REPORT ON THE ENVIRONMENTAL IMPACT ASSESSMENT OF THE BALTICA-1 OFFSHORE WIND FARM

APPENDIX 5

THE ASSESSED IMPACT OF THE BALTICA-1 OWF ON MIGRATORY BIRDS IN RELATION TO THE BARRIER EFFECT AND COLLISION RISK BASED ON MODEL CALCULATIONS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND DEFINITIONS

APV	the Applicant's Proposed Variant in three technically different calculation scenarios: APV (calculation scenario 1), APV (calculation scenario 2), APV (calculation scenario 3)
Avoidance level	the probability with which a bird will actively avoid a collision with wind turbine elements expressed as a percentage
CRM	Collision Risk Model
OWF	Offshore Wind Farm
PBR	Potential Biological Removal
RAV	Rational Alternative Variant

1 NON-SPECIALIST SUMMARY

Data from the migratory bird surveys conducted for the environmental impact assessment of the Baltica-1 OWF was used to select the species migrating across the Baltic Sea which may be impacted by the OWF, and the species observed most often in the course of surveys performed in 2020 during the spring and autumn migration periods. Bird migrations in the Baltica-1 OWF area were dominated by seabirds (the common scoter, velvet scoter, long-tailed duck, and auks) and birds flying long distances (geese and passerines). The species subject to the impact assessment range from species of little conservation value, through moderately to highly valuable ones (depending on the size of the possibly threatened populations, sensitivity of the species to specific impacts and their level of protection at the national and international scale). Species of high conservation value include sea ducks: the long-tailed duck, common scoter, and common crane.

The impact of the OWF on migratory birds is investigated in terms of the barrier effect and the risk of collision with the OWF elements. As a result of the barrier effect, birds approaching the OWF perceive it as a barrier and change the direction of their flight. To avoid the OWF, birds can adjust their flyway, thus lengthening their migration route. Analyses indicate that the energy expenditures associated with a longer migration route are going to be minimal at each phase of the investment implementation (up to 3.8% higher energy expenditure). However, the migration route is never the same for all individuals of a given species and the differences resulting from individual route choices and the impact of weather phenomena might exceed the ones caused by the barrier effect as such. Therefore, the significance of this impact has been assessed as negligible. Analyses of cumulative impact, i.e. the ones in which simultaneous operation of other OWFs in the vicinity of the Baltica-1 OWF was assumed, indicate that the additional energy expenditures would constitute a minor part of the entire energy necessary for seasonal migration. On this ground, the significance of the cumulative impact has been assessed as minor at the very most.

The impact in the form of the risk of collision, i.e. bird mortality resulting from collisions with OWF elements, has been presented as the total number of collisions of a given species during the spring and autumn migration periods. The risk of collision depends on the OWF parameters, such as the number of wind power stations, rotor diameter, the size of the clearance between the lower range of the rotor and the water surface, on biological and species parameters such as body size, flight speed, flight altitude, collision avoidance rate, and on the weather parameters. In limited visibility (low clouds, night, dense fog), birds can notice an OWF from a much closer distance, which translates into a higher collision risk. The analyses have evaluated both the Applicant's proposed variant (APV) and the rational alternative variant (RAV). Among all the analysed species, the significance of the impact related to the collision risk has been assessed as insignificant for the common scoter, long-tailed duck, common crane, and little gull. For the crane, the estimated maximum number of collisions equals 1 individual in the spring and 0 individuals in the autumn, regardless of the variant. For the remaining species, the significance of the collision risk was assessed to be negligible. The values obtained in the collision risk modelling were extrapolated in relation to the capacities of other projects expressed by the total value of the indicator. For the OWF areas: Bałtyk I, Bałtyk II, Bałtyk III, Baltic Power, Baltica 2, Baltica 3, BC-Wind, 44.E.1, FEW Baltic II, the data on the predicted mortality level (for given species/groups) included in the environmental documentation were used. For the other OWFs, the expected mortality rates were calculated for individual species and groups of species. For most species, mortality still remains at a low level. The cumulative impact in the case of the common scoter may cause up to

68 individuals to become subject to collisions, and in the case of the crane, there may be up to 177 individuals in autumn in the RAV. In the case of cumulative impact, it should be noted that due to the flight trajectory (from north-east to south-west and *vice versa*), it is very unlikely that migrating birds will encounter more than the nearest neighbouring OWF (e.g. Sodra Victoria, Njord, or Oland-Hoburg I). It must be emphasised that cumulative impacts deliberately overstate the mortality rates to the level possible only if birds encountered all the OWFs on their route. Therefore, the significance of the cumulative impact has been assessed as moderate for cranes and geese. The good state of their populations will not change even with the maximum rates of collision-related mortality. The low or negligible significance of the cumulative risk of collision was determined for all the other species and groups of birds.

2 INTRODUCTION

Based on data from the inventory surveys on migratory birds [Appendix 1, IM_5844_OOS_001_EN_01_ZAL_001 to the EIA Report], migration flows were calculated for individual species. The selection of species to be included in the analyses was dictated primarily by the number of observations (the list includes species and groups of species observed most frequently), as well as the expert knowledge on which species usually migrate across the Baltic Sea but were rarely encountered during the surveys (such as the crane) (Bednarska et al., 2017; Biegaj et al., 2015b; Gajewski et al., 2021; Opioła et al., 2020). The information on the species protection status and the importance of the species as a receptor according to the methodology adopted in the EIA Report were also taken into consideration. This information along with the size of biogeographic populations and the assessment of the resource significance are presented in the table below [Table 2.1]. This data provided a basis for the assessment of the Baltica-1 OWF's impact on migratory birds. The size of the vulnerable population was assessed as small when the estimated migration flight intensity of a given species through the Baltica-1 OWF area was less than 2% of the biogeographic population, moderate when it was 2–5%, and significant when its share exceeded 5%.

Table 2.1. The species and groups of species included in the analyses for the purposes of this Report with the significance assessment of the vulnerable population

No.	English name	Latin name	Biogeographic population abundance	Migration season	The estimated migration flight intensity [No. of individuals]	The share of biogeographical population [%]	The size of the vulnerable population	The receptor's significance
1.	Long-tailed duck	*Clangula hyemalis*	1,600,000	Spring	111,036	6.94	Significance	High
				Autumn	22,857	1.43	Low	
2.	Common scoter	*Melanitta nigra*	550,000	Spring	40,273	7.32	Significance	Moderate
				Autumn	84,983	15.45	Significance	
3.	Passerines (song thrush)	*Passeriformes*	100,000,000	Spring	46,872	0.05	Negligible	Low
				Autumn	65,456	0.07	Negligible	
4.	Black-throated diver	*Gavia arctica*	196,000	Spring	2413	1.23	Low	Low
				Autumn	119	0.06	Negligible	
5.	Greater white-fronted goose	*Anser albifrons*	600,000	Spring	1100	0.18	Negligible	Low
				Autumn	0	0.00	None	
6.	Greylag goose	*Anser anser*	850,000	Spring	2660	0.31	Negligible	Low
				Autumn	537	0.06	Negligible	
7.	Dabbling ducks	*Anatini*	6,500,000	Spring	2203	0.03	Negligible	Low
				Autumn	5928	0.09	Negligible	
8.	Greater scaup	*Aythya marila*	310,000	Spring	2074	0.67	Negligible	Low
				Autumn	529	0.17	Negligible	
9.	Lesser black-backed gull	*Larus fuscus*	1,200,000	Spring	5347	0.45	Negligible	Low
				Autumn	3776	0.31	Negligible	
10.	Little gull	*Hydrocoloeus minutus*	72,000	Spring	2915	4.05	Moderate	Moderate
				Autumn	2584	3.59	Moderate	
11.	Common wood pigeon	*Columba palumbus*	20,000,000	Spring	123	0.00	Negligible	Low

No.	English name	Latin name	Biogeographic population abundance	Migration season	The estimated migration flight intensity [No. of individuals]	The share of biogeographical population [%]	The size of the vulnerable population	The receptor's significance
				Autumn	0	0.00	None	
12.	Velvet scoter	*Melanitta fusca*	450,000	Spring	2455	0.55	Negligible	High
				Autumn	1542	0.34	Negligible	
13.	Eurasian curlew	*Numenius arquata*	450,000	Spring	3199	0.71	Negligible	Low
				Autumn	0	0.00	None	
14.	Eurasian skylark	*Alauda arvensis*	1,200,000	Spring	998	0.08	Negligible	Low
				Autumn	2134	0.18	Negligible	
15.	Whooper swan	*Cygnus cygnus*	60,000	Spring	66	0.11	Negligible	Low
				Autumn	0	0.00	Negligible	
16.	Accipitriformes (Eurasian sparrowhawk)	*Accipitridae*	4,030,000	Spring	49	0.00	Negligible	Moderate
				Autumn	13	0.00	Negligible	
17.	Common crane	*Grus grus*	410,000	Spring	276	0.07	Negligible	High
				Autumn	133	0.03	Negligible	
18.	Razorbill	*Alca torda*	250,000	Spring	20,006	8.00	Significance	Low
				Autumn	4878	1.95	Low	
19.	Charadriiformes (northern lapwing)	*Charadriidae*	1,600,000	Spring	14,973	0.94	Negligible	Low
				Autumn	4555	0.28	Negligible	
20.	Black guillemot	*Cepphus grylle*	242,000	Spring	632	0.26	Negligible	Low
				Autumn	75	0.03	Negligible	
21.	Eurasian wigeon	*Mareca penelope*	500,000	Spring	685	0.14	Negligible	Low
				Autumn	3286	0.66	Negligible	
22.	Black-legged kittiwake	*Rissa tridactyla*	840,000	Spring	0	0.00	Negligible	Low

