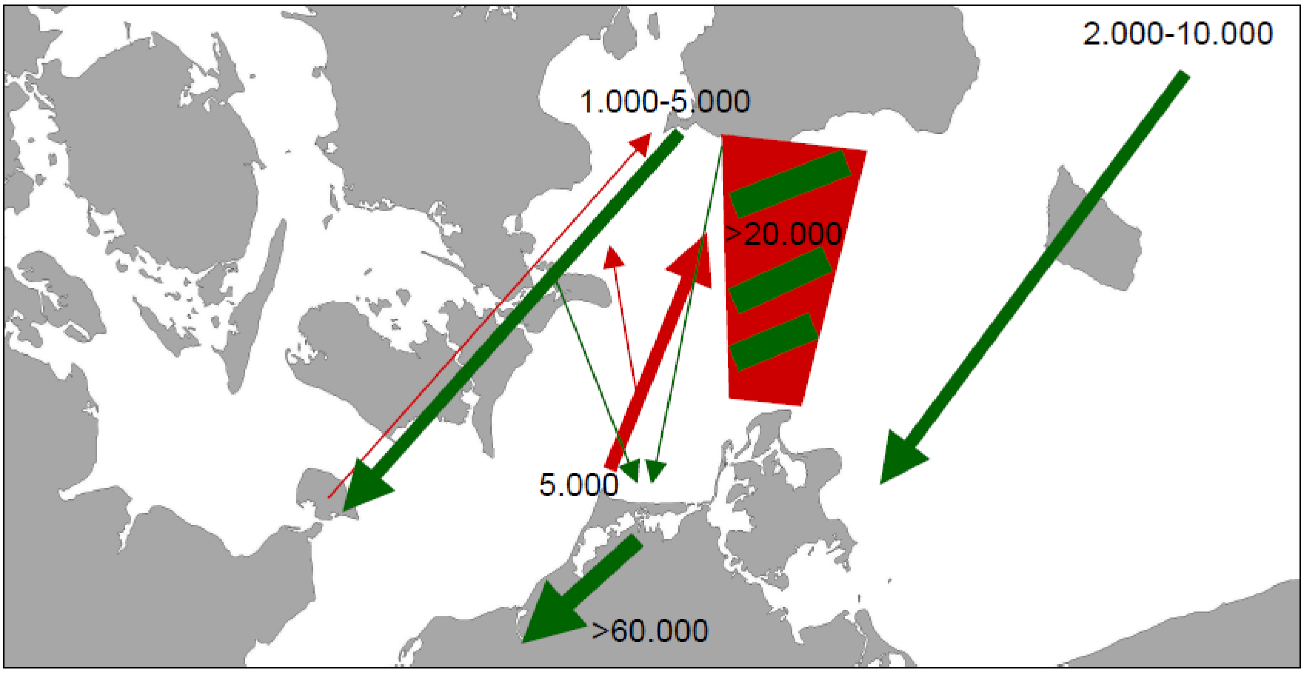


Figure 3. Migration routes of common cranes in the southern Baltic area (BSH 2021 based on Falsterbo, Bornholm and other observation data). Estimated numbers may be higher today due to an increasing population trend. Red arrows mark spring migration routes and green arrows autumn migration. The thickness of the lines indicate the assumed magnitude of migration and for the central route between southern Sweden and Rügen the approximate spatial extension of this migration corridor.

At Bornholm, the crane is a relatively common breeding bird, and the island probably holds the most dense population of breeding in the country. During the latest Danish breeding bird atlas, at least 70 pairs were breeding at the island, and the population is still increasing (Vikstrøm & Moshøj 2020).

The number of migrating cranes passing Bornholm is highly dependent on wind conditions, with the highest number during periods with westerly winds and generally more birds during autumn compared to spring (Table 1).

Table 1. Monthly distribution of the number of cranes observed at Bornholm 2010-2022. The numbers are "max numbers", i.e. the highest number of birds observed on a single day each month (DOFbasen 2022).

Month	Max number
January	14
February	55
March	200
April	220
May	35
June	13
July	45
August	126
September	3,814
October	8,885
November	200
December	3

3.1.2 CONSERVATION STATUS AND POTENTIAL THREATS

Due to its increasing population trend, the crane currently has a Red List status of "least concern" (BirdLife International 2021). However, its susceptibility to increasing offshore wind power generation remains not completely clear. One important behavioural trait in this regard might be the flight height of cranes crossing the Baltic Sea. Cranes tend to use soaring flight over land, but due to the lack of thermal updrafts over the open water, they have to gain or hold their altitude in powered flight after leaving the coasts (Alerstam 1990). Studies of flight altitudes of cranes in the Baltic offshore region so far reveal a certain variety, with cranes observed flying clearly below 200 m height as well as far above (Schulz et al. 2013; Skov et al. 2015). Also, a dependency on wind directions has been observed.

3.2 BIRDS OF PREY

3.2.1 BIOLOGY, DISTRIBUTION AND ABUNDANCE

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, many of them are long-distance migrants undertaking sometimes intercontinental flights (Bildstein 2006). Most birds of prey can soar, which is they are able to maintain flight without flapping their wings and making use of the rising air currents and thereby reducing energetic costs. Soaring is an efficient form of transport, both during and outside of long-distance migration (Bildstein 2017). Especially, long-distance migrants such as the European honey buzzard or Montagu's harrier, are strongly dependent on soaring flight to complete their migration routes. Whereas many species use soaring during their migration routes, others do migrate with powered flight (flapping their wings; examples are ospreys, harriers, most accipiters and falcons). Most raptors are day migrants, but few species such as peregrine falcons, ospreys, and merlins also migrate during nights. Migrating raptors travel over well-known corridors and often in flocks (Bildstein 2006).

The most important flyway for raptors in Europe is the western European-western Africa flyway (Bildstein 2017). A comparative study of satellite tracking and ring recoveries for four common raptor species show detailed information on the routes taken by these migrants (Strandberg et al. 2009). In Europe, there are about 39 species of breeding diurnal birds of prey (Stroud 2003).

Relative close to the pre-investigation area, at Falsterbo in South Sweden, raptor autumn migration has been studied since early 1940s (Kjellén & Roos 2000) whereas standardized counts of raptors and other migratory birds have been conducted since 1973 (Kjellén 2019). It has then been estimated that an average of 46,000 migrating raptors and falcons are observed annually. The most common species there are Eurasian sparrowhawk *Accipiter nisus*, common buzzard *Buteo buteo* and the red kite *Milvus milvus* (Kjellén 2019). Species with more southerly distribution, that is that breed close to Falsterbo are more easily observed than species with northerly distribution (Kjellén 2019). Similarly, thermal migrants tend to be more concentrated than active flyers at Falsterbo and also since raptors tend to fly at lower altitudes there, the censuses at Falsterbo have been particularly important for studies of raptors (e.g., Kjellén 1997).

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

There is, however, a large variation in the number of raptors being observed during the autumn migration every year. This may not only be linked to more birds being counted under favourable weather conditions (for example, when birds fly against the wind, they tend to fly at lower altitudes, and may be easily observed and counted), but also to real changes in the populations due to changes in productivity. For example, species like the Eurasian honey buzzard *Pernis apivorus* and the rough-legged buzzard *Buteo lagopus* are known to produce varying numbers of juveniles in relation to the availability of prey during the breeding season (e.g., wasps and rodents respectively, Kjellén 2019).

Table 2. Population size estimates, trends, average numbers seen at Falsterbo in Sweden (between 1942-1960 and between 1973-2019) and conservation status for the most common raptor species expected to migrate over the EIB pre-investigation area. Population trends: INC = increasing, DEC = declining, STA = stable.

Species	Most recent population estimate (Trend)[1]	Annual average numbers at Falsterbo (1942-1960)[2]	Average autumn migration numbers at Falsterbo[3]	Conservation status		
				European Birds Directive	CITES	Red List Birdlife 2021
Eurasian Sparrowhawk (*Accipiter nisus*)	728,000-1,150,000 (STA)	5,944	20,364	I (only ssp *granti*)	II	LC
Common Buzzard (*Buteo buteo*)	1,760,000-2,460,000 (INC)	17,086	14,383		II	LC

European Honey Buzzard (*Pernis apivorus*)	241,000-350,000 (STA)	7,979	6,491	I	II	LC
Red Kite (*Milvus milvus*)	65,100-76,600 (INC)	51	1,305	I	II	LC
Rough-legged buzzard (*Buteo lagopus*)	57,600-11,700 (STA)	139	889		II	LC
Common Kestrel (*Falco tinnunculus*)	823,000-1,270,000 (DEC)	271	690		II	LC
Western Marsh Harrier (*Circus aeruginosus*)	303,000-485,000 (STA)	28	659	I	II	LC
Osprey (*Pandion haliaetus*)	19,200-27,100 (INC)	68	270	I	II	LC
Hen Harrier (*Circus cyaneus*)	112,000-174,000 (DEC)	46	264	I	II	LC
Merlin (*Falco columbiarius*)	40,100-83,400 (DEC)	128	236	I	II	VU

[1] Population sizes and trends taken from Birdlife International (2021). INC: Increasing, STA: stable, DEC: decreasing. In cases where the trend is less certain a "?" may be appended.

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

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

[4] Conservation status categories are explained in the appendix

Bornholm is generally not known as an important migration site for migrating raptors. However, a variety of species, some of them in considerable numbers, are observed at Dueodde, the southern tip of the island during autumn. Especially, the number of rough-legged buzzard is noteworthy in some years (Table 2 and 3).

Table 3. Numbers of migrating raptors at Dueodde at Bornholm 2010-2021. The numbers are "max numbers", i.e. the highest number of raptors observed during a year in the period. Data from DOF-basen (2022).

Species	Max number 2010-2021
Eurasian sparrowhawk (*Accipiter nisus*)	202
Goshawk *(Accipiter gentilis)*	3
Common buzzard (*Buteo buteo*)	370
European honey buzzard (*Pernis apivorus*)	54
Rough-legged buzzard *(Buteo lagopus)*	211
Red kite (*Milvus milvus*)	14
Hobby *(Falco subbuteo)*	3
Red-footed falcon *(Falco vespertinus)*	2
Merlin (*Falco columbiarius*)	15
Hobby *(Falco subbuteo)*	23
Common kestrel (*Falco tinnunculus*)	128
Peregrine *(Falco peregrinus)*	2

Hen harrier (*Circus cyaneus*)	3
Marsh harrier (*Circus aerginosus*)	11
Pallid harrier *(Circus macrourus)*	1
Osprey (*Pandion haliaetus*)	9
White-tailed eagle (*Haliaeetus albicilla)*	1
Bonelli's eagle (*Aquila fasciata*)	1
Golden eagle (*Aquila chrysaetos*)	1

3.2.2 CONSERVATION STATUS AND POTENTIAL IMPACTS FROM OWF'S

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

Due to the particular vulnerability of birds of prey and the reduction of their population sizes because of the numerous threats they have already faced by the first half of the last century (Bijleveld 1974; Bildstein 2017), birds of prey are among the rarest birds in Europe: 46 % of European birds with less than 1,000 breeding pairs are birds of prey (Stroud 2003). Thus, many of the species are protected by European legislation and have also been included in other conventions (Table 3 for the most common species likely crossing through the Baltic Sea).

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

Despite estimates of collision rates of birds of prey with wind turbines are very variable and the difficulty of obtaining reliable data, some overall findings and conclusions have been achieved from the German database in Brandenburg (Rasran & Dürr 2017). Most frequently killed birds were red kite and common buzzard, but other species such as white-tailed eagle, common kestrel and black kite were also often reported as victims. Most collision victims were adult birds and mainly occurred in spring and late summer (Rasran & Dürr 2017). The collision risk directly depends on the rotor swept area, thus the flight height at which the species most commonly fly. Red kites often flew at heights within the rotor swept area. In fact, it was found that up to 50 % of all recorded red kite flights led into the risk area of wind turbines (Mammen et al. 2017).

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

4 METHODOLOGY

In this section, the observational methods to investigate flight height distributions collected from the survey vessel "Skoven" and the fieldwork process regarding GPS tagging of juvenile cranes, will be explained.

4.1 MEASURING AVOIDANCE BEHAVIOUR AND FLIGHT HEIGHT OF CRANES DURING MIGRATION

The main aim of the study was to identify avoidance behaviour of cranes towards offshore wind farms (OWFs). We differentiated avoidance behaviour at the macro-, meso, and micro scale. Macro avoidance is an avoidance response towards the wind farm array occurring outside the wind farm perimeter. Meso avoidance is any avoidance behaviour occurring towards turbines inside the wind farm array, whereas micro-avoidance is the last second evasive movements performed by a bird to avoid collision with rotor blades. While macro-avoidance can happen close to the OWF, it may also be triggered from further away (few km). To capture the avoidance behaviour on these different spatial scales we applied two techniques: Radar observation for assessments of macro- and meso- avoidance, and Laser Rangefinder (LRF) measurements for all three scales: macro-, meso-, and, if possible, micro avoidance. The LRF was used to collect flight height measurements of the migrating cranes, which are presented in this note as a supplement to the radar tracks.

The wind turbines at Kriegers Flak impose a collision risk zone from 25 - 189 meters, with 82-meter rotor blades centred around 107 meters turbine height.

The assessment of avoidance behaviour was done either directly in field by visual observations of changed behaviour in the flocks of migrating cranes, in either altitude or direction, or if no such information was provided, assessed from the radar tracks by combining the altitude of the migrating flocks of cranes with their direction. If the cranes were noted flying in an altitude within the risk zone of the windmills rotor blades and their direction was through the OWF's on the radar tracks, but no change in direction or altitude was observed by the visual observations, this has been described as possible avoidance behaviour.

4.1.1 GENERAL PROCEDURE OF VESSEL BASED SURVEYS

Two observers were positioned on the deck facing towards the expected migration direction while scouting for cranes migrating over the Baltic Sea – i.e., towards the approaching cranes and otherwise monitoring according to the agreed methods (document: `Methods: Vessel-based LRF migration monitoring´ and radar `document Method: radar tracing´, which can be provided if desired).

BEGIN AND END OF SURVEY

Previous data indicate that cranes may arrive at the anchoring site early in the morning but not earlier than 1.5 hours after civil twilight. Thus, observers started 1.5 hours after civil twilight. During mid-September the civil twilight is approximately 6:00 am local time and during mid-October its around 7:00 am.

Observations were stopped approximately one hour before sunset – but the observations continued if migratory behaviour of cranes was still prominent and detectable.

If no cranes were observed for two consecutive days and there were no clear signs of migration on the following day the survey trip was stopped, and the vessel returned to harbour. However, the decision to stop the survey was always made in consultation with the project management.

OTHER SPECIES

The main objective of this study is to detect avoidance behaviour of cranes. However, in cases of low or no activity of migrating cranes, observers detected and recorded avoidance behaviour and FHDs of birds of prey. However, radar tracks tracking of birds of prey was not implemented, in order not to overlook any cranes.