No.	English name	Latin name	Biogeographic population abundance	Migration season	The estimated migration flight intensity [No. of individuals]	The share of biogeographical population [%]	The size of the vulnerable population	The receptor's significance
				Autumn	35	0.00	Negligible	
23.	Common guillemot	*Uria aalge*	500,000	Spring	2203	0.44	Negligible	Low
				Autumn	5181	1.04	Low	
24.	Auks (razorbill)	*Alcidae*	1,000,000	Spring	25,234	2.52	Moderate	Low
				Autumn	12,327	1.23	Low	
25.	Divers (black-throated diver)	*Gaviidae*	400,000	Spring	4878	1.22	Low	Low
				Autumn	900	0.23	Negligible	
26.	Geese (greylag goose)	*Anseridae*	3,500,000	Spring	14,671	0.42	Negligible	Low
				Autumn	4755	0.14	Negligible	
27.	Owls (long-eared owl)	*Asio sp.*	1,280,000	Spring	98	0.01	Negligible	Low
				Autumn	0	0.00	Negligible	
28.	Skuas (Pomarine skua)	*Stercorariidae*	100,000	Spring	564	0.56	Negligible	Low
				Autumn	549	0.55	Negligible	
29.	Swans (whooper swan)	*Cygnidae*	300,000	Spring	1073	0.36	Negligible	Low
				Autumn	470	0.16	Negligible	
30.	Apodinae (common swift)	*Apus apus*	9,600,000	Spring	0	0.00	Negligible	Low
				Autumn	2456	0.03	Negligible	
31.	Terns (Arctic tern)	*Sternidae*	1,800,000	Spring	443	0.02	Negligible	Low
				Autumn	7033	0.39	Negligible	

3 METHODOLOGY

3.1 COLLISION RISK

To determine the risk of collision for individual bird species staying and migrating in the survey area, the commonly used Band Collision Risk Model (CRM) was used (the name „Band CRM model" refers to the author of the model and is commonly used in professional publications) (Band, 2012; Masden and Cook, 2016). The first version of the Band CRM was created in 2000 and is often referred to as the „basic" version. An extended version describing a more accurate vertical distribution of birds (flight altitude) in relation to the rotor range was created in 2012 (Band, 2012) [Figure 3.1]. In the case of sea ducks, the extended model was used as the amount of data necessary to create a dependable model of the vertical distribution of passing birds in 1-m intervals had been collected.

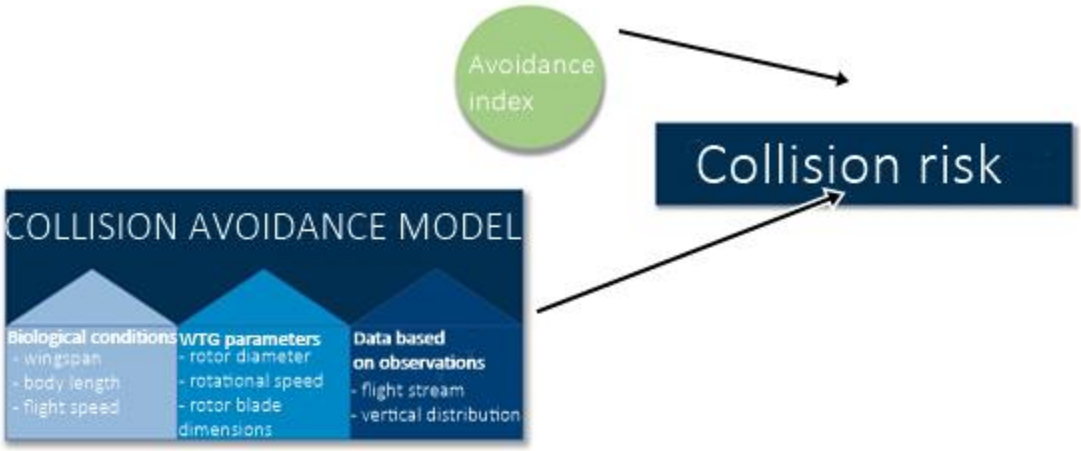

Figure 3.1. *The main assumptions and processes of the Band Collision Risk Model [Source: internal materials based on Band, 2012]*

To estimate the risk of bird collisions, quantitative data on stationing and migratory birds are required as well as the information on individual wind turbines and the parameters of the wind farm. Next, collision risk calculation consists of determining a range of assumptions. First, there is assumed the probability of collision with a rotor, which depends solely on what size a bird is (its wingspan and wing surface), the range and inclination angle of rotor blades, rotation speed, and bird flight speed. To make the calculations easier, a simplified representation of a bird was accepted that looks like a cross (with its wings right between the beak and the tail). The rotor blade was accepted to have a specific width and inclination angle, but no thickness, while bird flight was assumed not to be affected by any possible dangerous event (so-called near miss) despite the flow of air around the rotor blades. Next, an assumption was made that birds fly through wind power stations at right angles, even if they approach the rotor at a sharp angle. These simplifications are justified by the fact that flight at an angle means that a smaller area is crossed and the time necessary for crossing the plane of the rotor is longer (irrespective of rotor position), hence, these two variables probably balance each other out, and it may be assumed that the effect is the same as for a flight at 90 degrees (Band, 2012).

Band describes the model in six stages:

- Stage A – data is collected on the number of passages of birds that have not moved from the farm area, do not avoid it or have been attracted to the wind farm due to their curiosity and are potentially vulnerable to collisions;
- Stage B – bird activity data is used to estimate the potential number of birds passing through a wind power station rotor;
- Stage C – the collision risk for the passage of a single individual through a rotor is calculated;
- Stage D – thus calculated collision risk is multiplied to obtain the possible collision-related mortality rate for individual bird species, allowing for a proportionate amount of time when the wind power stations do not operate, assuming similar operation and lack of avoidance;
- Stage E – allows taking into account the share of birds that are most likely to avoid the wind farm or wind power stations because they have moved away from or by-passed the area; the attraction of birds to the wind farm, e.g. due to habitat change, is included;
- Stage F – the uncertainty of the collision risk analysis performed in this way is expressed.

The estimation of the collision risk is the result of the combination of the first 5 stages and their verification against the uncertainty from the last stage (F). Stage A defines bird flights, which allows for the “stream” of birds flying through the rotor to be calculated at stage B based on the bird density (stationing birds) and bird flight index (migratory birds). At stage C, the collision probability for a single flight is calculated based on the parameters of the wind power station and the bird involved. Stages B and C are then combined by multiplying the number of flights by the collision risk for a single flight and the operation time of the wind farm, which results in the number of collisions in a month, assuming there is no avoidance. The extended model used for three sea duck species allows for diversity of bird streams and probability of collision within the rotor cross-section therefore these results must be summed up for the entire surface of the rotor cross-section surface. The extended model is based on the assumption that bird flight density increases at lower altitudes. For the remaining species, the basic model was used, which is based on the proportional number of birds in the rotor rotation zone. At stage E the reaction of avoidance is added to obtain the final estimate of the number of collisions per month. For sea ducks, the default avoidance rates included in the Band model were used: 95, 98, 99 and 99.5% (Band, 2012), while for the remaining species, the avoidance rates were selected based on the available research and expert knowledge.

In the last stage (F), the uncertainties related to the previous stages are calculated. Every stage of collision risk calculation is associated with uncertainties (concerning e.g. density indices/bird flights, night activity, the percentages of altitude, size and uptime of a wind power station, and the simplification of the collision model). In this study, the uncertainty for individual stages was based on expert assessment and therefore, it should be used as the indicated uncertainty scope. The uncertainty of density/flight indices is at least 50% (e1 = 0.50). Due to the small amount of information on night activity, an uncertainty of 25% was assumed (e2 = 0.25). The uncertainty concerning birds that fly at the level of the rotor is at least 25% (e3 = 0.25) (Band, 2012), and at least 10% in the operation time (e4 = 0.10). Finally, the uncertainty resulting from the model simplifications is 25% (e5 = 0.25) (Band, 2012). Individual uncertainty components were summed up with the formula presented below (Band, 2012):

$$E = \sqrt{e_1^2 + e_2^2 + e_3^2 + e_4^2 + e_5^2}(\pm 67\%)$$

In conclusion, the uncertainty calculated at the final stage (accounting for all the previous stages and described sources of uncertainty) is estimated at approximately 67% for all the species, for which the collision risk has been modelled.

3.1.1 Collision risk modelling

Collision calculations have been performed for two variants, with three calculation scenarios for the APV. The APV assumes 60, 50, or 36 wind power stations with a unit power of 15, 20, and 25 MW, respectively, while the RAV assumes 64 wind power stations with a power of 15 MW. Detailed technical parameters of both variants, including calculation scenarios for the APV, are presented in the table below [Table 3.1]. The calculation scenarios for the APV fully illustrate the worst-case impact of this variant for the envelope resulting from the proposed parameters – clearance, maximum total blade rotation zone and rotor diameter range.

Table 3.1. The Baltica-1 OWF parameters in the two variants included in the collision risk modelling

Parameter	**Applicant Proposed Variant (APV)**			**Rational Alternative Variant (RAV)**
	Calculation scenario 1.	**Calculation scenario 2.**	**Calculation scenario 3.**	
Installed capacity [MW]	15	20	25	14
The number of wind power stations	60	50	36	64
The rotor diameter[m]	236	250	310	236
The clearance between the low rotor blade position and the water surface [m] (min.)	20			
Nacelle altitude [m]	138	145	175	138

Species characteristics: individual length, wingspan, and flight speed, included in the collision risk models, are presented in a table [Table 3.2]. The bird migration streams (based on the modelling of data from the observations conducted from research vessels) used in the calculations of collision risk for stationing bids and flight rates (the number of birds/month) are presented in Appendix 1 [IM_5844_OOS_001_EN_01_ZAL_001] to the EIA Report. The density of migrating birds was estimated for a belt of 10 km in width corresponding to the longest cross-section of the Baltica-1 OWF along the NW-SE axis, which is perpendicular to the main flight direction of migratory birds.