4.2 CRANE TAGGING PROJECT

4.2.1 OUTLINE AND PURPOSE

At Grimö Wildlife Research Station, SLU, Västmanland Sweden, there is an ongoing crane survey project, and an established expertise of capturing juvenile cranes for GPS-tagging. WSP Denmark has successfully established a collaboration with the research station for a tagging-project. This collaboration, and the expertise that they provide, ensures the highest possible chances of success.

While managing expectations, it became clear that no more than 10 to 12 tagged juvenile cranes could be expected under the already running survey project – yielding a catch per unit of effort (CPUE) of approximately 1 crane/day. This CPUE is obtained only under optimal conditions with good weather and a successful breeding season.

To reach the goal of 20 tagged cranes the only option is to increase the effort. There was a time slot of approximately 10-14 days of optimal tagging, where the juvenile cranes were big enough to carry the GPS-transmitter, but still not able to fly. Additionally, in this time slot it was possible to catch the birds with a method abiding to the ethical standards. Using two tagging teams at the same time it was therefore be necessary to increase the effort. Not every catching attempt was successful, and each territory holding crane pair, with offspring, can only be approached once.

Therefore, an alternate plan was made with the option of a secondary tagging area in Västerbotten, Northern Sweden. This area was selected as there is already an established colour ringing scheme running in the area. But more importantly because the data from this colour ringing scheme suggest that the cranes in northern Sweden migrate south, along the Swedish east coast, crossing the Baltic Sea at Bornholm. Mapping this migration route by means of GPS-data will be completely novel and can potentially be used to produce flight height profiles directly over the project area at Bornholm.

Tagging effort invested in two geographically distant areas would make it possible to get behavioral data on cranes from both the western and eastern part of the migration route – covering both existing wind farms and the project area.

METHOD OF THE FIELDWORK

To abide to animal welfare ethical standards, minimizing the risk of injuring birds, the best practice is to capture and GPS-tag juvenile cranes. It is possible to capture adult cranes using canon-nets, snares, and other highly invasive methods. However, these methods imply a higher risk of injury, lower chances of success and increased logistical cost regarding planning and execution of field activities.

The field work within each tagging area will consist of two parts. First a survey and mapping of territory holding crane pairs with offspring followed by the actual tagging efforts.

The survey and mapping of territories is carried out just before the tagging. It is done opportunistically by driving around and observing areas with reasonable accessibility. Having two areas with already established survey and ringing schemes we can draw on the local knowledge and experience of the crane's whereabouts. This reduces the number of field days considerably.

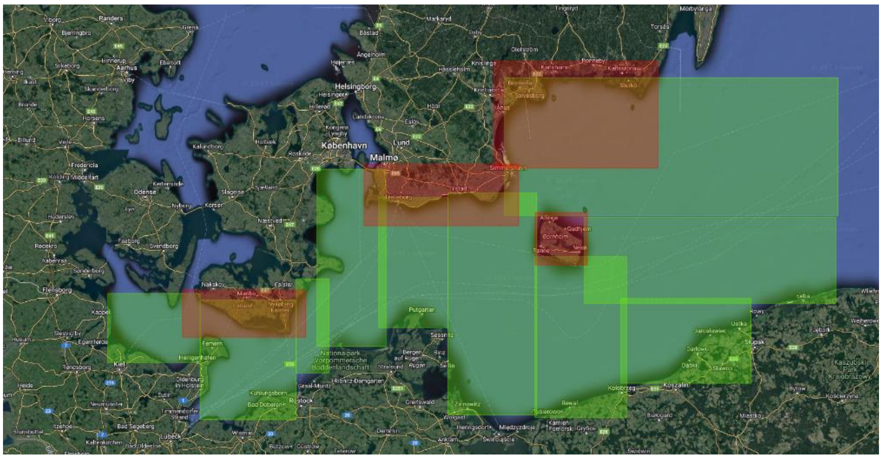
Observations from the survey are used to plan the tagging efforts.

Catching is done by localizing juvenile cranes and carried out optimally in dry fields with good access. Chances of this is best early in the morning, before the cranes retreat into the more wet habitats. When a juvenile crane is singled out an approach is made. Because the juvenile cranes are not yet able to fly, it is possible to catch them by hand after a short sprint. After capture, the juvenile crane is leg-fitted with an OrniTrack-R19 4G transmitter. The transmitter uploads to a database through the GSM/GPRS network.

Figure 4: A picture from the fieldwork during late summer 2023, in the area around Umeå, Sweden, showing the mounted GPS transmitter (223701) on a juvenile common crane (*Grus grus*) and the specific color ring combination for that individual.

Logging frequency was set to 3 hours, with a geofence in the Baltic Sea area where the logging frequency was increased to 1 second intervals and 60 seconds intervals to record fine scale behavioral data ("later described as geo-fencing"). The geo-fencing are monitored and changed manually from time to time, if non migrating cranes are roosting within the area and therefore draining the GPS transmitter from power unnecessarily.

Figure 5: A map showing the selected Geo-fencing on the 20-09-2023, with the red areas showing the 60 second intervals and the green areas showing the 1 second intervals.



ETHICAL STATEMENT

Capturing and tagging activities of common cranes was approved by the local animal ethics authority in Uppsala, Sweden (Dnr. 5.8.18 – 09841/2022). The ethical application was targeted and submitted under the project “Ecology, migration strategies and disease transmission in common cranes, in relation to agriculture and development of offshore wind power". The submitted application contained a detailed description of the planned field activities and applied procedures as well as an animal risk hazard assessment. Exemption was granted to perform tagging of cranes in the field (rather than in a laboratory) to reduce handling time and animal stress load. It was assessed that the animal stress and suffering resulting from the project activities were at a low and acceptable level and could be well justified by the expected knowledge gain of the tagging project. The field work was coordinated and undertaken by a small, dedicated team of experts experienced in capturing, handling and tagging of large birds such as cranes. Prior to the field activities, all participants had completed relevant courses in laboratory animal science and Swedish legislation & Ethics, animal welfare and “3R” (replacement, reduction, and refinement) offered by Swedish University of Agricultural Sciences (SLU).

METHOD OF THE SPATIAL MAPS

The spatial maps presented, showing the migratory routes of the juvenile cranes, are the raw data from the GPS transmitters mounted on the various cranes, with all available tracks during the crossing of open water included as well as the altitude of each known location. The start and end of each track is chosen as the approximate start and end of the crane’s movement within the geo-fence.

5 RESULTS

In this section, the migratory behaviors of the tagged cranes are presented by GPS transmissions of their very first migration south, during autumn 2022, and the return north during spring 2023.

Secondly, the observational results from the vessel survey, that describe the migratory behavior of cranes, flying above or in close proximity to Kriegers Flak or Baltic II wind farms during the study period in autumn 2022 and spring 2023, will be presented.

GPS TRANSMISSIONS OF THE TAGGED JUVENILE CRANES DURING AUTUMN 2022 AND SPRING 2023

In total, 11 cranes were successfully fitted with GPS transmitters (No. ID. Between 223692 – 223711) during late summer 2022. Afterwards the transmitters have provided real time transmissions of the crane's movements and migration, including the altitude of their position. The transmitters have been set to receive a GPS location every 900 seconds outside a "geo-fencing", that have been selected to cover the inner waters between Denmark and the surrounding countries, and one second within these "geo-fences". This have made it possible to track the exact route of migration for each individual, as well as displaying the changes in their flight height distribution while crossing the sea (Figure 6,7 and 8). The cranes displayed circling behavior in order to gain altitude. All the cranes performed this behavior prior to crossing the sea, while some also started circling during their crossing, either when reaching landmarks or even above the sea surface.

The 11 tagged cranes migrated south during autumn 2022 within the period from 18th of September – 19th of October. Migration routes and flight altitudes of the 11 birds are presented in Figure 6. A summary for each bird, presented by the number of the attached GPS transmitters is given below:

Autumn migration of cranes 2022

No. 223692: migrated across the Baltic Sea on the 30-09-2022, with the route of migration displayed from 09:00 – 15:00 LT. The crane crossed the sea at an altitude of around 100 - 300 meters, descending above the sea with a few intervals of flying closer than 10 meters from the surface.

No. 223693: migrated across the Baltic Sea on the 19-09-2022, with the route of migration displayed from 12:00 – 15:00 LT. The crane crossed the sea at an altitude of around 600 - 700 meters, descending above the sea.

No. 223695: migrated across the Baltic Sea on the 21-09-2022, with the route of migration displayed from 07:00 – 11:00 LT. The crane crossed the sea at an altitude of around 300 - 700 meters, descending above the sea.

No. 223697: migrated across the Baltic Sea and the Sound on the 19-09-2022, with the route of migration displayed from 07:00 – 12:00 LT. The crane crossed the sea at an altitude of around 200 - 700 meters, ascending several times when approaching land and descending above the sea.

No. 223698: migrated across the Baltic Sea on the 30-09-2022, with the route of migration displayed from 13:00 – 17:00 LT. The crane crossed the sea at an altitude of around 10 - 200 meters, descending above the sea, with a few intervals of flying closer than 10 meters from the surface.

No. 223700: migrated across the Baltic Sea on the 19-09-2022, with the route of migration displayed from 14:00 – 17:00 LT. The crane crossed the sea at an altitude of around 500 - 800 meters, descending over the sea, with a single increase in altitude north of the established windfarms Arcadis Ost 1 and Wikinger.

No. 223704: migrated across the Baltic Sea on the 01-10-2022 and 02-10-2023, with the route of migration displayed from 23:00 – 07:00 LT. The crane crossed the sea at an altitude of around 10 - 100 meters, descending above the sea, though the transmissions of the GPS on this individual are very limited during the crossing.

No. 223707: migrated across the Baltic Sea on the 30-09-2022, with the route of migration displayed from 13:00 – 17:00 LT. The crane crossed the sea at an altitude of around 10 - 250 meters, shifting in altitude while crossing the sea.

No. 223709: migrated across the Baltic Sea on the 21-09-2022, with the route of migration displayed from 08:00 – 12:00 LT. The crane crossed the sea at an altitude of around 250 - 900 meters, descending above the sea.

No. 223710: migrated across the Baltic Sea on the 18-09-2022, with the route of migration displayed from 11:00 – 15:00 LT. The crane crossed the sea at an altitude of around 150 - 650 meters, ascending in the middle of the crossing and afterwards descending for the remaining of the crossing.

No. 223711: migrated across the Baltic Sea on the 02-10-2022, with the route of migration displayed from 05:00 – 13:00 LT. The crane crossed the sea at an altitude of around 10 - 150 meters, descending above the sea, with a several intervals of flying closer than 10 meters from the surface.

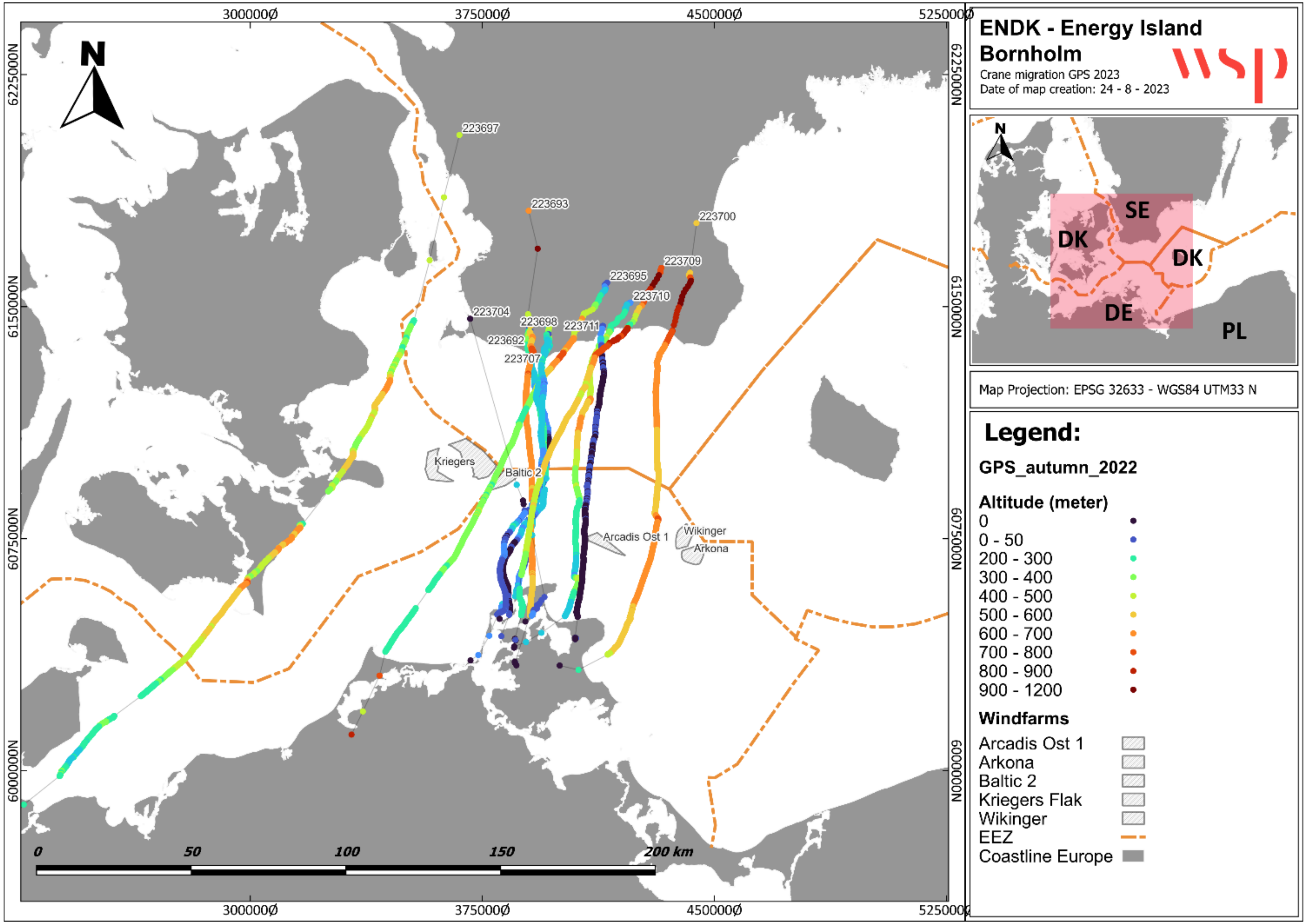


Figure 6. Displays a map over the western parts of the Baltic Sea, with the outline of the boarding countries, as well as the established windfarms, and the Exclusive Economic Zone (EEZ) between the countries. The GPS positions of each of the 11 tagged Common crane on their migration south, while crossing the sea, are shown. With the altitude of each GPS position displayed by color (from blue – red) and with a line drawn between two datapoints if there were no GPS positions available. Each crane is presented by the number of the GPS transmitter, ranging within no. 223692 – 223711.