Table 3.2. The biological parameters included in the collision risk modelling [Source: internal materials based on Alerstam et al., 2007]

No.	**Species/ group of species**	**Latin name**	**Body length [m]**	**Wingspan [m]**	**Flight speed [km/h]**	**The probability of flying at the rotor level**
1.	Greylag goose	*Anser anser*	0.48	1.68	17.1	11.01
2.	Greater white-fronted goose	*Anser albifrons*	0.18	0.36	16.1	30.00
3.	Common wood pigeon	*Columba palumbus*	0.43	0.77	16.3	12.00

No.	Species/ group of species	Latin name	Body length [m]	Wingspan [m]	Flight speed [km/h]	The probability of flying at the rotor level
4.	Common swift	*Apus apus*	0.18	0.44	30.8	47.00
5.	Eurasian curlew	*Numenius arquata*	0.58	0.82	16.3	19.23
6.	Whooper swan	*Cygnus cygnus*	1.6	2.35	17.3	40.61
7.	Long-tailed duck	*Clangula hyemalis*	0.47	0.82	22	0.6
8.	Common scoter	*Melanitta nigra*	0.58	0.97	22.1	2.04
9.	Little gull	*Hydrocoloeus minutus*	0.28	0.69	11.5	7.51
10.	Lesser black-backed gull	*Larus fuscus*	0.56	1.34	13.1	17.99
11.	Black-throated diver	*Gavia arctica*	0.75	1.22	19.3	8.23
12.	Common merganser	*Mergus merganser*	0.54	0.84	19.7	8.00
13.	Greater scaup	*Aythya marila*	0.51	0.8	21.3	13.42
14.	Eurasian skylark	*Alauda arvensis*	0.41	0.8	15.1	3.70
15.	Eurasian wigeon	*Mareca penelope*	0.5	0.85	20.6	22.15
16.	Red-breasted merganser	*Mergus serrator*	0.68	0.94	20	1.98
17.	Velvet scoter	*Melanitta fusca*	0.5	0.85	20.1	6.15
18.	Common crane	*Grus grus*	1.19	2.22	15	56.68
19.	Auks (razorbill)*	*Alca torda*	0.43	0.69	16	-
20.	Accipitriformes (common buzzard)*	*Buteo buteo*	0.56	1.3	11.6	40.00
21.	Geese (greylag goose)*	*Anser anser*	0.48	1.68	17.1	50.09
22.	Swans (whooper swan)*	*Cygnus cygnus*	1.6	2.35	17.3	78.23
23.	Divers (common diver)	*Gavia arctica*	0.75	1.22	19.3	14.12
24.	Terns (Arctic tern)*	*Sterna paradisaea*	0.39	0.77	12.1	3.14
25.	Charadriiformes (northern lapwing)*	*Vanellus vanellus*	0.31	0.72	12.8	15.00
26.	Owls (long-eared owl)*	*Asio otus*	0.37	0.98	12.5	40.00
27.	Passerines (song thrush)*	*Turdus philomelos*	0.22	0.36	11	16.90
28.	Skuas (Pomarine skua)*	*Stercorarius pomarinus*	0.5	1.25	15.2	15.00

**the morphological data of the species given in brackets were used for species groups*

The collision risk model for migratory birds is based on the data collected during observations conducted in spring and autumn. The analysis did not model the collision risk for wintering birds as the nature of their flights is different than migration (local) and the fact that at both survey stations, the share of birds flying at altitudes above 20 m above sea level did not exceed 2% of all observations (LP_01 – 2%, LP_02 – 0.3%). As the number of birds observed at the level of an operating rotor (in the collision zone) was too low, it was not possible to conduct modelling in this scope.

To enable the extrapolation of the number of migratory birds for the entire migration season and thus, to take into account the proportions between the abundances of birds flying downwind and upwind, the data from the weather model in hourly intervals was used. These data were obtained from the weather model for the region made available by StormGeo (www.storm.no). This model is based on global weather models managed by the European Centre for Medium-Range Weather Forecasts (Great Britain).

Its spatial resolution is 0.1°, and the temporal resolution is 1 hour. In the spring, defined as a headwind was the wind blowing in directions <135° and >315°, while the tailwind was >135° and <315°. In autumn, the values for headwind and tailwind were defined as opposites. Also, the headwind-to-tailwind ratio during the entire migration season was calculated, which allowed for the number of passing birds to be extrapolated taking into account the wind direction.

3.2 BARRIER EFFECT ASSESSMENT

The barrier effect impact on the local and long-distance migrations of seabirds, resulting in changes in their migration routes, flight courses and altitudes, and hence, energy expenditures, is described in detail for already functioning wind farms (Masden and Cook, 2016; Masden et al., 2009). The monitoring conducted at the existing OWFs included the visual and radar observations of behavioural responses of migratory birds to power station structures. At the Baltic Sea, data on the reactions of individual species have been collected for the Nysted wind farm. Waterbirds (ducks, geese, auks) responded at a distance of 5 km from a power station and changed the direction of their flight 3 km away from a wind farm (Paton et al., 2010). At a distance of 1–2 km, more than 50% of the birds flying towards the wind farm resigned from crossing it. The waterbirds which flew into the wind farm area minimised the risk of collision in three ways: by flying between the rows of wind turbines (often keeping an even distance from the wind power stations), by reducing the flight altitude below the rotor level, and by choosing the shortest route to get out of the wind farm.

The surveys conducted at the Nysted and Horns Rev 1 wind farms in Denmark have shown that more migratory seabirds than local seabirds avoid and bypass wind farm areas (Alerstam et al., 2007). Near the wind farms, large numbers of sea ducks, especially the common scoter (Horns Rev OWF) and common eider (Nysted OWF) were recorded. Although ducks generally avoided crossing the boundaries of wind farms, single individuals and groups of individuals of the species were recorded also within the farms. Birds of the *Melanitta* genus avoided wind power stations in the areas of Dutch OWFs (Jensen et al., 2014). No extreme reactions, such as turning back because of the encountered wind farm, could be observed. Birds bypassed the OWFs by flying over or around them (Alerstam et al., 2007; Pennycuick, 2001).

It has been assumed that the two variants of the Baltic Power OWF would cause the same barrier effect since the current state of knowledge on the behavioural response of birds does not allow us to differentiate the effect according to the types of power stations or their density. The entire Baltica-1 OWF Area will be perceived by the approaching birds as a barrier.

The hypothetical migration routes have been delineated based on data from a vertical radar on migratory bird flight directions. All migration routes have been simplified to show the shortest routes between breeding sites and wintering grounds which cross the Baltica-1 OWF area, taking into account the natural habitats (e.g. sea ducks fly mostly above water). The same routes were assumed both for spring and autumn migrations since no surveys are proving that it should be otherwise in the case of the species analysed.

Then, the migration routes were modified, assuming that the birds perceive the Baltica-1 OWF area as a barrier and avoid the farm from a distance of 1–2 km.

3.3 THE ANALYSIS OF THE POTENTIAL BIOLOGICAL REMOVAL (PBR) LEVEL

To assess whether the rate of collision for predicted birds migrating over the farm area will be significant for their population, a tool has been also used to help predict the significance of this additional mortality (Chylarecki et al., 2011). The model that allows for such an assessment includes the analysis of the potential biological removal (PBR) level, which allows for determining the level of additional mortality to which the studied populations may be exposed.

The PBR is expressed by the following formula:

$PBR = 0.5 * R_{max} * N_{min} * f$

where:

R_{max} – the maximum potential population growth rate;
N_{min} – the minimum population size;
f – a coefficient from the range [0.1; 1], reflecting the status of the population and its conservation priority (IUCN, 2021).

For bird species included in the category of "least concern" (LC), the coefficient f = 0.5 is recommended (if the population is stable or increasing, f = 1.0 can be used). For "near threatened" (NT) species, the coefficient f = 0.3 is used. For species threatened with extinction, which are included in the categories: "vulnerable" (VU), "endangered" (EN), and "critically endangered" (CR), f = 0.1 is used.

R_{max} was estimated based on the known mean age of first breeding in the population (a) and the annual survival rate of mature individuals (s), using the maximum population growth rate (λ_{max}):

$\lambda max = \{(s *a - s + a +1) + [(s - s *a - a - 1)2 - 4 *s * a2]-1\} / 2*a$,

$R_{max} = \lambda_{max} - 1$
N_{min} – the minimum biogeographical size of the migratory population (IUCN, 2021; Wetlands International, 2018).

Dillingham and Fletcher (2008) recommend using the threat categories proposed by the International Union for Conservation of Nature (IUCN, 2021), which refer to the global population status and for which the conservative (= minimum) variant of its size estimation is always chosen. The parameter values used to obtain the potential biological removal (PBR) level for a given species are presented in the table below [Table 3.3]. The analysis included key species of high importance, which are the objects of protection in the Natura 2000 site *Hoburgs bank och Midsjöbankarna*, as well as species for which the modelling results indicate a moderate risk of collision in the case of cumulative impact. As the numbers recorded turned out too low, it was not possible to model the risk of collision for the black guillemot and common eider and to refer to the obtained PBR values.

Table 3.3. The parameter values used to calculate the potential biological removal (PBR) level for selected species

Species	**Latin name**	**s**	**a**	**N_min**	**F (European population)**	**PBR**
Black guillemot	*Cepphus grylle*	0.87	4	53,000	0.5	1829
Long-tailed duck	*Clangula hyemalis*	0.72	3	423,000	0.1	4782
Common eider	*Somateria mollissima*	0.916	4	740,000	0.1	4322
Common crane	*Grus grus*	0.9	3	366,000	0.5	13,932
Greater white-fronted goose	*Anser albifrons*	0.724	3	611,000	0.5	34,363
Greylag goose	*Anser anser*	0.83	3	850,000	1	79,914

(s) the annual survival rate of mature individuals;
(a) the average age of first breeding in the population;
(f) a coefficient from the range [0.1; 1], reflecting the status of the population and its conservation priority (IUCN, 2021)

4 RESULTS

4.1 THE BARRIER EFFECT

The presence of an OWF creates a barrier effect influencing the behaviour (movement) of migratory birds. The scale of the impact will depend on the size of the area planned for the development of wind power stations, its shape and location in relation to the main direction of bird migrations. Birds may be forced to change their flight direction horizontally or vertically, which may slightly extend the journey and increase energy expenditures. The surveys conducted so far on this topic indicate that bypassing even a few OWFs increases both the total length of the migration route, and the energy expenditure associated with the migration only slightly (Alerstam et al., 2007; Dansk Ornitologisk Forening; Lely Wind Farm Fully Decommissioned, 2016). These results have been included as a reference for this document, but it should be emphasised that the surveys presented in the literature concern other marine areas. Masden et al. (2009) present the results for the Nysted OWF in the Baltic Sea (165 MW). In a report developed by Jensen et al. (2014), the situation of the Horns Rev 3 OWF is presented (400 MW, Horns Rev 3, North Sea). In the case of the Horns Rev 3 OWF, which borders on two other OWFs – Horns Rev 1 OWF (160 MW) and Horns Rev 2 OWF (209 MW), it was recognised that no cumulative impacts would occur.

Only representative species were chosen for the analysis, and their selection was made based on expert assessment. The list of species is limited due to the limited availability of source data necessary to estimate the energy expenditures (including body weight, wingspan, wing area, flight altitude, the percentage of fat tissue, and distance to be covered during the migration).

Extending the route by 12.4 km due to the OWF barrier effect will increase the energy expenditure needed to cover the route by a negligible amount (Merkel and Johansen, 2011; Pennycuick, 2001) [Figure 4.1]. Additionally, in the case of passerine birds moving mainly at night and high altitudes (above the rotor range), the barrier effect will not occur as the birds will fly over the OWF. Therefore, the significance of the barrier effect's impact on all the bird groups and species included in the analysis was considered insignificant.

Long-tailed ducks' migration takes place across the entire width of the Baltic Sea. Therefore, only a small percentage of birds will be forced to change their flight path due to a barrier in the form of the Baltica-1 OWF. The energy cost related to the potential route extension has a negligible significance for long-tailed ducks since migration routes within a population differ from one another depending on the selected way (along the southern coast of Sweden, through the Southern Baltic Sea etc.) and on the weather conditions at the time of the flight. Hence, the impact has been assessed as low.

Migration of common scoters takes place across the entire width of the Baltic Sea. The energy cost related to the potential route extension is of negligible significance, just like in the case of long-tailed ducks, because migration routes within a population differ from one another depending on the selected way (along the southern coast of Sweden, through the Southern Baltic Sea etc.) and on the weather conditions at the time of the flight. The impact is considered low.

Migratory dabbling ducks such as teals, wigeons, and mallards would use up a comparable amount of energy to sea ducks due to the extended routes. Dabbling ducks are smaller than the sea ducks described above, therefore their energy demand is even lower. The significance of the barrier effect's impact on dabbling ducks was considered insignificant, taking into account the scale of impact and the fact that most of them belong to game species in Poland.

Divers will probably avoid flying into the OWF area and it may be expected that they will avoid the Baltica OWF area, thus making the flight route longer. The related consequences in the form of increased energy costs will be small, comparable to the impact on sea ducks. The migration route is similar to that of the long-tailed duck – from wintering grounds in the Baltic Sea in the directions of the Kara Sea and the Arctic. Therefore the change of the route will correspond to an equally low percentage of the total length of the migration route. Therefore, this impact on both diver species was considered insignificant.

Migratory auks can also be compared to divers and sea ducks in terms of their body size and way of moving. They also move with a broad front and the natural differences in the length of the flight route may be greater than the additional distance covered due to the presence of the OWF planned to be implemented on the flight route of part of these birds [Table 4.1]. For all these species (the razorbill, black guillemot, common guillemot), the impact was considered insignificant.

Great black cormorants, similar to other waterbirds, move across the Southern Baltic Sea with a broad front and the differences between the length of the flights of individual species may be greater than the added distance resulting from the barrier effect. The barrier effect was assessed as insignificant for the great black cormorant if the birds bypassed the Baltica-1 OWF. However, in many cases, it was observed that OWFs are not considered barriers for the great black cormorants, and the birds continue to fly across their areas without changing their flight trajectories (Kahlert et al., 2012).

The migration of swans will also take place through a broad front and the differences between the flighty length of individual species may be greater than the additional distance resulting from the barrier effect [Table 4.1]. Concerning the varied status of swan species, this impact will be insignificant for the mute swan and whooper swan, and of low significance for the tundra swan.

The change of route related to the barrier effect will increase the energy expenditures in geese by 1.39% and will have a negligible significance for the condition of these birds. Taking into account the assumptions made in the impact assessment, its negligible scale, and the great sizes of biogeographic populations, it was considered that the barrier effect would be insignificant for all goose species (the greater white-fronted goose, bean goose, and greylag goose).

During their flight above open waters, cranes fly in a broad front because there are no elements in the landscape which would help them concentrate within a selected flight corridor. The increase in energy expenditures at the level of 0.25% is negligible and will have no significance for the condition of the crane, taking into account the diversity of specific routes chosen by individual birds and the fact that in bad weather, the route may become even longer. The slightly higher energy expenditure than in the case of the other species analysed is primarily related to a shorter total migration route [Table 4.1]. The impact of the barrier effect was considered insignificant.

All migrating seagull species (the little gull, black-headed gull, lesser black-backed gull, common gull) bypass the Southern Baltic Sea on their route between the nesting grounds in Eastern Europe and the wintering grounds at the shores of the Atlantic Ocean. Just as for other seabirds, there is no specific migration corridor above the Baltic Sea waters and this sea basin is crossed with a broad front. For all these species, the impact of the barrier effect was considered insignificant (except for the little gull, for which the impact is of low significance, due to the high conservation value of the species), since the energy demand of these birds is lower than, e.g., for sea ducks; therefore, the increase in the energy expenditures in relation to route elongation will be insignificant for the condition of these birds.

The impact of the barrier effect for terns was also considered insignificant, as these birds show a comparable manner of crossing the Baltic Sea as seagulls. The increased energy cost will have no impact on the condition of terns. Additionally, terns have ones of the lowest energy expenditures among the birds assessed.

The impact of the barrier effect for plovers was considered insignificant due to the fact that these birds migrate via the Baltic Sea with a broad front and the final length of the flight may differ for individual birds, taking into account for instance the influence of unfavourable weather.

The impact of the barrier effect on passerines is insignificant. The majority of passerines are nocturnal migrants that fly at very large altitudes. Energy expenditure on avoiding the OWF will concern only a small fraction of passerines flying lower than the majority of these birds, e.g. due to unfavourable weather conditions forcing them to reduce their flight altitudes.

Table 4.1. The estimated energetic cost of flight taking into account the barrier effect generated by the Baltica-1 OWF area for selected species during a migration [Source: internal materials based on Baak, 2019; Månson et al., 2022; MoveBank; Opioła et al., 2020]

Species	The distance to be covered during the migration [km]	The energy cost during the migration [kJ]	% by which the energy costs will be increased due to the barrier effect
Black guillemot *Cepphus grylle*	470	963	3.84%
Common crane *Grus grus*	3492	40,500	0.25%
Common scoter *Melanitta nigra*	3060	8180	0.37%
Eurasian curlew *Numenius arquata*	2572	5400	0.74%
Whooper swan *Cygnus cygnus*	3442	96,300	0.52%
Long-tailed duck *Clangula hyemalis*	3442	9620	0.52%
Greylag goose *Anser anser*	1300	14,400	1.39%
Eurasian wigeon *Mareca penelope*	3248	7080	0.42%
Common buzzard *Buteo buteo*	1213	3070	1.30%

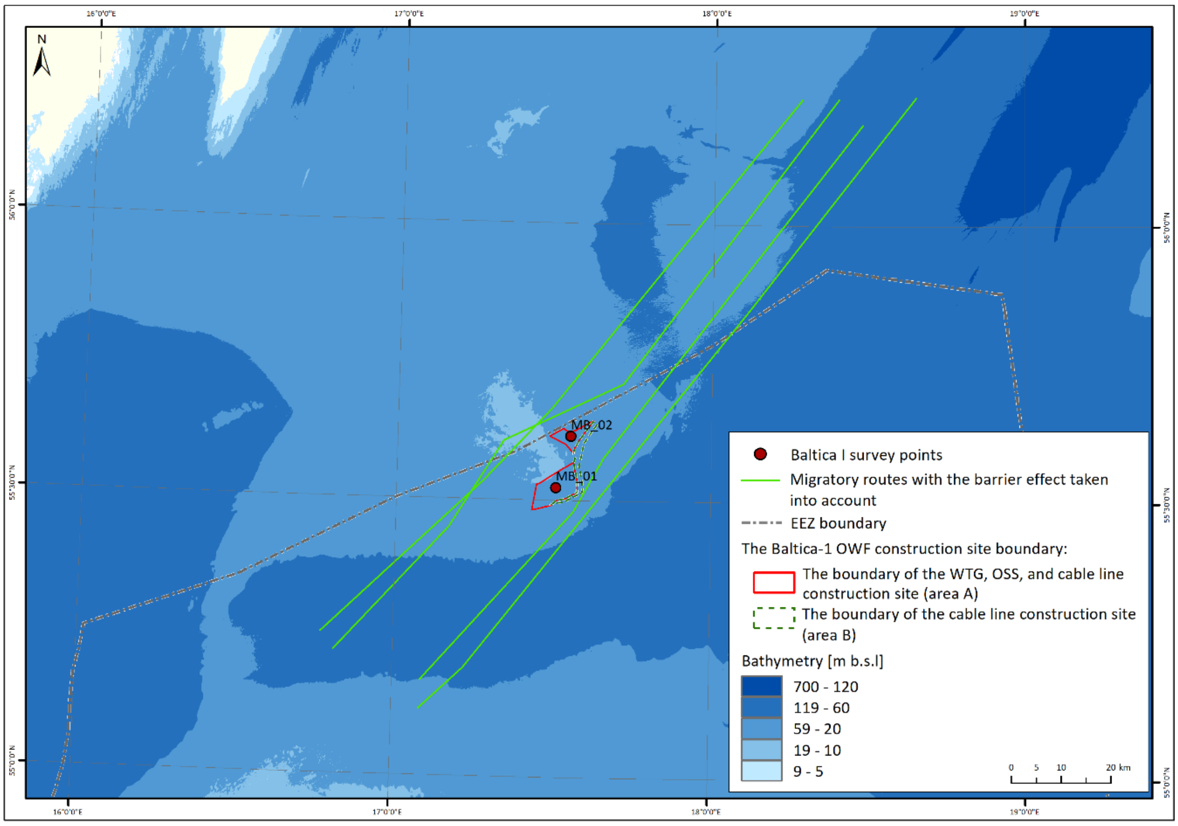

Figure 4.1. The theoretical flight routes of migrating birds taking into account the barrier effect

4.1.1 Cumulative barrier effect

In the case of cumulative impacts, in which, at the request of the Regional Directorate for Environmental Protection, also very distant OWFs were taken into account [Table 4.19], the theoretical route bypassing the OWFs causes a quite significant increase in energy expenditure only in the case of the black guillemot [Table 4.2]. However, using expert knowledge, a situation in which this species would choose such a route is unlikely, due to the large expanses of open, undeveloped waters of the Baltic Sea between individual OWF groups [Figure 4.2].