Spring migration of cranes 2022

In spring 2023, seven of the 11 cranes migrated all the way back to Sweden while four of the cranes stopped their migration in the northern parts of Germany. Of the seven cranes that migrated northward back to Sweden, six crossed the Baltic Sea, while one crossed Kattegat, all within the period from 23rd of April – 3rd of June, during spring 2023 (Figure 7 and 8). Migration routes and flight altitudes are presented in Figure 5. A summary for each bird, presented by the number of the attached GPS transmitters is given below:

No. 223693: migrated across the Baltic Sea on the 27-05-2023, with the route of migration displayed from 04:00 – 11:00 LT. The crane crossed the sea at an altitude of around 50 - 500 meters, descending over the sea, with a few intervals of flying closer than 10 meters from the surface, before ascending again when approaching shore.

No. 223698: migrated across the Baltic Sea on the 01-05-2023, with the route of migration displayed from 03:00 – 07:00 LT. The crane crossed the sea at an altitude of around 50 - 100 meters, descending above the sea.

No. 223704: migrated across the Baltic Sea and the Sound on the 02-06-2023 and the 03-06-2023, with the route of migration displayed from 07:00 on the 02-06-2023 – 11:00 the 03-06-2023 LT. The crane crossed the sea at an altitude of around 50 - 700 meters, ascending several times when approaching land and descending above the sea, then had a stopover on Zealand before migrating to Sweden, across the Sound, on the 3rd of June.

No. 223707: migrated across the Baltic Sea on the 18-05-2023, with the route of migration displayed from 11:00 – 15:00 LT. The crane crossed the sea at an altitude of around 150 - 500 meters, descending above the sea.

No. 223709: migrated across the Baltic Sea and the Sound on the 23-04-2023, with the route of migration displayed from 09:00 – 14:00 LT. The crane crossed the sea at an altitude of around 150 - 300 meters ascending several times when approaching land and descending above the sea.

No. 223710: migrated across Kattegat on the 09-05-2023 (see Figure 8), with the route of migration displayed from 07:00 – 10:00 LT. The crane crossed the sea at an altitude of around 50 - 300 meters, descending above the sea.

No. 223711: migrated across the Baltic Sea on the 01-05-2023, with the route of migration displayed from 09:00 – 12:00 LT. The crane crossed the sea in an altitude of around 50 - 850 meters, descending above the sea.

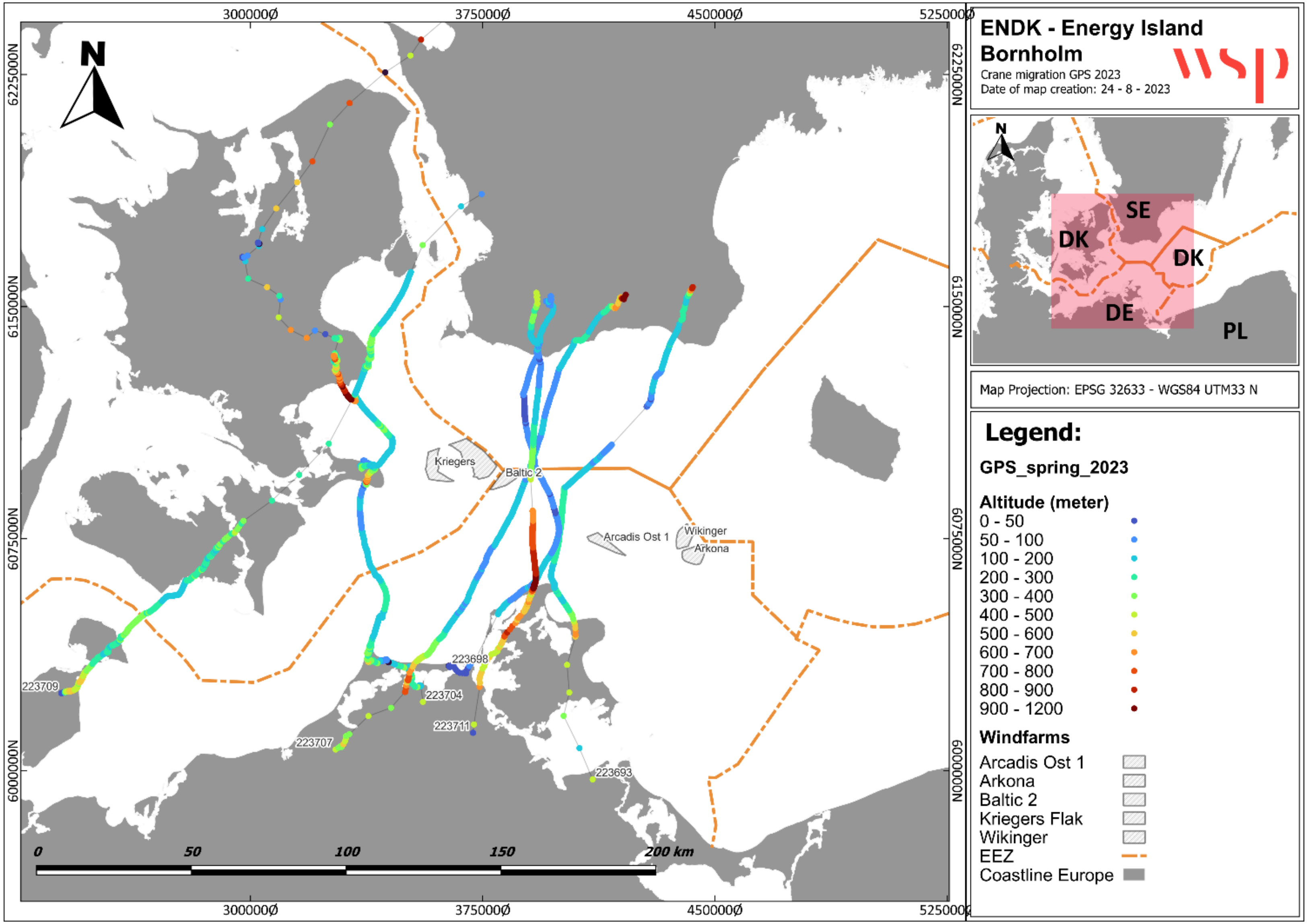


Figure 7. Displays a map over the western parts of the Baltic Sea, with the outline of the boarding countries, as well as the established windfarms, and the Exclusive Economic Zone (EEZ) between the countries. The GPS positions of each tagged Common crane on their migration north, while crossing the sea, are shown. With the altitude of each GPS position displayed by color (from blue – red) and with a line drawn between two datapoints if there were no GPS positions available. Each crane is presented by the number of the GPS transmitter, ranging within no. 223692 – 223711.

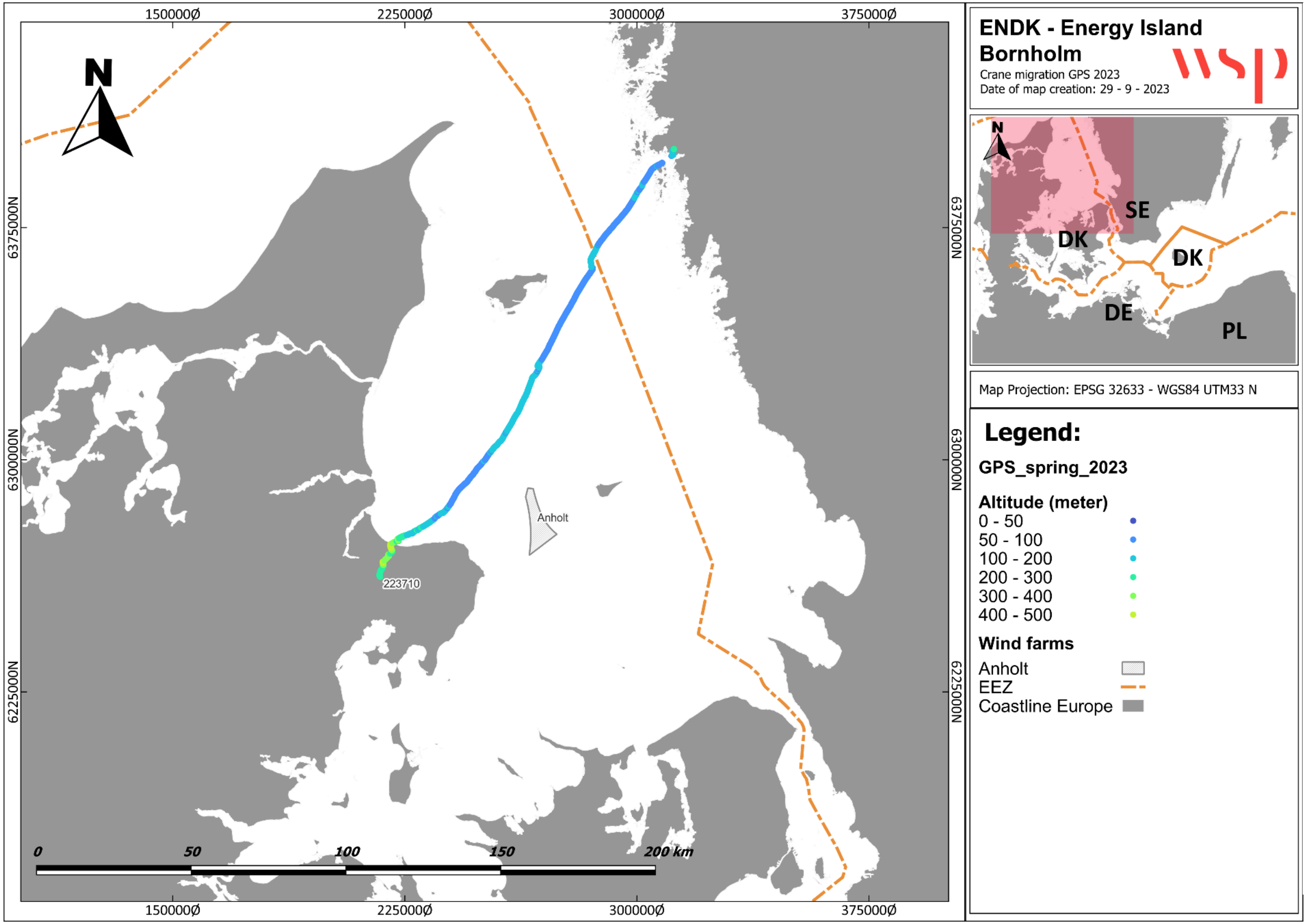


Figure 8. Displays a map of Kattegat with the outline of the boarding countries, as well as the Exclusive Economic Zone (EEZ) between the countries. The GPS positions of the tagged Common crane no. 223710, during the migration north, while crossing the sea, are shown. With the altitude of each GPS position displayed by color (from blue – red) and with a line drawn between two datapoints if there were no GPS positions available.

VESSEL SURVEY DURING AUTUMN 2022

A total of 3,425 migrating cranes distributed over 47 different flocks were observed during autumn 2022. Of these, 16 flocks of 1,239 cranes displayed avoidance behaviour in relation to the wind turbines in either Kriegers Flak or Baltic 2. This is equivalent to 36 % of all the migrating cranes and 34 percent of the observed flocks (Table 6, Figure 9 – 13). Out of the total numbers of observed cranes, 1,114 cranes showed avoidance behaviour at the macro scale, whereas 125 cranes reacted at the meso or micro scale, equivalent to 33 % and 4 %, respectively. Estimated flight heights were in the range of 2 - 900 meters. No collisions between cranes and wind turbines were observed within the study period.

Avoidance behaviour measured by radar tracks

The migrating cranes that showed possible avoidance behaviour was a total of 874 cranes distributed in 10 flocks and, equivalent to 26 % of the total number of migrating cranes observed. The cranes that showed possible avoidance behaviour towards the OWF were flying within the risk zone of the wind turbines, but with no distinctive avoidance behaviour detected by the observers and have therefore been interpreted solely from radar tracks. A total of 357 cranes, distributed in four flocks, showed possible avoidance behaviour on macro scale and 517 cranes, distributed on six flocks, showed possible avoidance behaviour on meso scale. The cranes were noted flying within the risk zone of the OWF, but with no detectable change in altitude or direction that with certainty could be interpreted as avoidance behaviour (Table 6, Figure 7 – 11).

The remaining 1,312 migrating cranes, distributed on 21 flocks, showed no avoidance behaviour towards the OWF, equivalent to 38 % of all the cranes observed, with the cranes flying either far above or far around the OWF (Table 6, Figure 9 – 13).

Based on a total of 14 individual birds of prey, distributed between three species, sparrowhawk, marsh harrier and red kite, five individuals showed possible avoidance behaviour and the red kite was detected expressing micro avoidance behaviour (table 6). Together, that is a possible response to the OWF equivalent to 43 percent of the total amount of birds of prey observed, whereas the remaining eight individuals showed no detectable response the OWF.

Flight height measurements by LRF

Based on the collected laser rangefinder (LRF) data (Table 4), it was also possible to estimate an average flight height of the migrating cranes within and outside the OWF, together with an estimated flight height in four different scenarios of turbine activity: Operative (OP); Idle (IDL); Not Operative (NO); No information (NA).

The difference in the average altitude of the migrating cranes outside and inside the OWF were 223 and 308 meters, respectively, equivalent to an average increase in flight altitude of 28 % above the OWF compared to outside of the OWF. The flight height also varied with the activity of the wind turbines. With an average flight height of 354 meters and 583 meters above the OWF while the wind turbines were operating at operative speed and while idling, respectively. The average flight height while the wind turbines were not operative was down to 136 meters. This is equivalent to a percentwise difference between operative and not operative of 62 % and a percentwise difference between idling and not operative of 77 %.

Table 4. Average flight height in meters (m) of migrating common cranes (*Grus grus*) during autumn 2022, based on data points collected by Laser-rangefinder (Number of data points from LRF (n), with the given Standard deviation). OWF=Offshore wind farm. The number of individuals and flocks, of which the datapoints are based on, have been noted, as well as the range of flight height distribution. Secondly, an average flight height in meters (m) in four different scenarios of wind turbine movement: Operative (OP), Idle (IDL), Not operative (NO), No information (NA) has been calculated. For details on each flock see appendix 8.1.1.

Within OWF	Number of datapoints from LRF (n)	Individuals (n)	Flocks (n)	Average flight height (m)	Standard Deviation	Minimum height (m)	Maximum Height (m)
Not within or above the OWF	157	1,215	18	222.5	216.7	0	1,034
Within or above the OWF	39	881	10	308.2	332.7	0	1,329
Turbine rotation	**Number of datapoints from LRF (n)**	**Individuals (n)**		**Average flight height (m)**	**Standard Deviation**	**Minimum height (m)**	**Maximum Height (m)**
Operative (OP)	14	1,095	-	353.6	312.1	0	1,034
Idle (IDL)	2	145	-	583.4	582.1	145	1,329
Not Operative (NO)	2	88	-	135.7	20.8	82	202
No information (NA)	2	20	-	45	42.9	0	79

5.1.1 VESSEL SURVEY DURING SPRING 2023

A total of 1,041 migrating cranes distributed over 37 different flocks were observed during spring 2023. Two of these flocks, consisting of 16 and 25 individuals, respectively, showed signs of avoidance behaviour at the meso scale i.e., a response towards individual turbines inside the Kriegers Flak or Baltic 2 wind farm arrays. This is equivalent to 4 % of the total number of migrating cranes and 5 % of all the flocks observed (Table 6, Figure 14 – 17). Estimated flight heights during spring 2023 were in the range of 50 - 400 meters. No collisions were observed within the study period.