The increase in energy costs, as presented in the following table [Table 4.2] for selected species based on calculations conducted in the Flight program, is negligible, which means that the significance of the cumulative impact in the form of the barrier effect is insignificant. The analysis of energy costs for selected species reflects the true situation for all species that are the subject of the Investment's impact assessment (species representative of different ecological groups of birds were selected for the analysis).

Table 4.2. The estimated energy cost of the migration flight taking into account the barrier effect for selected bird species [Source: internal materials based on: Baak, 2019; Månson et al., 2022; MoveBank; Opioła et al., 2020]

Species	The distance to be covered during the migration [km]	The energy cost during the migration [kJ]	% by which the energy costs will be increased due to the occurrence of a cumulative barrier effect
Black guillemot *Cepphus grylle*	470	963	24.61%
Common crane *Grus grus*	3492	40,500	2.96%
Common scoter *Melanitta nigra*	3060	8180	3.18%
Eurasian curlew *Numenius arquata*	2572	5400	4.07%
Whooper swan *Cygnus cygnus*	3442	96,300	3.01%
Long-tailed duck *Clangula hyemalis*	3442	9620	2.70%
Greylag goose *Anser anser*	1300	14,400	8.33%
Eurasian wigeon *Mareca penelope*	3248	7080	2.97%
Common buzzard *Buteo buteo*	1213	3070	9.12%

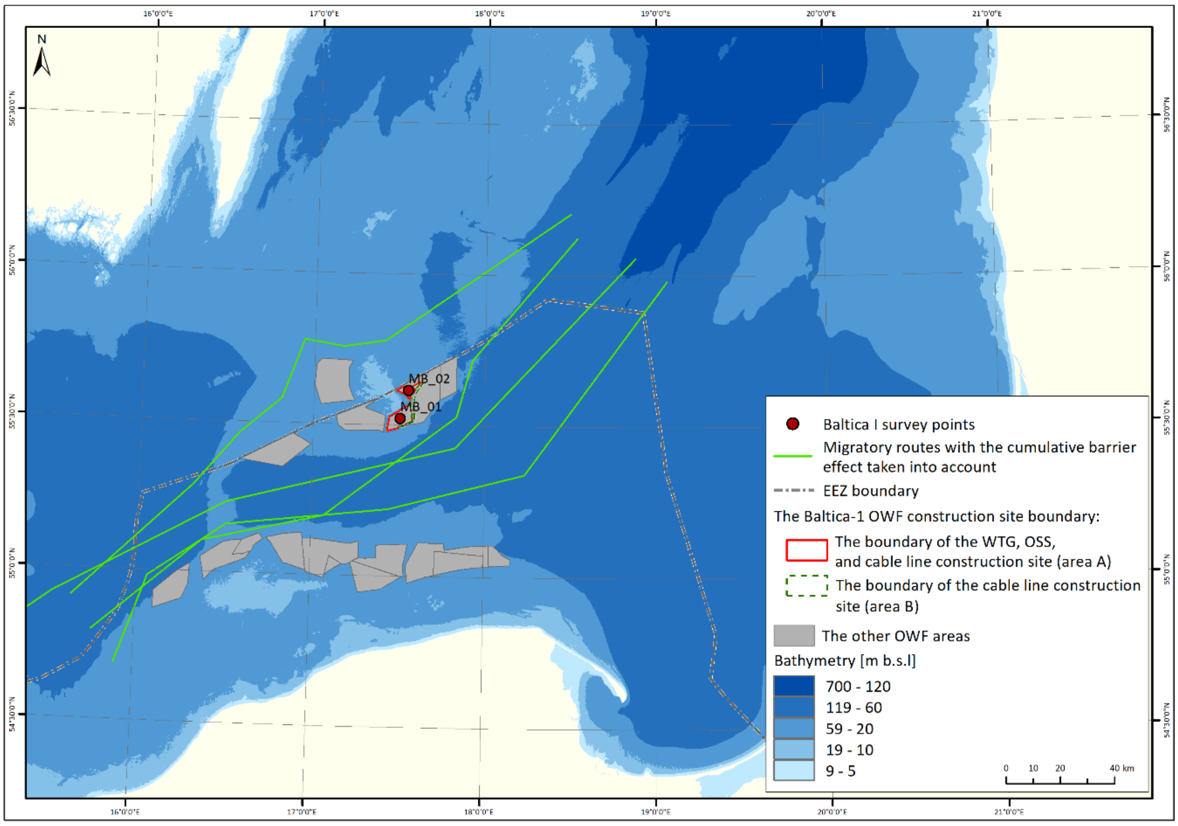

Figure 4.2. The theoretical flight routes of migrating birds taking into account the cumulative barrier effect

4.2 COLLISION RISK

The results of the collision risk modelling are presented below. The values shown in the tables are rounded off to the nearest whole number.

4.2.1 Long-tailed duck

Observations conducted as part of the surveys indicated that the long-tailed duck can be observed within the survey area of the Baltica-1 OWF in relatively high numbers, both in spring (8294 individuals) and in autumn (1595 individuals). Studies have shown that sea ducks are characterised by a high collision avoidance rate of 99.3% (Johnston et al., 2014) or higher, as in the surveys conducted by Garthe's team, where it was 99.9% (Alerstam et al., 2007). For both variants, a zero risk of collision in autumn and 0–2 collisions in spring were related to the lowest level of avoidance. For the level of avoidance of 99% and 99.5%, the risk of collision is zero for all variants. Despite the collisions estimated to be at zero level, infrequent collisions cannot be ruled out [Table 4.3]. The long-tailed duck is a species of great conservation value, and though its collision rates are negligible, the impact has been classified as one of low significance.

Table 4.3. The estimated number of collisions involving long-tailed ducks in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	2	0
98%	APV (calculation scenario 1.)	1	0

Avoidance level	Variant	Spring	Autumn
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	2	0
98%	APV (calculation scenario 2.)	1	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	2	0
98%	APV (calculation scenario 3.)	1	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	2	0
98%	RAV	1	0
99%	RAV	0	0
99.5%	RAV	0	0

4.2.2 Common scoter

The monitoring indicated that the common scoter was observed in high numbers within the survey area of the Baltica-1 OWF, especially in the spring (3015 specimens in total). In the autumn, it was observed much less frequently (789 individuals in total). Sea ducks were shown to have a high collision avoidance rate of 99.3% according to Poot et al. (2011) or even higher – 99.9% – in accordance with Smart Wind (2013). Assuming that the correct avoidance rate is 99.5%, the collision risk for both variants was estimated at 0–1 collision. Taking into account the high significance of the common scoter and negligible collision values, the significance of the impact was considered to be low [Table 4.4].

Table 4.4. The estimated number of collisions involving the common scoter in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	3	7
98%	APV (calculation scenario 1.)	1	3
99%	APV (calculation scenario 1.)	1	1
99.5%	APV (calculation scenario 1.)	0	1
95%	APV (calculation scenario 2.)	3	6
98%	APV (calculation scenario 2.)	1	2
99%	APV (calculation scenario 2.)	1	1
99.5%	APV (calculation scenario 2.)	0	1
95%	APV (calculation scenario 3.)	2	5
98%	APV (calculation scenario 3.)	1	2
99%	APV (calculation scenario 3.)	0	1
99.5%	APV (calculation scenario 3.)	0	1
95%	RAV	3	7

Avoidance level	Variant	Spring	Autumn
98%	RAV	1	3
99%	RAV	1	1
99.5%	RAV	0	1

4.2.3 Velvet scoter

The monitoring indicated that the velvet scoter can be observed within the survey area of the Baltica-1 OWF in numbers smaller than any other sea duck species, both in spring (175 individuals) and autumn (55 individuals). Sea ducks were shown to have a high collision avoidance rate of 99.3% according to Poot et al. (2011) or even higher – 99.9% – in accordance with Smart Wind (2013). The scenario with the collision avoidance rate at the level of 99.5% is the most correct and according to the collision risk modelling carried out for both variants, 0–1 birds will be involved in collisions (with 1 individual at an avoidance rate of 95%) [Table 4.5]. As with other sea ducks, single collisions cannot be excluded completely. The significance of the impact in the described variant was determined as negligible.

Table 4.5. The estimated number of collisions involving the velvet scoter in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	1	0
98%	APV (calculation scenario 1.)	0	0
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	1	0
98%	APV (calculation scenario 2.)	0	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	0	0
98%	APV (calculation scenario 3.)	0	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	1	0
98%	RAV	0	0
99%	RAV	0	0
99.5%	RAV	0	0

4.2.4 Common crane

With the assumed collision avoidance rate of 83% (Mortensen et al., 2020), the estimated risk of collisions in autumn indicates a number of collisions of 1–2. There is no variant, in which there are no collisions whatsoever.

Collisions cannot be excluded in the case of migrating cranes encountering severe weather conditions during their journey, such as limited visibility due to fog, darkness, or fierce winds. Bird migration is the most intensive when weather conditions are favourable, but sudden weather deteriorations or fog above the sea cannot be ruled out, as they are pretty frequent in the spring.

Considering the size of the biogeographic population (410,000 specimens [Garthe and Hüppop, 2004]), in the worst-case scenario with the highest number of collisions, the number of specimens involved will not exceed 0.001% of the biogeographic population. This is why the significance of the impact was assessed to be low [Table 4.6].