Avoidance behaviour measured by radar tracks

The migrating cranes that showed possible avoidance behaviour were a total of 552 cranes, distributed in 20 flocks. This was equivalent to 53 % of the total number of migrating cranes. The cranes that showed possible avoidance behaviour towards the OWF, were flying within the risk zone of the wind turbines, but with no distinctive avoidance behaviour detected by the observers and have therefore been interpreted solely from radar tracks. All 552 cranes showed possible avoidance behaviour on meso scale. The cranes were noted flying within the risk zone of the OWF, but with no detectable change in altitude or direction that with certainty could be interpreted as avoidance behaviour (Table 6, Figure 14 – 17).

The final 448 migrating cranes, distributed on 15 flocks, showed no avoidance behaviour towards the OWF, equivalent to 43 % of all the cranes observed, with the cranes flying either far above or far around the OWF (Table 6, Figure 14 – 17).

Flight height measured by LRF

Based on the collected laser rangefinder (LRF) data (Table 5), it was also possible to estimate an average flight height of the migrating cranes within and outside the OWF. The difference in the altitude of the migrating cranes outside versus inside the OWF were 123 and 125 meters, respectively, equivalent to an average increase of altitude by 1.4 % above the OWF. During spring 2023 measurements were recorded only during operative (OP) mode.

Table 5. Average flight height in meters (m) of migrating common cranes (*Grus grus*) during spring 2023, based on data points collected by Laser-rangefinder (Number of data points from LRF (n), with the given Standard deviation). OWF= Offshore wind farm. The number of individuals and flocks, of which the datapoints are based on, have been noted. During spring 2023 measurements were recorded only during operative (OP) mode of the wind turbines. For details of each flock see appendix 8.1.2.

Within OWF	Number of datapoints from LRF (n)	Individuals (n)	Flocks (n)	Average flight height (m)	Standard Deviation	Minimum height (m)	Maximum Height (m)
Not within or above the OWF	74	201	8	123.3	51.2	52	265
Within or above the OWF	4	50	2	125.0	88.4	73	257

5.1.2 SURVEY PERIOD AND MIGRATORY BEHAVIOUR IN REGARD TO WEATHER CONDITIONS AND WIND TURBINE ACTIVITY

Weather data was recorded in the field per hour during the active observation periods by a weather recording radar based on the vessel, from 06:30 at the earliest – 17:00 being the latest time recorded within the study period.

The **20-09-2022** the wind came from the north with a mean wind speed of 6.7 m/s (n = 10), at that date 12 flocks of migrating cranes were recorded, heading south or southwest, five of which showed tracks on the radar (Table 5; Figure 4). The flocks were recorded throughout the day, in a time spectrum from 09:25 – 16:33. Of the 12 tracks, one flock showed macro avoidance behaviour (Track 1, Figure 9; Table 6), and the remaining flocks showed no signs of detectable avoidance behaviour, flying either far above or at a faraway distance of the OWFs (Table 6, track 2 – 5, Figure 9).

Besides the recorded flocks of cranes, two sparrowhawks were recorded heading southwest, at the time 13:17, expressing possible meso/ micro avoidance behaviour flying low in between the turbines (Table 6).

The turbines were recorded being operative at non-limited speed, when the three flocks of cranes, showing possible macro avoidance behaviour, one flock showing no avoidance behaviour and the two recorded sparrowhawks migrated past the area (Table 6).

The **21-09-2022** the wind came from northeast and turned northwest during the day, with a mean wind speed of 4.5 m/s (n = 11), at that date 10 flocks of migrating cranes were recorded, heading south or southwest, which all showed tracks on the radar (Table 6; Figure 10). The flocks were recorded in the morning, in a time range from 08:53 – 10:50. Of the 10 tracks, one flock showed macro avoidance behaviour (Track 6, Figure 8; Table 6), one showed meso/ micro avoidance behaviour (Track 10, Figure 10), while the remaining flocks showed no signs of detectable avoidance behaviour, flying either far above or at a faraway distance of the OWFs (Table 6, Figure 8).

The turbines were recorded being operative at non-limited speed, while track no. 6; 9-11 and 13 passed through the wind farm, with the flocks in track no. 6 and 10 showing detected macro avoidance behaviour and detected meso/ micro avoidance, respectively (table 6).

The **22-09-2022** the wind came from west and turned southwest during the day, with a mean wind speed of 3.4 m/s (n = 11), at that date zero flocks of migrating cranes were recorded. One sparrowhawk was recorded heading west, at the time 09:07, expressing possible meso/ micro avoidance behaviour flying low in between the turbines (Table 6).

The turbines were recorded being operative at non-limited speed when the sparrowhawk was recorded, which showed possible meso/ micro avoidance behaviour (Table 6).

The **04-10-2022** the wind came from northwest and turned southwest during the day, with a mean wind speed of 6 m/s (n = 11), at that date six flocks of migrating cranes were recorded, heading south or southwest, which all showed tracks on the radar (Table 6; Figure 11). The flocks were recorded in the morning and in the early afternoon, in a time range from 08:32 – 12:53. Of the six tracks, four flocks showed macro avoidance behaviour (track 17 – 19 and 21, figure 9; Table 6), while one flock showed possible meso/ micro avoidance behaviour (track 16, figure 11) and one flock showed possible macro avoidance behaviour (track 20, figure 11), both flocks flying in close proximity to the OWFs, but with no detectable change in altitude or direction.

Besides the recorded flocks of cranes, five sparrowhawks were recorded heading southwest, in a time range from 08:22 – 10:36, two of which expressed possible meso/ micro avoidance behaviour flying low in between the turbines, the rest showed no detectable avoidance behaviour (Table 6).

In the case of track 17, showing macro avoidance behaviour, the wind turbines were operative at non-limited speed (Table 6). For two of the sparrowhawks, that showed possible meso avoidance behaviour, the wind turbines were both operational and, for the one at 08:22, not operational.

The **05-10-2022** the wind came from southwest, with a mean wind speed of 9 m/s (n = 12), at that date only one flock of migrating cranes were recorded, heading south (Table 6). The flock was recorded in the early afternoon, at 13:19 and showed macro avoidance behaviour, but did not get detected by the radar.

The **12-10-2022** the wind came from south, with a mean wind speed of 4 m/s (n = 9), at that date 14 flocks of migrating cranes were recorded, heading south or southwest, which all showed tracks on the radar (Table 6; Figure 12). The flocks were recorded in the morning and in the afternoon, in a time range from 07:52 – 14:33. Of the 14 tracks, seven flocks showed macro avoidance behaviour (Track 22; 26; 28-30; 32 and 34, Figure 12; Table 6), while one flock showed meso/ micro avoidance behaviour (Track 31, Figure 12). Three flocks showed possible meso avoidance behaviour (Track 25, 33 and 35, Figure 12), flying in close proximity to the OWFs, but with no detectable change in altitude or direction. The remaining flocks, although expressing flight heights within the risk zone, was not recorded expressing any avoidance behaviour (Track 23, 24 and 27, figure 12).

Besides the recorded flocks of cranes, four sparrowhawks were recorded heading southwest, in a time range from 08:14 – 08:40, not expressing any avoidance behaviour. The same accounts for a single marsh harrier, that was heading southwest at 08:19, that did not express any avoidance behaviour. A red kite, heading southwest at 08:04, expressed micro avoidance behaviour flying close to the rotor blades (Table 6).

In the cases of track 22 and 30, the flocks showing detected macro avoidance behaviour, the wind turbines were not operative. In the case of track 23 and 32, the flocks showing possible macro avoidance behaviour, the wind turbines were operative. In both track 24 and 26, the flocks that showed detected macro avoidance behaviour, the wind turbines were idling (Table 6). In the cases of one of the sparrowhawks, the marsh harrier and the red kite, the wind turbines were not operative.

The **13-10-2022** the wind came from south, with a mean wind speed of 6.6 m/s (n = 10), at that date four flocks of migrating cranes were recorded, heading south, where two of the flocks showed tracks on the radar (Table 6; Track 36 and 37, Figure 13). The flocks were recorded in the morning and in the afternoon, in a time spectrum from 09:16 – 14:20. In both tracks the flocks showed possible meso/ micro avoidance behaviour (Track 36 and 37, Figure 13) flying in close proximity to the OWFs, but with no detectable change in altitude or direction. The remaining two flocks, although expressing a flight height below the risk zone, was not recorded expressing and avoidance behaviour (Table 6).

The **10-03-2023** no weather data was recorded. One flock of cranes were recorded migrating north, showing tracks on the radar (Table 6; Track 38, Figure 14). The flock was recorded a 12:31 far from the OWF's, no avoidance behaviour detected.

No data about the activity of the wind turbines was available for this day.

The **16-03-2023** no weather data was recorded. At that date 17 flocks of migrating cranes were recorded, heading north, where all the flocks showed tracks on the radar (Table 6; Track 39 - 55, Figure 15). The flocks were recorded in the morning and in the afternoon, in a time range from 08:53 – 14:23. Of the 14 tracks, two flocks showed macro avoidance behaviour (Track 39 and 50, Figure 15; Table 6), while eight flocks showed possible meso/ micro avoidance behaviour (Track 40, 46 – 48, 51 - 52 and 54 - 55, Figure 15), flying in close proximity to the OWFs, but with no detectable change in altitude or direction, and the remaining flocks was not recorded expressing any avoidance behaviour (Track 41 - 45, 49 and 53, Figure 15).

In the cases of track 39 and 40, one showing macro avoidance behaviour and one showing possible meso avoidance, respectively, the wind turbines were operative at non-limited speed (Table 6), for the rest of the day, on the 16th of march, the wind turbines were idle.

The **18-03-2023** no weather data was recorded. At that date eight flocks of migrating cranes were recorded, heading north, where all the flocks showed tracks on the radar (Table 6; Track 56 - 63, Figure 16). The flocks were recorded in the before noon and in the afternoon, in a time range from 10:47 – 12:43. Of the eight tracks, five flocks showed possible meso/ micro avoidance behaviour (Track 56, 58 – 60 and 63, Figure 16), flying in close proximity to the OWFs, but with no detectable change in altitude or direction, and the remaining flocks was not recorded expressing any avoidance behaviour (Track 57 and 61- 62, Figure 16).

No data about the activity of the wind turbines was available for this day.

The **19-03-2023** no weather data was recorded. At that date 11 flocks of migrating cranes were recorded, heading north, where all the flocks showed tracks on the radar (Table 6; Track 64 - 74, Figure 17). The flocks were recorded from before noon and into the afternoon, in a time range from 10:34 – 14:12. Of the 11 tracks, seven flocks showed possible meso/ micro avoidance behaviour (Track 64 - 65, 67 and 69 - 72, Figure 17), flying in close proximity to the turbines, but with no detectable change in altitude or direction, and the remaining flocks was not recorded expressing any avoidance behaviour (Track 66, 68 and 73- 74, Figure 17).

No data about the activity of the wind turbines was available for this day.

Table 6. Vessel based visual observations of migrating Common cranes (*Grus grus*) and three species of raptor: Eurasian sparrowhawk (*Accipiter nisus*), red kite (*Milvus milvus*) and western marsh harrier (*Circus aeruginosus*) in the autumn period 2022 and spring period 2023. The observed migratory behavior was noted with date, time, species of bird, flock size (number of individuals), flight direction, height of flight (start, mid and end of visual observation), average flight height in meters (m) based on data points collected by Laser-rangefinder (mean LRF height outside OWF and mean LRF height inside OWF), whether the wind turbines were operational and to what degree (Operative (OP), Idle (IDL), Not operative (NO), No information (NA)), The track number identical to the tracks displayed on figure 7 - 15 and additional comment of e.g., avoidance behavior. Comments relate to the whole flock.

Date	Time in UTC (hh:mm:ss)	Species	Flock size (Number of individuals)	Flight direction	Flight Height (m) Start	Flight Height (m) Middle	Flight Height (m) End	Mean LRF height outside OWF	Mean LRF height inside OWF	Windmills operating (OP: NO: IDL)	Track number	Comment
20-09-2022	09:25:00	Common crane (*Grus grus*)	60	S	150	-	500	-	-	-	1	**Macro** avoidance detected outside of OWF, circling from 150 m to 500 m height.
20-09-2022	10:34:25	Common crane (*Grus grus*)	72	SW	300	-	300	-	-	-	-	Above OWF, **no** avoidance behavior detected.
20-09-2022	11:28:30	Common crane (*Grus grus*)	90	S	600	-	600	-	-	-	-	Above OWF, **no** avoidance behavior detected.
20-09-2022	11:51:00	Common crane (*Grus grus*)	60	S	400	-	400	-	-	-	-	Passing east of Baltic 2, **no** avoidance behavior detected.
20-09-2022	12:00:00	Common crane (*Grus grus*)	28	S	300	-	300	-	-	-	2	Passing east of Baltic 2, **no** avoidance behavior detected.
20-09-2022	12:31:00	Common crane (*Grus grus*)	15	S	500	-	500	-	-	-	-	4 km distance, passing above Kriegers Flak, **no** avoidance behavior detected.

20-09-2022	12:46:00	Common crane (*Grus grus*)	80	S	800	-	800	-	-	-	3	Passing east of Baltic 2, **no** avoidance behavior detected.
20-09-2022	15:56:12	Common crane (*Grus grus*)	120	SW	600	-	600	714.2	-	OP	-	Gaining height 2 km North of Baltic 2, then passing above the OWF in the East. **Possible macro** avoidance behavior detected.
20-09-2022	15:57:52	Common crane (*Grus grus*)	130	SW	700	-	700	-	735.2	OP	-	Gaining height 2 km North of Baltic 2, then passing above the OWF in the East. **Possible macro** avoidance behavior detected.
20-09-2022	15:59:51	Common crane (*Grus grus*)	12	SW	700	-	700	762.2	751	OP	-	Gaining height 2 km North of Baltic 2, then passing above the OWF in the East. **Possible macro** avoidance behavior detected.
20-09-2022	16:19:00	Common crane (*Grus grus*)	35	S	300	-	300	-	-	-	4	Passing east of Baltic 2, **no** avoidance behavior detected.
20-09-2022	16:33:16	Common crane (*Grus grus*)	80	SW	900	-	900	939.7	-	OP	5	Passing above OWF, **no** avoidance behavior detected.
21-09-2022	08:53:41	Common crane (*Grus grus*)	7	SW	150	-	200	184.6	-	OP	6	Passing between Baltic 2 and Kriegers Flak, briefly circling in the distance. **Macro** avoidance behavior detected.

21-09-2022	09:28:00	Common crane (*Grus grus*)	120	S	200	-	200	-	-	-	7	Passing east of Baltic 2, **no** avoidance behavior detected.
21-09-2022	09:32:00	Common crane (*Grus grus*)	70	SW	200	-	200	-	-	-	8	Passing east of Baltic 2, **no** avoidance behavior detected.
21-09-2022	10:00:52	Common crane (*Grus grus*)	48	SW	350	-	350	336.8	-	OP	9	No avoidance behavior detected.
21-09-2022	10:15:40	Common crane (*Grus grus*)	40	S	180	-	200	182.1	-	OP	10	**Meso/ Micro** avoidance behavior detected, passing either through or above OWF.
21-09-2022	10:19:34	Common crane (*Grus grus*)	110	SW	400	-	400	405.4	-	OP	11	No avoidance behavior detected.
21-09-2022	10:35:00	Common crane (*Grus grus*)	100	SW	400	-	400	-	-	-	12	No avoidance behavior detected.
21-09-2022	10:38:14	Common crane (*Grus grus*)	130	SW	400	-	400	361.5	388	OP	13	No avoidance behavior detected.

21-09-2022	10:50:00	Common crane (*Grus grus*)	60	S	400	-	400	-	-	-	14	No avoidance behavior detected.
21-09-2022	10:50:00	Common crane (*Grus grus*)	60	S	600	-	600	-	-	-	15	No avoidance behavior detected.
04-10-2022	08:32:00	Common crane (*Grus grus*)	47	S	80	-	80	-	-	-	16	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
04-10-2022	09:25:00	Common crane (*Grus grus*)	183	SW	10	50	150	62.4	(114)	OP	17	**Macro avoidance behavior detected** (gaining height) 2 km before reaching Baltic 2, splitting up in 3 flocks while passing through the gap between Kriegers Flak and Baltic 2.
04-10-2022	10:49:00	Common crane (*Grus grus*)	200	SW	10	-	80	-	-	-	18	Passing SE of Baltic 2, gaining height when approaching OWF, not entering Baltic 2. **Macro avoidance behavior detected.**
04-10-2022	10:49:00	Common crane (*Grus grus*)	20	SW	10	-	80	-	-	-	19	Passing SE of Baltic 2, gaining height when approaching OWF, not entering Baltic 2. **Macro avoidance behavior detected.**
04-10-2022	11:38:00	Common crane (*Grus grus*)	95	S	100	-	100	-	-	-	20	Passing SE of Baltic 2, **Possible macro avoidance behavior detected.**

04-10-2022	12:53:00	Common crane (*Grus grus*)	38	SW	30	70	100	18.9	-	-	21	Aiming for gap between Kriegers Flak and Baltic 2, flying into Baltic 2 in SW corner, gaining height up to 100m. **Macro avoidance behavior detected.**
05-10-2022	13:19:02	Common crane (*Grus grus*)	13	S	2	50	150	15.5	45.8	-	-	Flock disintegrated and rejoined while gaining height (from 2 - 150 m) while passing Baltic 2. **Macro avoidance behavior detected.**
12-10-2022	07:52:00	Common crane (*Grus grus*)	3	SW	40	80	130	-	(121)	NO	22	**Macro avoidance behavior detected.**
12-10-2022	07:58:00	Common crane (*Grus grus*)	4	S	130	130	130	128.2	-	OP	23	No additional comment.
12-10-2022	08:24:00	Common crane *(Grus grus)*	35	SW	300	300	300	661	1329	IDL	24	No additional comment.
12-10-2022	08:42:00	Common crane *(Grus grus)*	140	SW	150	150	150	-	-	-	25	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
12-10-2022	09:50:00	Common crane *(Grus grus)*	110	SW	150	170	200	166	175.7	IDL	26	**Macro avoidance behavior detected.**

12-10-2022	10:20:00	Common crane *(Grus grus)*	95	S	100	100	100	-	-	-	27	No additional comment.
12-10-2022	10:22:00	Common crane *(Grus grus)*	55	S	100	150	200	-	-	-	28	**Macro avoidance behavior detected.**
12-10-2022	10:55:00	Common crane *(Grus grus)*	60	S	20	30	40	-	-	-	29	**Macro avoidance behavior detected.**
12-10-2022	11:10:00	Common crane *(Grus grus)*	85	S	100	150	200	157.2	138.2	NO	30	**Macro avoidance behavior detected.**
12-10-2022	11:35:00	Common crane *(Grus grus)*	85	SW	5	15	10	-	-	-	31	**Meso/ micro avoidance behavior detected.**
12-10-2022	12:00:00	Common crane *(Grus grus)*	180	S	100	120	150	100.9	110.5	OP	32	**Macro avoidance behavior detected.**
12-10-2022	12:24:00	Common crane *(Grus grus)*	55	S	120	120	120	-	-	-	33	Passing through OWF, **Possible meso/micro** avoidance behavior detected.

12-10-2022	12:46:00	Common crane *(Grus grus)*	100	SW	100	120	140	-	-	-	34	**Macro avoidance behavior detected.**
12-10-2022	14:33:00	Common crane *(Grus grus)*	50	S	150	150	150	-	-	-	35	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
13-10-2022	09:16:00	Common crane *(Grus grus)*	2	S	79	71	76	75.3	-	-	-	No additional comment.
13-10-2022	12:13:00	Common crane *(Grus grus)*	18	S	-	-	-	25.4	-	-	-	No additional comment.
13-10-2022	13:59:00	Common crane *(Grus grus)*	95	S	120	120	120	-	-	-	37	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
13-10-2022	14:20:00	Common crane *(Grus grus)*	130	S	120	120	120	-	-	-	36	Passing east of OWF, **Possible meso/micro** avoidance behavior detected.

20-09-2022	13:17:09	Eurasian sparrowhawk *(Accipiter nisus)*	2	SW	30	30	30	24.8	-	OP	-	Flying towards and through OWF. **Possible meso avoidance behavior detected.**
22-09-2022	09:51:22	Eurasian sparrowhawk *(Accipiter nisus)*	1	W	20	-	20	17	-	OP	-	Flying into Kriegers flak. **Possible meso avoidance behavior detected.**
04-10-2022	08:22:19	Eurasian sparrowhawk *(Accipiter nisus)*	1	SW	1	-	1	1	-	NO	-	With prey, passing low between Kriegers Flak and Baltic 2. **Possible meso avoidance behavior detected.**
04-10-2022	09:07:11	Eurasian sparrowhawk *(Accipiter nisus)*	1	SW	10	-	2	17	-	OP	-	No additional comment.
04-10-2022	10:03:54	Eurasian sparrowhawk *(Accipiter nisus)*	1	SW	20	-	20	19.4	-	OP	-	Aiming for gap between Kriegers Flak and Baltic 2. **Possible meso avoidance behavior detected.**
04-10-2022	10:23:51	Eurasian sparrowhawk *(Accipiter nisus)*	1	SW	5	-	10	20.5	-	OP	-	No additional comment.
04-10-2022	10:36:30	Eurasian sparrowhawk *(Accipiter nisus)*	1	SW	20	-	20	-	-	-	-	No additional comment.

12-10-2022	08:04:00	Red kite *(Milvus milvus)*	1	SW	40	50	40	82.5	-	NO	-	**Micro avoidance behavior detected**, "slipped" around windmill blades.
12-10-2022	08:14:00	Eurasian sparrowhawk *(Accipiter nisus)*	1	SW	40	60	80	79.3	-	-	-	No additional comment.
12-10-2022	08:19:00	Western marsh harrier *(Circus aeruginosus)*	1	SW	100	100	100	4.5	-	NO	-	No additional comment.
12-10-2022	08:40:00	Eurasian sparrowhawk *(Accipiter nisus)*	3	SW	1	3	1	2	-	NO	-	No additional comment.
Date	**Time in UTC** (hh:mm:ss)	**Species**	**Flock size (Number of individuals)**	**Flight direction**	**Flight Height (m) Start**	**Flight Height (m) Middle**	**Flight Height (m) End**	**Mean LRF height outside OWF**	**Mean LRF height inside OWF**	**Windmills operating** (OP: NO: IDL)	**Track number**	**Comment**
10-03-2023	12:31:18	Common crane *(Grus grus)*	7	N	100	100	100	-	-	-	38	No additional comment.
16-03-2023	08:53:40	Common crane *(Grus grus)*	16	N	50	-	100	-	-	OP	39	**Meso avoidance behavior detected.**

16-03-2023	09:19:02	Common crane *(Grus grus)*	40	N	150	150	150	-	-	OP	40	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
16-03-2023	09:36:43	Common crane *(Grus grus)*	24	N	200	200	200	-	-	IDL	41	No additional comment.
16-03-2023	10:10:33	Common crane *(Grus grus)*	45	N	150	150	150	-	-	IDL	42	No additional comment.
16-03-2023	10:16:22	Common crane *(Grus grus)*	5	N	100	100	100	-	-	IDL	43	No additional comment.
16-03-2023	10:36:53	Common crane *(Grus grus)*	12	N	200	200	200	-	-	IDL	44	No additional comment.
16-03-2023	10:43:44	Common crane *(Grus grus)*	20	N	150	150	150	-	-	IDL	45	No additional comment.
16-03-2023	10:50:33	Common crane *(Grus grus)*	25	N	100	100	100	-	-	IDL	46	Passing through OWF, **Possible meso/micro** avoidance behavior detected.

16-03-2023	10:52:30	Common crane *(Grus grus)*	12	N	150	150	150	-	-	IDL	47	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
16-03-2023	12:41:59	Common crane *(Grus grus)*	80	N	100	100	100	-	-	IDL	48	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
16-03-2023	13:07:28	Common crane *(Grus grus)*	25	N	300	300	300	-	-	IDL	49	No additional comment.
16-03-2023	13:27:20	Common crane *(Grus grus)*	25	N	300	400	400	-	-	IDL	50	**Macro avoidance behavior detected.**
16-03-2023	13:32:27	Common crane *(Grus grus)*	20	N	75	75	75	-	-	IDL	51	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
16-03-2023	13:32:05	Common crane *(Grus grus)*	15	N	200	200	200	-	-	IDL	52	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
16-03-2023	13:40:50	Common crane *(Grus grus)*	35	N	300	300	300	-	-	IDL	53	No additional comment.

16-03-2023	13:50:25	Common crane *(Grus grus)*	8	N	50	50	50	-	-	IDL	54	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
16-03-2023	14:23:24	Common crane *(Grus grus)*	15	N	80	80	80	-	-	IDL	55	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
18-03-2023	10:47:32	Common crane *(Grus grus)*	16	N	50	50	50	-	-	-	56	Passing through OWF, **Possible meso/micro** avoidance behavior detected..
18-03-2023	11:50:05	Common crane *(Grus grus)*	40	N	200	200	200	-	-	-	57	No additional comment.
18-03-2023	11:57:34	Common crane *(Grus grus)*	45	N	150	150	150	-	-	-	58	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
18-03-2023	12:02:37	Common crane *(Grus grus)*	45	N	200	200	200	-	-	-	59	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
18-03-2023	12:10:00	Common crane *(Grus grus)*	35	N	200	200	200	-	-	-	60	Passing through OWF, **Possible meso/micro** avoidance behavior detected.

18-03-2023	12:16:23	Common crane *(Grus grus)*	20	N	100	100	100	-	-	-	61	No additional comment.
18-03-2023	12:26:45	Common crane *(Grus grus)*	70	N	200	200	200	-	-	-	62	No additional comment.
18-03-2023	12:43:20	Common crane *(Grus grus)*	25	N	100	100	100	-	-	-	63	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	10:34:11	Common crane *(Grus grus)*	26	N	50	50	50	-	-	-	64	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	12:41:48	Common crane *(Grus grus)*	20	N	120	120	120	-	-	-	65	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	12:56:34	Common crane *(Grus grus)*	30	N	-	-	-	-	-	-	66	No additional comment.
19-03-2023	13:01:25	Common crane *(Grus grus)*	25	N	100	100	100	-	-	-	67	Passing through OWF, **Possible meso/micro** avoidance behavior detected.

19-03-2023	13:14:53	Common crane *(Grus grus)*	35	N	-	-	-	-	-	-	68	No additional comment.
19-03-2023	13:15:57	Common crane *(Grus grus)*	30	N	100	100	100	-	-	-	69	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	13:24:13	Common crane *(Grus grus)*	15	N	200	200	200	-	-	-	70	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	13:45:32	Common crane *(Grus grus)*	20	N	70	70	70	-	-	-	71	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	13:47:08	Common crane *(Grus grus)*	35	E	100	100	100	-	-	-	72	Passing through OWF, **Possible meso/micro** avoidance behavior detected.
19-03-2023	14:05:19	Common crane *(Grus grus)*	20	N	150	150	150	-	-	-	73	No additional comment.
19-03-2023	14:12:22	Common crane *(Grus grus)*	60	N	300	300	300	-	-	-	74	No additional comment.

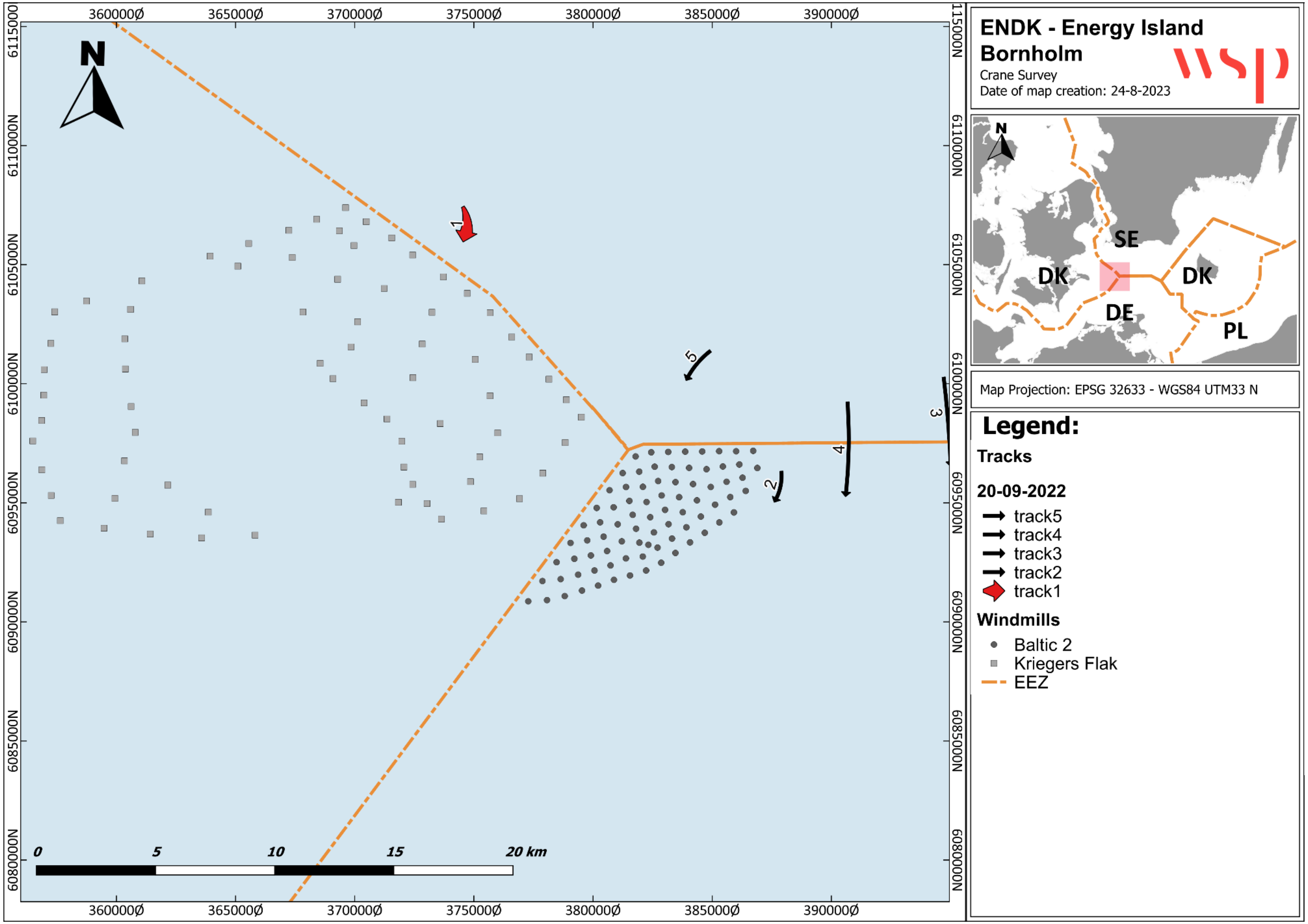


Figure 9. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

The 20-09-2022 the wind came from the north with a mean wind speed of 6.7 m/s.