Table 4.6. The estimated number of collisions involving the common crane in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	1	0
98%	APV (calculation scenario 1.)	0	0
99%	APV (calculation scenario 1.)	0	0
83%	APV (calculation scenario 1.)	1	0
95%	APV (calculation scenario 2.)	1	0
98%	APV (calculation scenario 2.)	0	0
99%	APV (calculation scenario 2.)	0	0
83%	APV (calculation scenario 2.)	1	0
95%	APV (calculation scenario 3.)	1	0
98%	APV (calculation scenario 3.)	0	0
99%	APV (calculation scenario 3.)	0	0
83%	APV (calculation scenario 3.)	0	0
95%	RAV	1	0
98%	RAV	0	0
99%	RAV	0	0
83%	RAV	1	0

4.2.5 Little gull

The little gull is a species observed in relatively high numbers in the Baltica-1 OWF area, both in the spring (188) and autumn (108). A high collision avoidance index was demonstrated for seagulls: 98% according to Krijgsveld et al. (2011), above 99.9% according to Forewind (2013). The scenario with the collision avoidance index of 99% was considered the most appropriate, also taking into account the recommendations developed by Cook et al. (2014). The estimated number of birds that have collisions in this scenario is zero [Table 4.7].

The number of collisions is negligible in both seasons, however, due to the high importance of the species, the significance of the impact is low for all versions of the analysed variants.

Table 4.7. The estimated number of collisions involving the little gull in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	1	1
98%	APV (calculation scenario 1.)	0	0
99%	APV (calculation scenario 1.)	0	0

Avoidance level	Variant	Spring	Autumn
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	1	1
98%	APV (calculation scenario 2.)	0	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	1	1
98%	APV (calculation scenario 3.)	0	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	1	1
98%	RAV	0	0
99%	RAV	0	0
99.5%	RAV	0	0

4.2.6 Lesser black-backed gull

A high collision avoidance index was demonstrated for seagulls: 98% according to Krijgsveld et al. (2011), above 99.9% according to Forewind (2013). The scenario with a 99% collision avoidance index was considered the most appropriate, also considering recommendations prepared by Cook et al. (2014). The estimated number of birds that have collisions in this scenario equals 1 specimen during both seasons [Table 4.8]. Low collision rates account for less than 0.01% of the European population of lesser black-backed gull (1,200,000 individuals), and the significance of the impact is negligible for this species.

Table 4.8. The estimated number of collisions involving the lesser black-backed gull in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	5	4
98%	APV (calculation scenario 1.)	2	1
99%	APV (calculation scenario 1.)	1	1
99.5%	APV (calculation scenario 1.)	1	0
95%	APV (calculation scenario 2.)	5	3
98%	APV (calculation scenario 2.)	2	1
99%	APV (calculation scenario 2.)	1	1
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	4	3
98%	APV (calculation scenario 3.)	2	1
99%	APV (calculation scenario 3.)	1	1
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	5	4
98%	RAV	2	2

Avoidance level	Variant	Spring	Autumn
99%	RAV	1	1
99.5%	RAV	1	0

4.2.7 Eurasian wigeon

The results of surveys indicate that the species of dabbling ducks (such as the Eurasian wigeon, garganey, etc.) frequently fly across the Baltica-1 OWF area. The collision modelling indicates from 0 to 2 collisions per migration season depending on the avoidance rate.

Krijgsveld et al. (2011) pointed to a collision avoidance rate of 98.3% for ducks other than sea ducks; therefore, it was assumed that the scenario with the closest avoidance rate of 99% is the most appropriate. In that case, zero individuals will collide in spring and autumn [Table 4.9]. The numbers of collisions estimated for both variants are remarkably similar.

The estimated collision numbers are low and will involve less than 0.01% of the biogeographic population of these very numerous species (6,500,000 individuals [Krijgsveld et al., 2011]). Therefore, the significance of collisions as an impact is considered negligible.

Table 4.9. The estimated number of collisions involving the Eurasian wigeon in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	0	2
98%	APV (calculation scenario 1.)	0	1
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	0	2
98%	APV (calculation scenario 2.)	0	1
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	0	2
98%	APV (calculation scenario 3.)	0	1
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	1	2
98%	RAV	0	1
99%	RAV	0	0
99.5%	RAV	0	0

4.2.8 Eurasian curlew

The Eurasian curlew was the most frequently observed representative of the Charadriiformes order, but the observations of this species were still rather sparse (292 individuals in spring and none in autumn). With the 98% avoidance scenario applied, there will be one collision in spring. In the case of avoidance rates of 99% and 99.5%, there will be zero collisions [Table 4.10]. The significance of the impact was regarded as negligible for all versions of the analysed variants.

Table 4.10. The estimated number of collisions involving the Eurasian curlew in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	2	0
98%	APV (calculation scenario 1.)	1	0
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	2	0
98%	APV (calculation scenario 2.)	1	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	2	0
98%	APV (calculation scenario 3.)	1	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	2	0
98%	RAV	1	0
99%	RAV	0	0
99.5%	RAV	0	0

4.2.9 Waders

Collision modelling was performed also for all observed waders together. Waders are not too abundant migrants that cross the Baltica-1 OWF area. Waders usually migrate at large altitudes and are observed when they fly above the OWF (Krijgsveld et al., 2011; Krijgsveld, 2014). Therefore, it should be noted that the number of waders may be underestimated, because these birds migrate at high altitudes and mainly at night (Newton, 2010). Due to the flight altitude, the probability of collision is small. Referring to Krijgsveld et al. (2011), who determined that waders avoid collisions at the level of 98.3%, the scenario with 98% avoidance was considered to be the most fitting. In this scenario, the number of collisions equals up to 4 individuals in spring and 1 in autumn [Table 4.11].

Even if the estimated numbers of waders that fly at potential collision altitudes were doubled, they still would not exceed 0.01% of biogeographic populations of species such as the European golden plover, Eurasian curlew, and grey plover. The significance of the impact was regarded as negligible for all versions of the analysed variants.

Table 4.11. The estimated number of collisions involving waders in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	10	3
98%	APV (calculation scenario 1.)	4	1
99%	APV (calculation scenario 1.)	2	1
99.5%	APV (calculation scenario 1.)	1	0
95%	APV (calculation scenario 2.)	10	3
98%	APV (calculation scenario 2.)	4	1

Avoidance level	Variant	Spring	Autumn
99%	APV (calculation scenario 2.)	2	1
99.5%	APV (calculation scenario 2.)	1	0
95%	APV (calculation scenario 3.)	8	3
98%	APV (calculation scenario 3.)	3	1
99%	APV (calculation scenario 3.)	2	1
99.5%	APV (calculation scenario 3.)	1	0
95%	RAV	11	3
98%	RAV	4	1
99%	RAV	2	1
99.5%	RAV	1	0

4.2.10 Greater scaup

The greater scaup is a species observed in relatively high numbers in the Baltica-1 OWF area, in both the spring and the autumn. It was shown that sea ducks are characterised by a high collision avoidance index of 99.3% according to Krijgsveld et al. (2011), or even higher – 99.9% – in accordance with Smart Wind (2013). A scenario with the collision avoidance index at the level of 99.5% is the most appropriate and following the collision risk model used for this scenario, 0 individuals will have collisions in both the spring and the autumn [Table 4.12].

The estimated collision rate is negligible and accounts for less than 0.01% of the European population (12,000 individuals). The significance of the impact was regarded as negligible for all versions of the analysed variants.

Table 4.12. The estimated number of collisions involving the greater scaup in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	1	0
98%	APV (calculation scenario 1.)	0	0
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	1	0
98%	APV (calculation scenario 2.)	0	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	1	0
98%	APV (calculation scenario 3.)	0	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	1	0
98%	RAV	0	0
99%	RAV	0	0
99.5%	RAV	0	0

4.2.11 Common swift

Swifts were observed only in autumn (88 individuals). Similarly to other birds of comparable size, i.e. passerines, swifts migrate mainly at much higher altitudes, beyond the range of the rotor blades. Only in rare cases do they fly at lower altitudes, mainly in case of bad weather. Due to the very large biogeographic population of this species, which numbers almost 10 million individuals, and the collision rate at the level of 0–3 individuals in autumn [Table 4.13], the significance of the impact was considered negligible.

Table 4.13. The estimated number of collisions involving the common swift in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	0	3
98%	APV (calculation scenario 1.)	0	1
99%	APV (calculation scenario 1.)	0	1
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	0	3
98%	APV (calculation scenario 2.)	0	1
99%	APV (calculation scenario 2.)	0	1
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	0	2
98%	APV (calculation scenario 3.)	0	1
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	0	3
98%	RAV	0	1
99%	RAV	0	1
99.5%	RAV	0	0

4.2.12 Swans

Based on the flight stream patterns, more than 1,071 swans may fly through the Baltica-1 OWF area in spring and more than 469 in autumn. The estimated numbers of collisions amount to 0–4 collisions in spring and 0–2 in autumn, depending on the scenario (collision avoidance index). Krijgsveld et al. (2011) calculated that the avoidance index is 99.2%, and the scenario with the index of 99% was assumed in the present report, according to which no collision will take place in spring and 0–1 collision will take place in autumn [Table 4.14].

The significance of the impact was regarded as negligible for all versions of the analysed variants.

Table 4.14. The estimated number of collisions involving swans in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	4	2
98%	APV (calculation scenario 1.)	1	1
99%	APV (calculation scenario 1.)	1	0
99.5%	APV (calculation scenario 1.)	0	0

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 2.)	3	1
98%	APV (calculation scenario 2.)	1	1
99%	APV (calculation scenario 2.)	1	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	3	1
98%	APV (calculation scenario 3.)	1	0
99%	APV (calculation scenario 3.)	1	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	4	2
98%	RAV	2	1
99%	RAV	1	0
99.5%	RAV	0	0

4.2.13 Passerines

Data on passerines collected during the monitoring do not allow to specify the collision risk for individual species. Firstly, the observation of small birds flying at great altitudes is difficult, as such birds can be differentiated only to the level of 50 m a.s.l. At the same time, the vertical radar settings do not allow the reading and identification of species flying at the collision altitudes. Nevertheless, these data provide a general picture of the expected collisions of passerine birds. Most passerines migrate at night, as shown by acoustic data. The majority of them migrate at altitudes higher than 200 m; however, at night or in bad weather, they may be forced to fly at lower altitudes, which may increase the risk of collision. Considering the size of passerine populations flying across the Baltic Sea during their mass migrations in spring and autumn, it should be assumed that collisions of passerines will be far more numerous than those involving other groups of birds [Table 4.15]. However, given the natural mortality rate of passerines in the first year of life, such as that of the European robin, which reaches 60%, the mortality increased due to collisions should be accepted as an impact of negligible significance for the huge biogeographic populations of these species. Hence, the significance of the impact has been assessed as negligible.