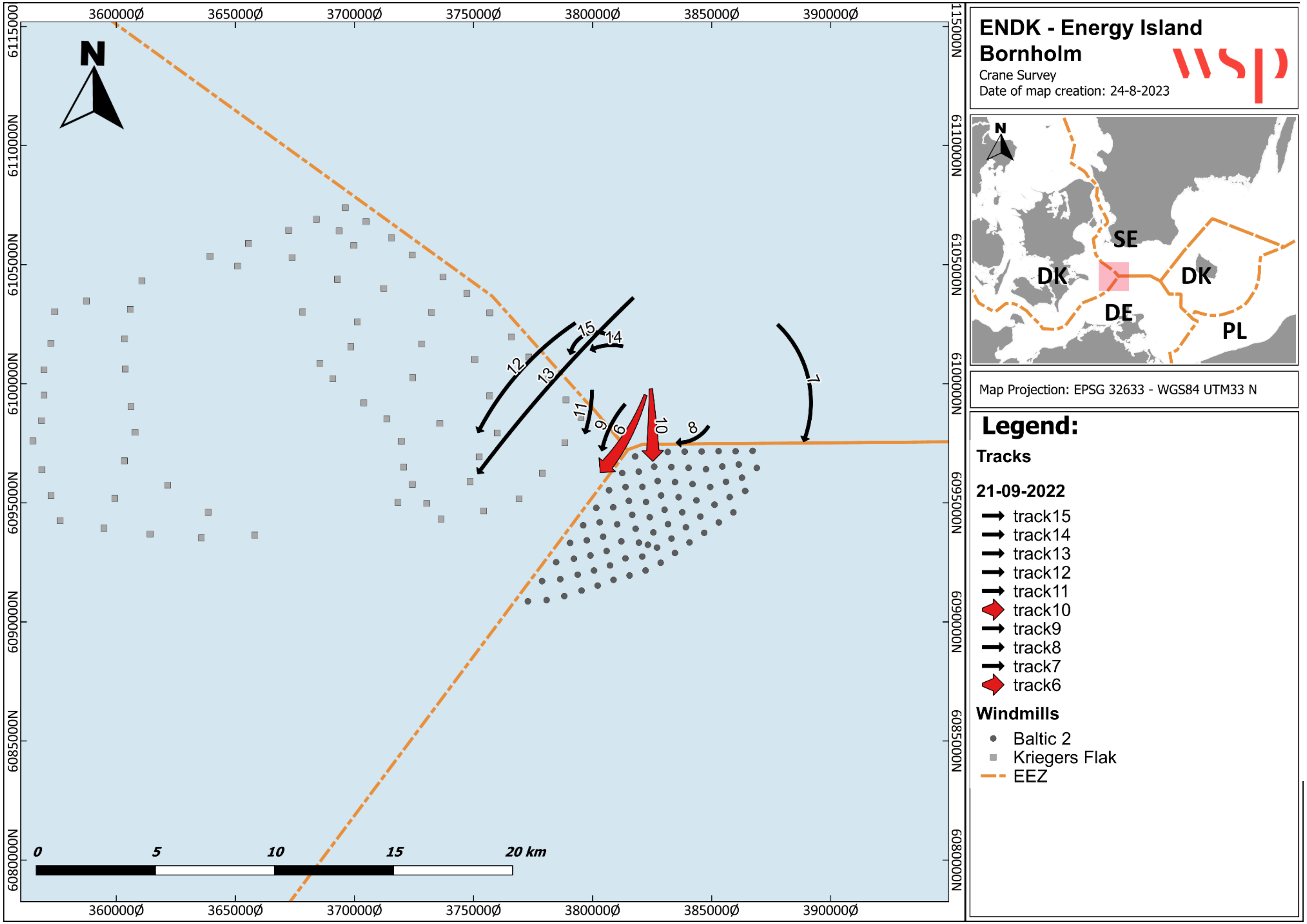


Figure 10. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

The 21-09-2022 the wind came from northeast and turned northwest during the day, with a mean wind speed of 4.5 m/s.

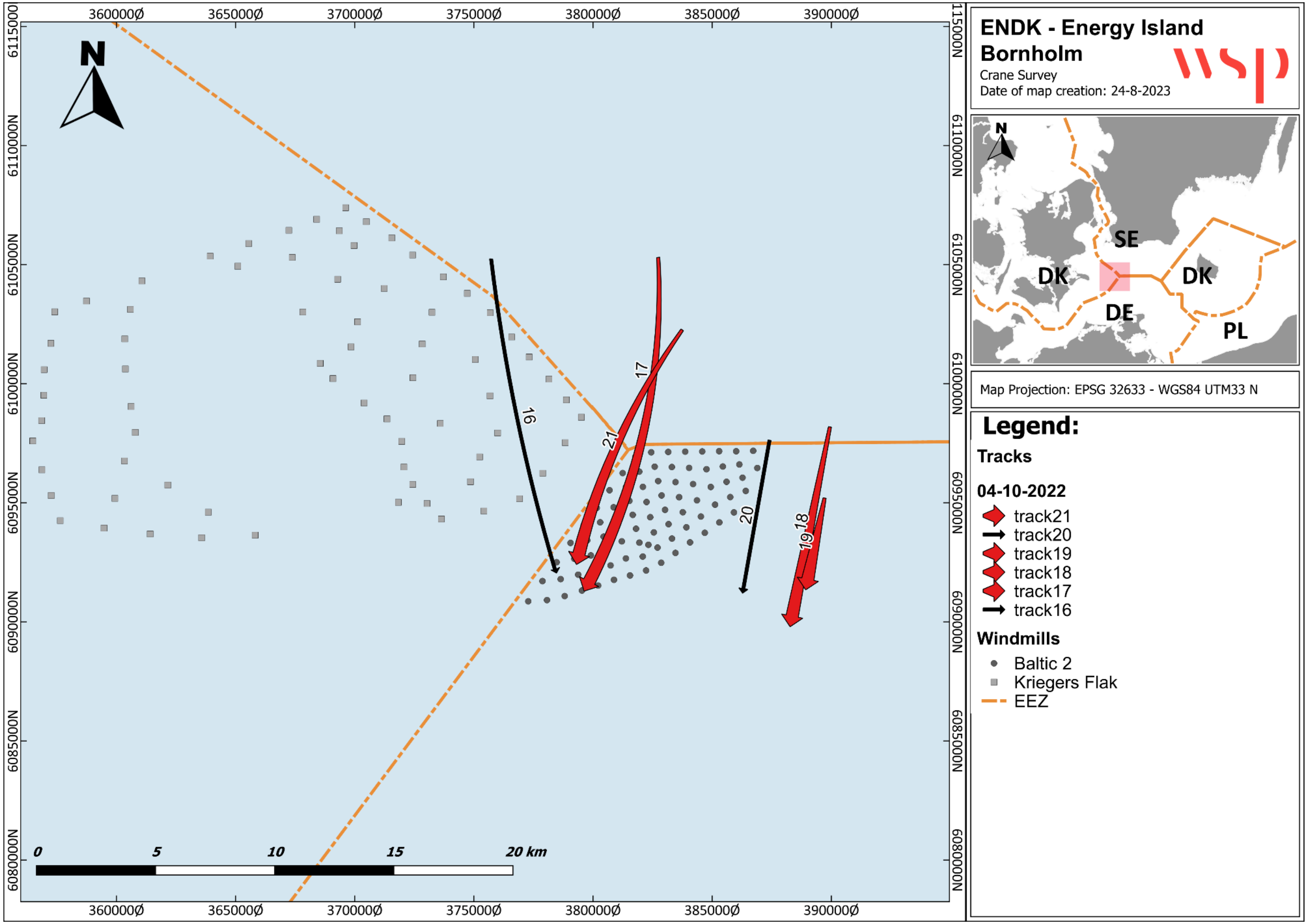


Figure 11. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

The 04-10-2022 the wind came from northwest and turned southwest during the day, with a mean wind speed of 6 m/s.

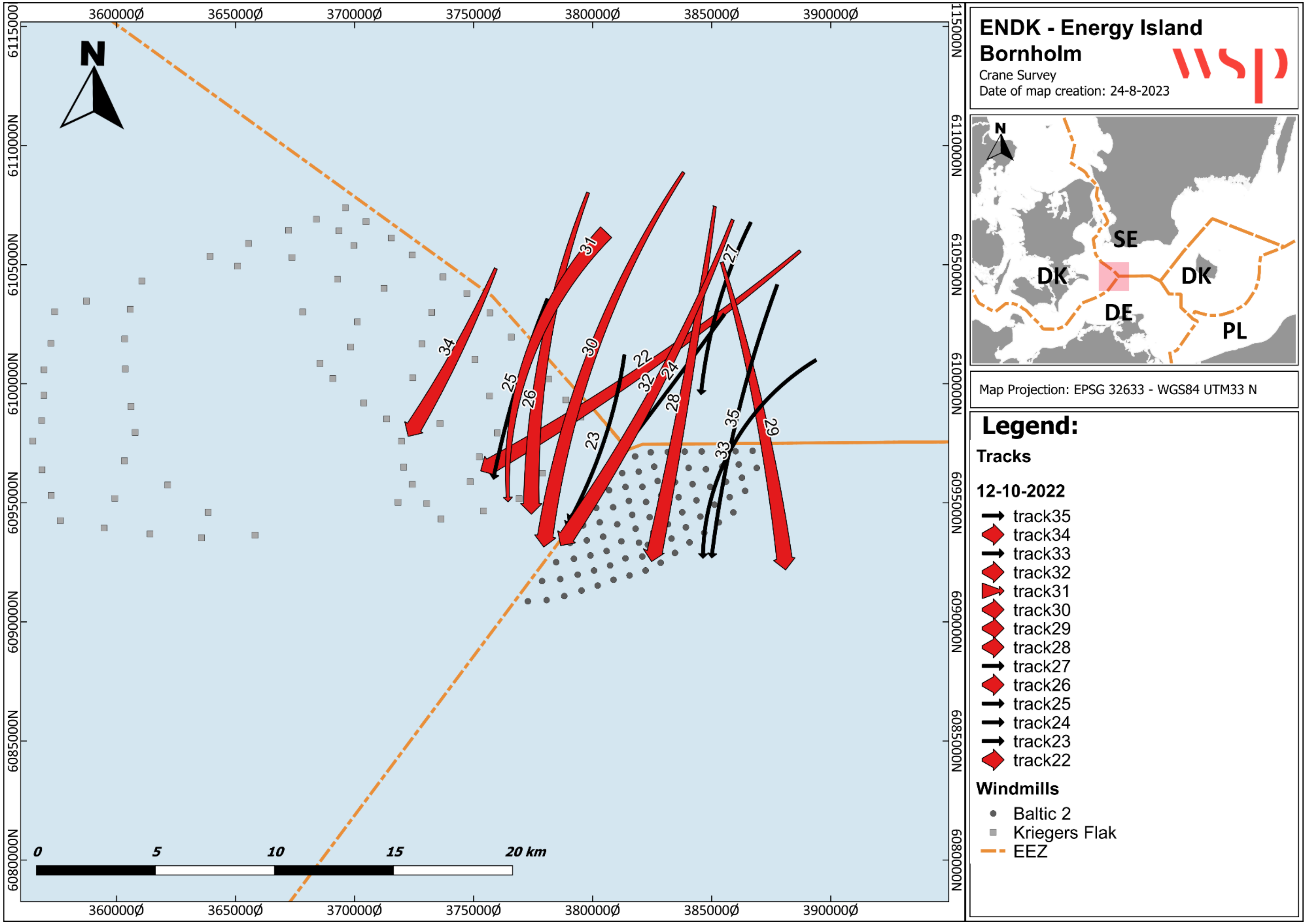


Figure 12. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

The 12-10-2022 the wind came from south, with a mean wind speed of 4 m/s.

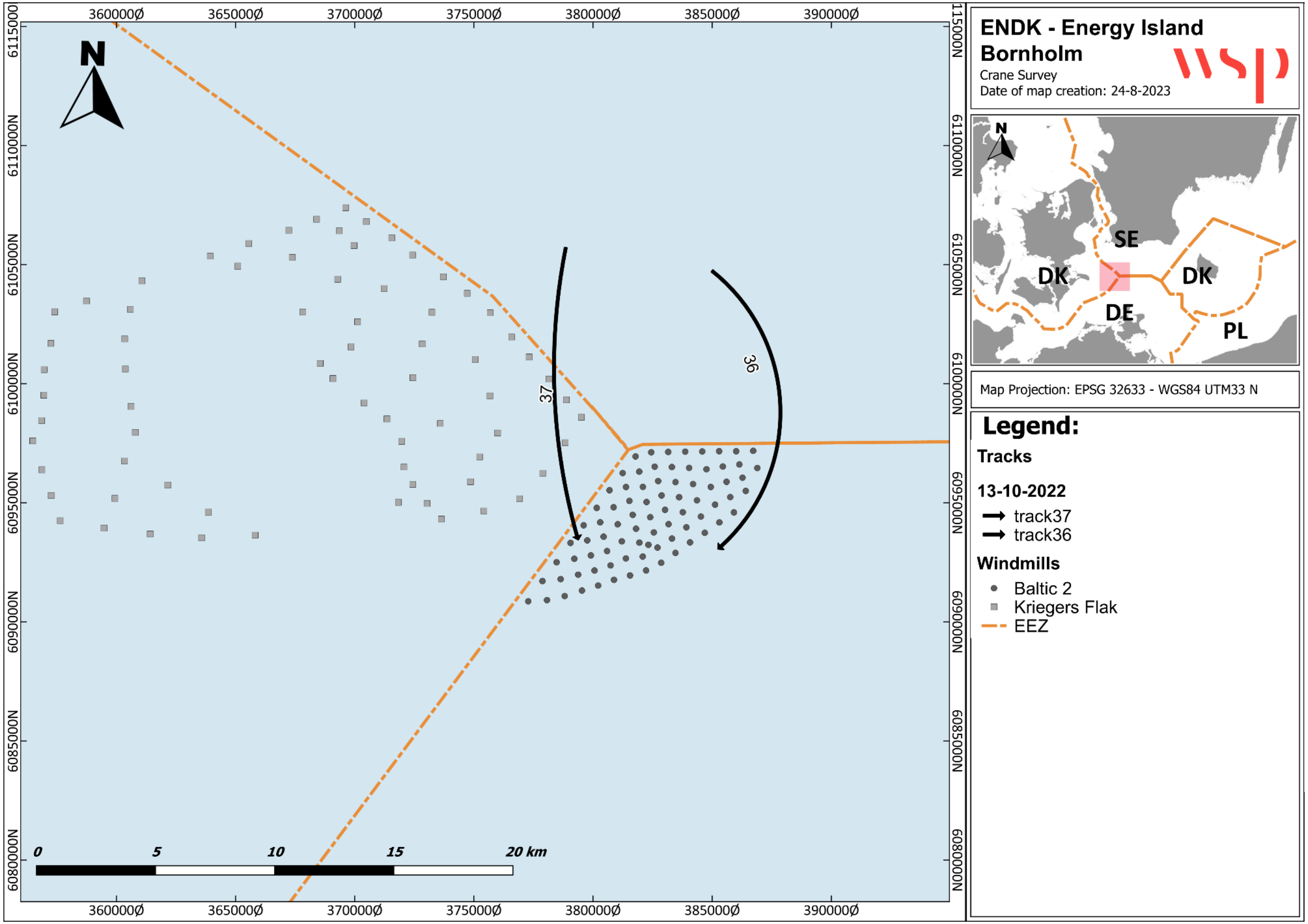


Figure 13. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

The 13-10-2022 the wind came from south, with a mean wind speed of 6.6 m/s.