Table 4.15. The estimated number of collisions involving passerines in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	38	54
98%	APV (calculation scenario 1.)	15	21
99%	APV (calculation scenario 1.)	8	11
99.5%	APV (calculation scenario 1.)	4	5
95%	APV (calculation scenario 2.)	35	49
98%	APV (calculation scenario 2.)	14	20
99%	APV (calculation scenario 2.)	7	10
99.5%	APV (calculation scenario 2.)	4	5
95%	APV (calculation scenario 3.)	31	43

Avoidance level	Variant	Spring	Autumn
98%	APV (calculation scenario 3.)	12	17
99%	APV (calculation scenario 3.)	6	9
99.5%	APV (calculation scenario 3.)	3	4
95%	RAV	40	56
98%	RAV	16	22
99%	RAV	8	11
99.5%	RAV	4	6

4.2.14 Geese

The number of collisions estimated for geese is moderate. Taking into account the size of the biogeographical population of the species included in this assessment, the birds that would be subject to collisions constitute less than 0.01% of the total population. Because of this, as well as due to the low significance of the species, the collision impact was considered negligible [Table 4.16].

Table 4.16. The estimated number of collisions involving geese in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	26	8
98%	APV (calculation scenario 1.)	10	3
99%	APV (calculation scenario 1.)	5	2
99.5%	APV (calculation scenario 1.)	3	1
95%	APV (calculation scenario 2.)	23	8
98%	APV (calculation scenario 2.)	9	3
99%	APV (calculation scenario 2.)	5	2
99.5%	APV (calculation scenario 2.)	2	1
95%	APV (calculation scenario 3.)	20	7
98%	APV (calculation scenario 3.)	8	3
99%	APV (calculation scenario 3.)	4	1
99.5%	APV (calculation scenario 3.)	2	1
95%	RAV	27	9
98%	RAV	11	4
99%	RAV	5	2
99.5%	RAV	3	1

4.2.15 Black-throated diver and red-throated diver

The pre-investment monitoring surveys have shown that divers appear in the Baltica-1 area more frequently in spring. The total number of individuals of both diver species recorded based on visual observations in the spring season was 157 and 13 individuals were recorded in the autumn season, with the black-throated diver being the more numerous species overall. Both species demonstrate a strong avoidance reaction, and according to Smart Wind (2013) and Krijgsveld et al. (2011), the avoidance rates for divers are 98%, which in relation to the estimated number of collisions gives a result of 0 collisions in spring and 0 in autumn [Table 4.17, Table 4.18]. Assuming the lowest avoidance rate of 95%, there may be one collision in spring and none in autumn in the case of the black-throated diver and 0 collisions in the case of the red-throated diver in both spring and autumn. The significance of the impact related to the collisions of divers is assessed as negligible for both species.

Table 4.17. The estimated number of collisions involving the black-throated diver in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	1	0
98%	APV (calculation scenario 1.)	0	0
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	1	0
98%	APV (calculation scenario 2.)	0	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	1	0
98%	APV (calculation scenario 3.)	0	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	1	0
98%	RAV	0	0
99%	RAV	0	0
99.5%	RAV	0	0

Table 4.18. The estimated number of collisions involving the red-throated diver in the Baltica-1 OWF area

Avoidance level	Variant	Spring	Autumn
95%	APV (calculation scenario 1.)	0	0
98%	APV (calculation scenario 1.)	0	0
99%	APV (calculation scenario 1.)	0	0
99.5%	APV (calculation scenario 1.)	0	0
95%	APV (calculation scenario 2.)	0	0
98%	APV (calculation scenario 2.)	0	0
99%	APV (calculation scenario 2.)	0	0
99.5%	APV (calculation scenario 2.)	0	0
95%	APV (calculation scenario 3.)	0	0
98%	APV (calculation scenario 3.)	0	0
99%	APV (calculation scenario 3.)	0	0
99.5%	APV (calculation scenario 3.)	0	0
95%	RAV	0	0
98%	RAV	0	0

Avoidance level	Variant	Spring	Autumn
99%	RAV	0	0
99.5%	RAV	0	0

In the case of the remaining groups and species (lark, wood pigeon, whooper swan, red-breasted merganser, common merganser, owls, Accipitriformes, skuas, and terns) for all avoidance levels, the risk of collision is zero individuals in spring and autumn, and therefore, the impact magnitude was considered insignificant. In the case of the black guillemot, no bird flights were observed within the range of the rotor blades, hence modelling the risk of collision for this species was impossible.

4.2.16 Auks

In the case of auks, including the black guillemot, based on visual observations, no flights were observed within the range of the rotor blades, hence the modelling of the risk of collision for this group of species proved impossible. A total of 12 black guillemots were observed in spring at station MB_01 and 20 individuals at station MB_02, while 2 individuals were recorded in autumn at station MB_01 and 1 individual at station MB_02. None of the observed black guillemots was flying at an altitude over 10 m a.s.l. The significance of the impact related to the collision in the case of the black guillemot is therefore assessed as negligible. This assessment was made using the expert method due to the lack of possibility to model the risk of collision and make an assessment based on the results obtained in this way.

4.2.17 Collision risk: cumulative impacts

To estimate the potential risk of collision, the OWF projects listed in the following table [Table 4.19] were taken into account. The selected projects are planned for implementation on the bird migration route through the Baltic Sea and may affect a total or partial change of the flight route for individual species. The selection of OWFs for the cumulative impact analysis took account of a wide range of the bird migration phenomenon with reference to the flight zones above the considered Baltica-1 OWF area and other OWF projects included in the analysis.

The values obtained in the collision risk modelling were extrapolated in relation to the capacities of individual projects expressed by the total value of the index [Table 4.19]. For the OWF areas: Bałtyk I, Bałtyk II, Bałtyk III, Baltic Power, Baltica 2, Baltica 3, BC-Wind, 44.E.1, FEW Baltic II, the data on the predicted mortality level (for given species/groups) included in the environmental documentation were used. For the remaining OWFs, the predicted mortality of individual species and groups of species was calculated based on the results of collision modelling conducted for the Baltica-1 OWF, taking into account the proportion of their installed or planned capacities. The next table [Table 4.20] presents the cumulative collision risk at an avoidance rate of 99% for all species and groups except for the common crane, for which the avoidance rate of 83% was used.

Table 4.19. The planned OWFs investigated in relation to the cumulative impacts of the Baltica-1 OWF

No.	OWF name	Authority	The number of WTGs (max.)	OWF maximum capacity [MW]	Area [km^2]	How it was included in the analysis	Indicator
1.	Bornholm Bassin Syd	DK	129	1500	481.5	Based on the indicator	1.67

No.	OWF name	Authority	The number of WTGs (max.)	OWF maximum capacity [MW]	Area [km²]	How it was included in the analysis	Indicator
2.	FEW Baltic II	PL	25	440	39.65	Based on the EIA Report	N/A
3.	Bałtyk II	PL	60	1200	122	Based on the EIA Report	N/A
4.	Baltica (Baltica 2 & Baltica 3)	PL	209	2550	270	Based on the EIA Report	N/A
5.	Bałtyk III	PL	60	1200	117	Based on the EIA Report	N/A
6.	Baltic Power	PL	76	1200	131	Based on the EIA Report	N/A
7.	BC-Wind	PL	41	500	86	Based on the EIA Report	N/A
8.	Bornholm Bassin Ost	DK	85	1500	325.49	Based on the indicator	1.67
9.	Baltic Edge	SE	67	1000	233	Based on the indicator	1.11
10.	Baltic Offshore Beta, Neptunus, Cirrus	SE	N/D	3420	814.34	Based on the indicator; the capacity was determined by calculating the total surface area of the OWFs and power density for Baltic Offshore Beta	3.80
11.	Sodra Victoria	SE	120	2000	190.87	Based on the indicator	2.22
12.	Bałtyk I	PL	104	1560	129	Based on the EIA Report	N/A
13.	Baltica 1	PL	60	900	86	The authors' calculations	N/A
14.	Njord	SE	89	1300	244.88	Based on the indicator	1.44
15.	14.E.1 (Energa OWF 1)	PL	N/D	812	82.44	Based on the indicator	0.90
16.	14.E.2 (Energa OWF 2)	PL	N/D	896	91.18	Based on the indicator	1.00
17.	14.E.3 (Orlen Neptun)	PL	N/D	1204	125.89	Based on the indicator	1.34
18.	14.E.4 (Orlen Neptun)	PL	N/D	1204	147.69	Based on the indicator	1.34
19.	43.E.1	PL	113	1694.2	118	Based on the indicator	1.88
20.	44.E.1	PL	95	1832	121	Based on the EIA Report	N/A
21.	46.E.1 (Orlen Neptun)	PL	N/D	966	116.63	Based on the indicator	1.07
22.	60.E.3 (Baltica 1+)	PL	N/D	1185	139.7	Based on the indicator	1.32