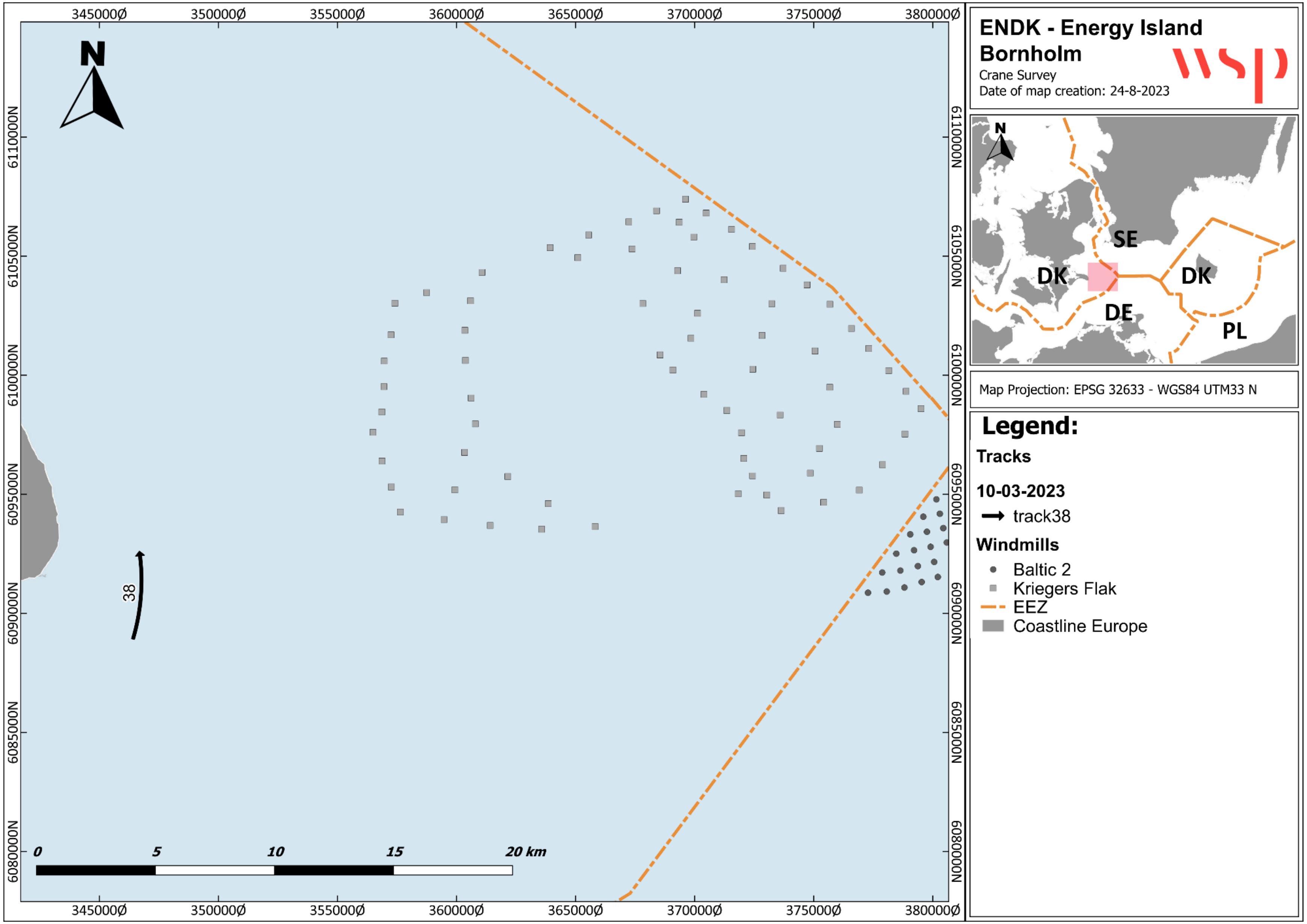


Figure 14. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

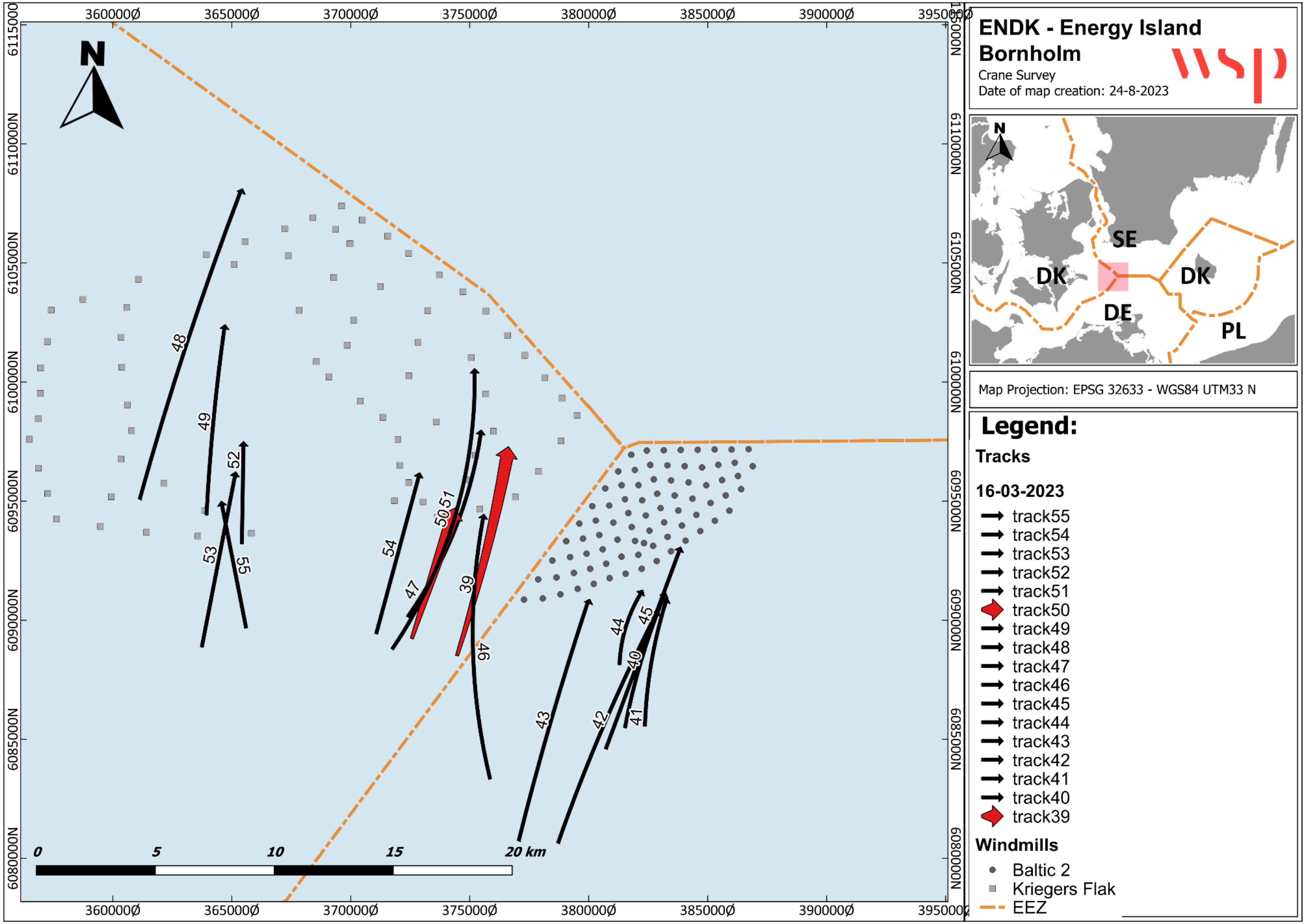


Figure 15. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

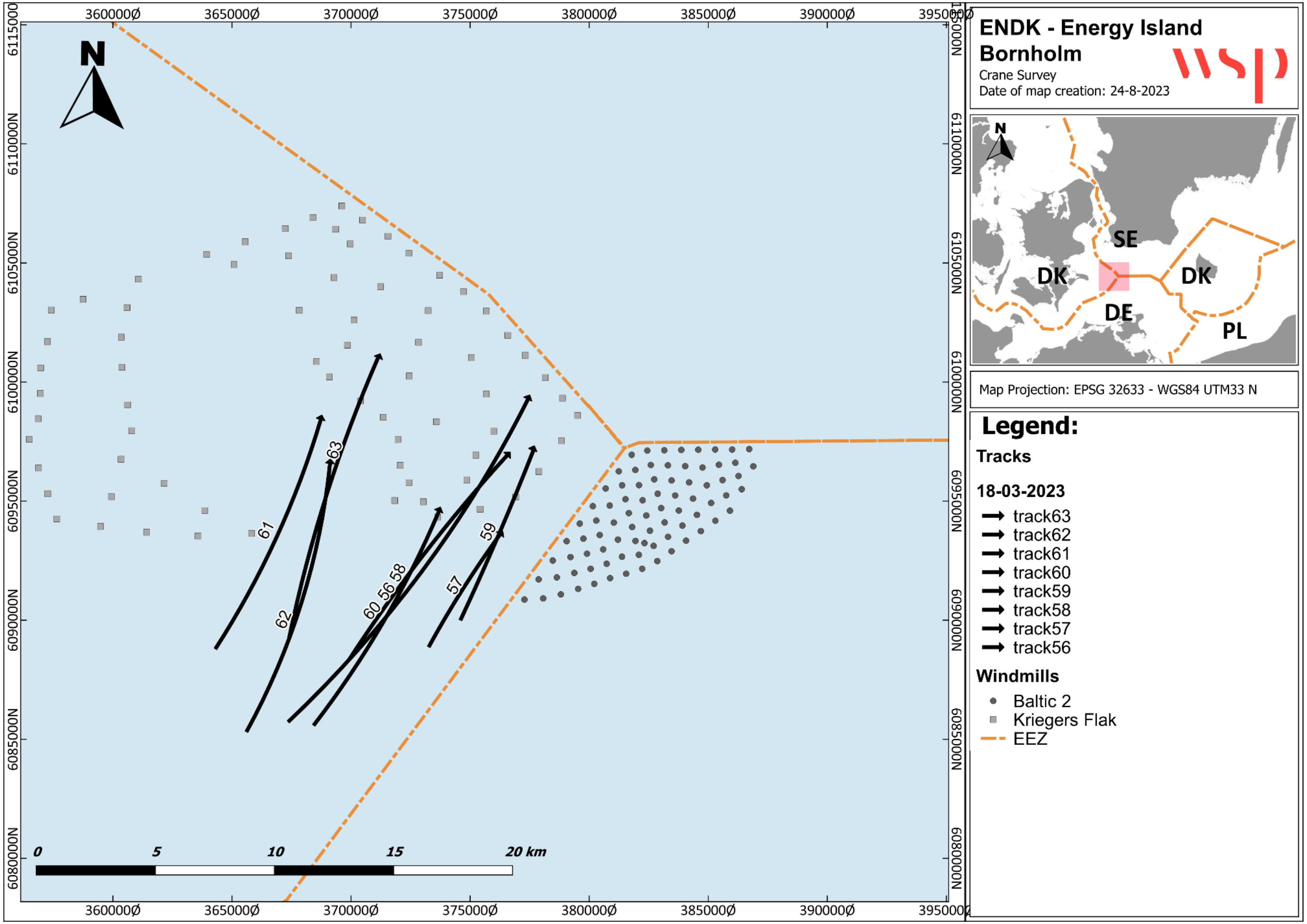


Figure 16. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

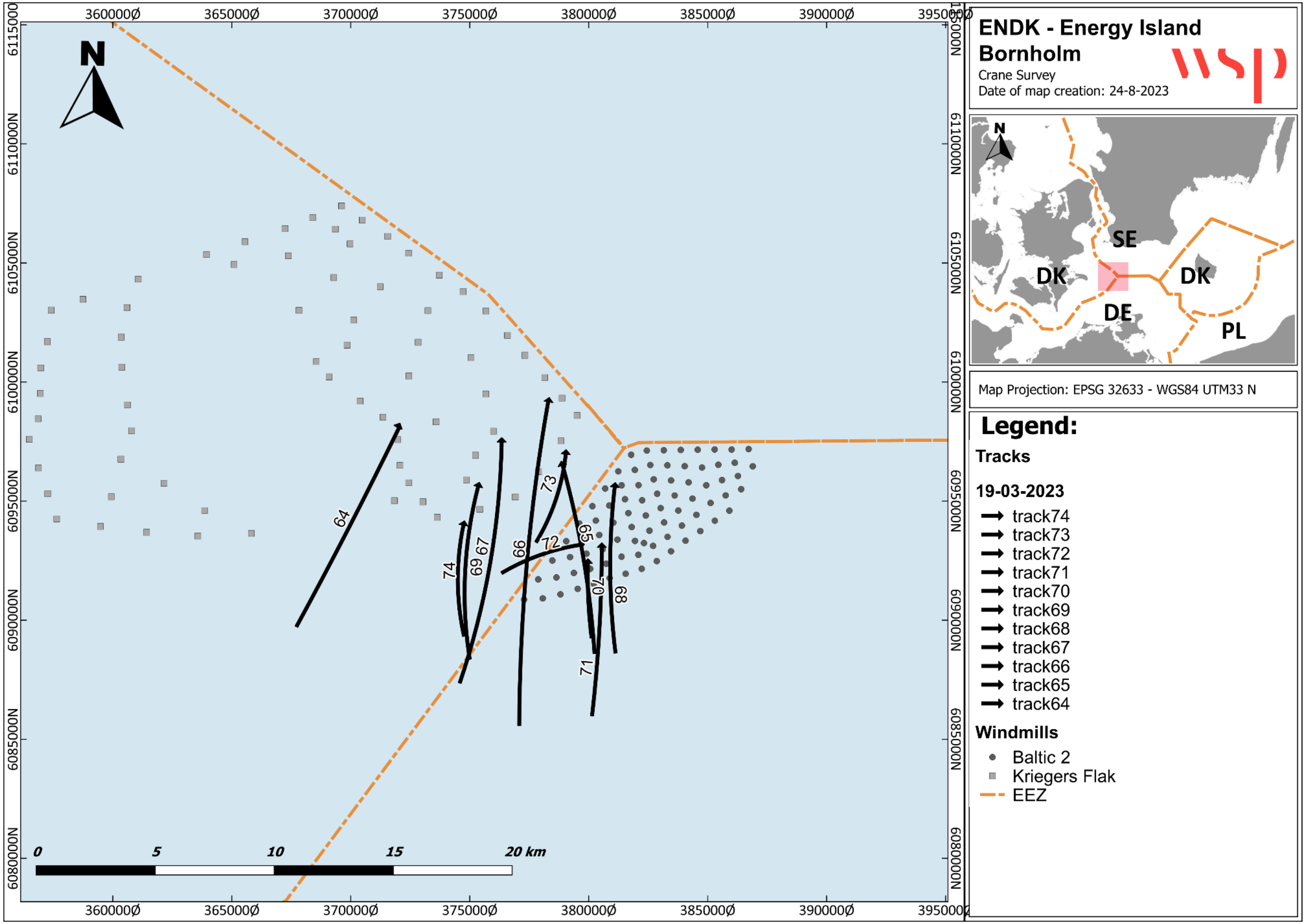


Figure 17. Displays a map of the area surrounding Kriegers flak and Baltic 2, that show the day specific recorded tracks of migrating flocks of cranes, as direction determined arrows. Detected avoidance behavior in marked with a red arrow, that either become wide in the part that show the direction of the track, indicating an increase in altitude when approaching the OWF (e.g., Track 1, Figure 4) or narrow in the part that show the direction of the track indicating a decrease in altitude when approaching the OWF (e.g., Track 31, Figure 10). The remaining, black, arrows show the routes of the flocks of cranes that either showed no avoidance behavior, or possible avoidance behavior. For specific details on each track see table 6, in combination with the map.

6 CONCLUSIVE REMARKS

The purpose of this note was to describe the response of migrating cranes, and secondly birds of prey, and their response to operating offshore windfarms during their annual migration across the Baltic Sea. The note has been based on observations and data gathered from the field during autumn 2022 and spring 2023, together with satellite transmissions of juvenile cranes tagged with a GPS transmitter during summer 2022. The final technical background note will include the adequate statistics to assess whether the observed patterns are statistically significant. It will also present a comparative analysis of the behavioural patterns of crane avoidance between these extensive field data with estimates with from Band Collision Risk Models, to assess to what degree the models and the visual interpretation match.

The satellite data from the transmissions of the tagged cranes, following their migration across the Baltic Sea, Kattegat and the Sound during autumn 2022 and spring 2023, have provided essential real time data on migration routes and flight behaviour of cranes migrating over open water. In this note, the data are only briefly depicted with overall descriptions of the routes and variation of flight altitudes of each crane that crossed the sea during 2022 or 2023. The cranes migrated in a timespan from early morning to late afternoon, and in heights of just above sea surface and up to more than one kilometre. Several cranes showed circling behaviour during the crossing when approaching the coast, probably to benefit from the thermal up winds, but the same behaviour was also observed over open water without thermals. Some cranes even flew though the gap between the OWFs Kriegers flak and Baltic 2 and the gap between the OWF's Arcadis Ost 1 and Wikinger, showing possible avoidance behavior ascending by circling before crossing close to the OWF's. This data will be presented in detail in future updates of this note, including the adequate statistical analysis in order to assess the pattens observed, following the GPS tagged cranes from 2022 and similar tagged cranes from late summer 2023, across a longer period of time.

Avoidance rates are a crucial factor in collision risk models (CRMs; Band 2012; May 2015), as earlier described (see Methodology). Unfortunately, data-based descriptions of avoidance behaviour towards OWFs and FHD of cranes migrating over the sea are very limited. This lack of knowledge leads to the practice of assuming rather low avoidance rates in collision risk models during EIAs, following a precautionary principle.

In this note, spatial flight height distributions and avoidance behaviour of migrating cranes and birds of prey was investigated. This was achieved using vessel-based surveys near the OWFs Kriegers flak and Baltic 2, during the birds migration over the Baltic Sea in autumn 2022 and spring 2023. By combining radar and laser rangefinder methods, we were able to determine large distance (macro-) avoidance behaviour, as well as birds flying close to, and even within the OWFs allowing determination of meso- and micro avoidance behaviour. At the same time, we gathered data of the local wind conditions and noted whether the wind turbines were operative and to what degree of activity.

During the survey period 4,466 cranes, distributed in 84 different flocks of varying sizes, migrated in relatively close proximity to the two operating OWFs: Kriegers flak and Baltic 2. Within the same period, ten sparrowhawks, one marsh harrier and one red kite, also migrated through the area in relatively close proximity to the OWF.

No collisions between migrating birds and wind turbines were observed throughout the survey period. On the other hand, several observations of avoidance behaviour, both from crane flocks and amongst the different birds of prey was observed.

In total 51 % of all cranes migrating through the area showed detectable avoidance behaviour and 32 % showed possible avoidance behaviour, an accumulative percentage of 83 % of cranes showing response or possible response to the OWFs.

Most of the avoidance behaviour observed was macro avoidance, as bird flocks typically became aware of the OWF from a faraway distance and either increased/- decreased in altitude or took an alternative route. Whereas only two cases of meso avoidance behaviour were detected i.e., flying in between the risk area of the wind turbines, either in between the turbines. Another tendency was found when looking into the average flight height of the migrating cranes within the area of the OWF compared to outside of the OWF, during autumn 2022. The average flight altitude of the migrating cranes outside and inside the OWF were 223 and 308 meters, respectively, equivalent to an average increase of altitude by 28 % above the OWF. The flight height also varied with the activity of the wind turbines. With an average flight height of 354 meters and 583 meters above the OWF while the wind turbines were operating at normal speed and while idling, respectively. The average flight height while the wind turbines were not operative was down to 136 meters. This is equivalent to a percentwise difference between operative and not operative of 62 percent and a percentwise difference between idling and not operative of 77 %. Whether the birds of prey can detect the OWF in the same matter and display similar response, is difficult to determine, since only a few observations of avoidance behaviour were observed while the wind turbines were operative. But it appears that every individual of birds of prey were able to enter the OWF without colliding, meaning that they could detect and manoeuvre in between the wind turbines within the survey period.

These strictly descriptive results combined, indicate that the migrating flocks of cranes that came close to the OWFs Kriegers flak and Baltic 2, were able to recognise the OWF at a faraway distance and take necessary precaution, either by an increase in altitude or by a change of direction, suggesting an avoidance rate of roughly 100 %. The results also suggest that the OWF had no influence on the migratory behaviour in the remaining flocks, that passed the Baltic Sea though route at a greater distance to the OFW’s, within the survey period.

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8 APPENDIX

8.1.1 LASER RANGEFINDER DATA AUTUMN 2022

Average flight height in meters (m) of migrating common cranes (*Grus grus*) during autumn 2022, based on data points collected by Laser-rangefinder (Number of data points from LRF (n), with the given Standard deviation). The number of individuals, of which the datapoints are based on, have been noted, as well as the range of flight height distribution. Secondly, an average flight height in meters (m) in four different scenarios of wind turbine movement: Operative (OP), Idle (IDL), Not operative (NO), No information (NA) has been calculated.

Number of datapoints from LRF (n)	Individuals (n)	Average flight height (m)	Standard Deviation	Minimum height (m)	Maximum Height (m)	Turbine Rotation
5	120	714.2	18.6	699	736	Op
6	130	735.2	9.7	721	748	Op
9	12	757.2	13.3	741	781	Op
3	80	939.7	106.7	824	1034	Op
7	7	184.6	15.7	164	204	Op
17	48	336.8	9.5	322	357	Op
14	40	182.1	16.6	162	220	Op
10	110	405.4	7.7	394	414	Op
13	130	365.6	20.9	330	409	Op
16	183	61.7	46.7	0	150	Op
14	38	12.1	12.1	0	36	Op
12	13	25.5	35.3	0	118	Op
1	3	121.0	NA	121	121	No
5	4	128.2	4.8	122	135	Op
2	35	995.0	472.3	661	1329	idl
5	110	171.8	16.3	145	187	idl
25	85	150.4	29.7	82	202	No
17	180	102.0	13.5	79	137	Op
3	2	75.3	4.0	71	79	NA
12	18	14.7	20.9	0	60	NA

8.1.2 LASER RANGEFINDER DATA SPRING 2023

The average flight height in meters (m) of migrating common cranes (*Grus grus*) during spring 2023, based on data points collected by Laser-rangefinder (Number of data points from LRF (n), with the given Standard deviation). The number of individuals, of which the datapoints are based on, have been noted, as well as the range of flight height distribution.

During spring 2023 measurements were recorded only during operative (OP) mode of the wind turbines.

Number of datapoints from LRF (n)	Individuals (n)	Average flight height (m)	Standard Deviation	Minimum height (m)	Maximum Height (m)	Turbine Rotation
3	5	135.7	3.1	133	139	Op
6	3	112.7	8.1	100	123	Op
1	8	71.0	NA	71	71	Op
13	80	134.7	7.3	121	148	Op
8	25	112.8	14.8	100	141	Op
28	42	79.8	9.8	52	100	Op
11	30	137.0	3.2	133	143	Op
8	8	259.4	3.2	256	265	Op

8.1.3 EU BIRDS DIRECTIVE

(EUR-Lex - 02009L0147-20190626 - EN - EUR-Lex (europa.eu))

EU Birds Directive:

Annex I	Annex I of the EU Birds Directive includes a total of 194 species. These are species threatened with extinction, rare due to low populations or small distribution areas or particularly in need of protection due to their habitat requirements.	
Annex II	It includes 82 species that can be hunted. However, the hunting periods are limited and hunting is forbidden when birds are at their most vulnerable: during their return migration to nesting areas, reproduction and the raising of their chicks.	The difference between Part A and B lies in the geographical area where this hunting applies. Species listed in Part A may be hunted in the geographical sea and land area where this Directive applies, whereas species listed in Part B may be hunted only in the Member States in respect of which they are indicated.
Annex III	activities that directly threaten birds, such as their deliberate killing, capture or trade, or the destruction of their nests, are banned. Nonetheless, the Member	Again, species listed in Part A includes species that have been legally killed or captured or otherwise legally acquired.

	States can allow these activities for the species listed in this annex.	Part B includes the same but for some of the Member States as indicated in the EU Birds Directive.

European Red List of Birds (Birdlife International, 2021)

CR – Critically Endangered:	“Critically Endangered”. A taxon is Critically Endangered when, according to the best available data, there is an extremely high risk that the taxon will become extinct in the wild in the immediate future.
EN – Endangered:	“Endangered”. A taxon is Endangered when, according to the best available data, there is a very high risk that the taxon will become extinct in the wild in the immediate future.
VU – Vulnerable:	“Vulnerable”. A taxon is Vulnerable if, according to the best available data, it is considered to be facing a high risk of extinction in the wild is a high risk that the taxon will become extinct in nature in the immediate future.
NT - Near Threatened	“Near Threatened”. A taxon is Near Threatened if the assessment does not result in being classified as CR, EN, or VU, but is expected to be classified in one of the categories in the near future
LC - Least Concern	“Least Concern”. A taxon is Least Concern if the assessment does not lead to its classification as CR, EN, VU or NT. Widespread species and those with large numbers of individuals are listed here.
NE - Not evaluated	“Not Evaluated”.

Population status according to the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (**AEWA**)

A 1b:	Species that are listed as “Threatened” in the current IUCN Red List
A 1c:	Populations of fewer than approx.10,000 individuals.
A 2:	Populations of approx. 10,000 to 25,000 individuals.
A 3b:	Populations of approx. 25,000 to 100,000 individuals that are considered endangered due to their reliance on a critically endangered habitat type.
A 3c:	Populations of approx. 25,000 to 100,000 individuals that are

	considered endangered due to a significant long-term decline.
A 4:	Species that are listed as “Near Threatened” in the IUCN Red List, but which do not meet the criteria for classification in categories A 1, A 2 or A 3,
B 1:	Populations of approx. 25,000 to 100,000 individuals that do not meet the requirements for column A.
B 2a:	Populations of more than approx. 100,000 individuals for which special attention appears to be necessary due to the concentration on a small number of sites at each stage of their annual cycle.
B 2b:	Populations of more than approx. 100,000 individuals, for which special attention appears to be necessary due to the reliance on a critically endangered habitat type.
B 2c:	Populations of more than approx. 100,000 individuals for which special attention appears to be necessary due to a significant long-term decline.
B 2d:	Populations of more than approx. 100,000 individuals for which special attention appears to be necessary due to large fluctuations in population size or trends.
C 1:	Populations of more than approx.100,000 individuals for which international cooperation could be of considerable benefit and that do not meet the conditions for column A or B.
( ):	Population situation unknown, endangerment status estimated.
*:	Populations marked with an asterisk may exceptionally continue to be hunted on the basis of sustainable use, provided that the hunting of these populations corresponds to a long cultural tradition (see Annex 3, paragraph 2.2.1).
[N]:	Type of AEWA agreement for which Germany is not a range state.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora)

Appendix I	includes all species threatened with extinction which are or may be affected by trade. Trade in specimens of these species must be subject to particularly strict regulation in order not to endanger further their survival and must only be authorized in exceptional circumstances

Appendix II/A	Includes all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival;
Appendix II/B	Includes other species which must be subject to regulation in order that trade in specimens of certain species referred to in sub-paragraph (a) of this paragraph may be brought under effective control
Appendix III	includes all species which any Party identifies as being subject to regulation within its jurisdiction for the purpose of preventing or restricting exploitation, and as needing the co-operation of other Parties in the control of trade.

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