No.	OWF name	Authority	The number of WTGs (max.)	OWF maximum capacity [MW]	Area [km^2]	How it was included in the analysis	Indicator
23.	60.E.4 (Baltica 5)	PL	N/D	555	73.63	Based on the indicator	0.62
24.	Baltica 2+	PL	N/D	210	16.6	Based on the indicator	0.23
25.	Öland-Hoburg II	SE	50	750	518.07	Based on the indicator	0.83
26.	Blekinge	SE	73	1000	170.41	Based on the indicator	1.11
27.	Kriegers Flak	DE	72	604.8	203.98	Based on the indicator	0.67
28.	Kriegers Flak 2	SE	50	640	62.07	Based on the indicator	0.71
29.	Kriegers Flak 2 – Nord	DK	35	500	97.25	Based on the indicator	0.56
30.	Kriegers Flak 2 – Syd	DE	35	500	75.37	Based on the indicator	0.56
31.	Bornholm I	DK	104	1500	247.9	Based on the indicator	1.67
32.	Bornholm II	DK	104	1500	269.32	Based on the indicator	1.67
33.	Aflandshage	DK	26	286	42.77	Based on the indicator	0.32
34.	Nordre Flint	DE	15	160	17.32	Based on the indicator	0.18
35.	Kadet Banke	DE	72	864	76.37	Based on the indicator	0.96
36.	Arkona (Germany)	DE	60	384	37.22	Based on the indicator	0.43
37.	Wikinger	DE	70	350	33.51	Based on the indicator	0.39
38.	Windanker (O-1.3)	DE	20	300	17.88	Based on the indicator	0.33
39.	O 2.2	DE	69	1000	23.13	Based on the indicator	1.11
40.	Baltic Eagle	DE	50	475	50.75	Based on the indicator	0.53
41.	Arcadis Ost 1	DE	27	256.5	47	Based on the indicator	0.29
42.	Arkona (Sweden)	SE	70	1200	198	Based on the indicator	1.33
43.	Skane	SE	110	1500	499.27	Based on the indicator	1.67
44.	Triton	SE	129	1800	167.62	Based on the indicator	2.00
45.	Sydkustens Vind (Kustvind)	SE	37	500	61.08	Based on the indicator	0.56
46.	Baltic 1	DE	21	48.3	6.61	Based on the indicator	0.05

No.	OWF name	Authority	The number of WTGs (max.)	OWF maximum capacity [MW]	Area [km^2]	How it was included in the analysis	Indicator
47.	Baltic 2	DE	80	288	30.87	Based on the indicator	0.32
48.	Sjollen	SE	23	300	23.37	Based on the indicator	0.33
49.	Lillgrund	SE	48	110.4	6.96	Based on the indicator	0.12
Aggregate indicator						**40.29**	

Table 4.20. The cumulative impacts as the overall collision risk

Species/ group of species	Collision avoidance level	Variant	Cumulative collision risk in spring	Cumulative collision risk in autumn
Greater scaup	99%	APV (calculation scenario 1.)	7	2
		APV (calculation scenario 2.)	7	2
		APV (calculation scenario 3.)	6	1
		RAV	8	2
Long-tailed duck	99%	APV (calculation scenario 1.)	24	10
		APV (calculation scenario 2.)	22	10
		APV (calculation scenario 3.)	20	9
		RAV	25	10
Loons	99%	APV (calculation scenario 1.)	39	20
		APV (calculation scenario 2.)	37	20
		APV (calculation scenario 3.)	34	19
		RAV	40	20
Geese	99%	APV (calculation scenario 1.)	337	193
		APV (calculation scenario 2.)	317	186
		APV (calculation scenario 3.)	290	178
		RAV	347	196
Common crane	83%	APV (calculation scenario 1.)	176	163
		APV (calculation scenario 2.)	173	162
		APV (calculation scenario 3.)	170	160
		RAV	177	163
Little gull	99%	APV (calculation scenario 1.)	40	39
		APV (calculation scenario 2.)	39	39
		APV (calculation scenario 3.)	39	38
		RAV	41	40
Lesser black-backed gull	99%	APV (calculation scenario 1.)	82	70
		APV (calculation scenario 2.)	78	67
		APV (calculation scenario 3.)	73	63
		RAV	84	71
Eurasian wigeon	99%	APV (calculation scenario 1.)	15	30

Species/ group of species	Collision avoidance level	Variant	Cumulative collision risk in spring	Cumulative collision risk in autumn
		APV (calculation scenario 2.)	14	28
		APV (calculation scenario 3.)	14	26
		RAV	15	31
Velvet scoter	99%	APV (calculation scenario 1.)	11	9
		APV (calculation scenario 2.)	10	9
		APV (calculation scenario 3.)	10	8
		RAV	11	9
Common scoter	99%	APV (calculation scenario 1.)	67	95
		APV (calculation scenario 2.)	64	90
		APV (calculation scenario 3.)	61	84
		RAV	68	98
Passerines	99%	APV (calculation scenario 1.)	495	621
		APV (calculation scenario 2.)	468	584
		APV (calculation scenario 3.)	435	537
		RAV	510	641
Swans	99%	APV (calculation scenario 1.)	35	18
		APV (calculation scenario 2.)	31	16
		APV (calculation scenario 3.)	27	14
		RAV	36	18
Common swift	99%	APV (calculation scenario 1.)	73	98
		APV (calculation scenario 2.)	73	96
		APV (calculation scenario 3.)	73	93
		RAV	73	100
Waders	99%	APV (calculation scenario 1.)	16	41
		APV (calculation scenario 2.)	16	38
		APV (calculation scenario 3.)	16	35
		RAV	16	42

It should be noted that the spatial dispersion of these projects is exceedingly high, and it is unlikely that the same streams of birds migrating through the Baltic Sea will be the receptor of impacts from all OWFs included in the decision RDOŚ-Gd-WOO.420.59.2023.AM.13 issued for Baltica-1. The most likely cumulative impacts concern rather several OWFs in the immediate vicinity of the Baltica-1 OWF, such as Bałtyk I, Sodra Victoria, Njord, Oland-Hoburg I, and Baltic Edge, which would make the estimated cumulative risk of collision considerably lower. Nevertheless, even assuming the worst-case scenario, the significance of the impact for most birds still remains negligible and low, except for cranes and geese, for which the significance of the impact is moderate. In the case of species for which the modelling results indicated a collision risk of 0 individuals for the Baltica-1 OWF alone, the estimated cumulative collision risk will be, in each variant, the resultant of the total predicted mortality for the OWFs included in the analysis, data on which are available in the environmental documentation (lark

– n.d., wood pigeon – 4, whooper swan – n.d., red-breasted merganser – n.d., common merganser – n.d., owls – 1, Accipitriformes – 1, skuas – 0, terns – 11).

The calculated level of potential biological removal (PBR) for the long-tailed duck is 4782 individuals [Table 3.3] and it is higher than the predicted mortality associated with collisions obtained in the modelling conducted for the farm [Table 4.3] and for the cumulative effect [Table 4.20]. In relation to the dominant goose species in the study (white-fronted goose, greylag goose), the PBR value is respectively: 34,368 for the white-fronted goose and 79,914 for the greylag goose [Table 3.3] and it is higher than the predicted mortality obtained in the modelling for geese as a group, both for the farm [Table 4.16] and the cumulative impact [Table 4.20]. The calculated PBR limit value for the common crane is 27,863 [Table 3.3] and it is higher than the mortality predicted in the analysis for the farm [Table 4.6] and in the case of cumulative impact [Table 4.20]. The obtained PBR values were not related to the predicted mortality level for the black guillemot and eider due to the too-low numbers recorded in the survey, flights at non-collision altitudes, and the lack of possibility and need to conduct collision risk modelling for these species.

5 THE SUMMARY OF THE RESULTS AND CONCLUSIONS

Birds migrating across the Southern Baltic Sea may collide with wind power station elements (a tower and rotor parts) if they do not notice these obstacles in time, for example, in conditions of limited visibility due to weather conditions or at night. The risk of collision and habitat loss are considered to be potentially the greatest impacts of an OWF on birds since the impacts are generally permanent and continue throughout the OWF operation while the mitigation measures for these impacts are limited. Collision risk may be considered as the opposite of the barrier effect with an increasing risk of a collision when the barrier effect is less pronounced. The behavioural aspects important in the collision risk assessment include the flight altitude, flight speed, and the OWF avoidance rate (Alerstam et al., 2007; Dansk Ornitologisk Forening; Fijn et al., 2015). The flight altitude may depend on the direction and speed of wind, visibility, or precipitation; thus, the risk of collision will be probable only when a bird flies at the level of an operating rotor. The flight speed affects the collision risk. At a higher flight speed, a bird has a better chance of avoiding a collision when flying at the level of an operating rotor. The OWF avoidance can be divided into “macro” avoidance (avoiding the entire OWF as a whole), “meso” avoidance (avoiding a single wind power station), and “micro” avoidance (avoiding collision with rotor elements). Impacts in the form of collision risk and barrier effect on birds migrating in the area of the Baltica-1 OWF were determined to be negligible, and of low significance, and in the case of geese and cranes (collision risk in cumulative impacts), they were assessed as moderate. Considering the large dispersion of OWF projects included in the cumulative impact analysis, it should be noted that the same birds flying through and near the Baltica-1 OWF cannot encounter all of them. The flight takes place mainly from the north-east towards the south-west during autumn migrations and in the opposite direction during spring migrations. Some of these projects are located 200 km west of the Baltica-1 OWF, which means that birds flying through the Baltica-1 OWF area would have to change the direction of migration completely and cover the Baltic Sea area in the east-west axis, which would be inefficient in terms of energy costs. Extending the time of flight over the open waters of the Baltic Sea more than doubles the energy expenditure.

The collision risk considered both in the variant chosen by the Applicant and in the alternative variant was considered negligible and of little importance. Only in the case of groups of birds in which many species were analysed collectively at the same time did the collision rate values increase to over 50 individuals per season (as in the case of passerines). It should be noted that in the case of species groups migrating as abundantly as passerines or geese, we are dealing with huge populations (the population of the robin alone is estimated at over 100 million individuals). Therefore, the percentage of birds flying at collision levels and potentially colliding does not even constitute 0.01% of the population and taking into account the annual natural mortality of juveniles reaching 60%, the additional, very low mortality caused by collisions will not affect the population status in any way. Moreover, it should be noted that consideration is given only to the individuals noticed by observers up to the level of 100–150 m above sea level. The vast majority of migrating birds cover the route at altitudes above the top of the turbines, and they only fly lower, as already mentioned, when visibility is limited or there is precipitation. However, it should be emphasised that the calculation scenarios for the APV fully illustrate the worst-case impact of this variant for the envelope resulting from the proposed parameters – clearance, maximum total blade rotation zone and rotor diameter range.

In the case of the barrier effect, the additional distance of 21 km, or even 128 km as in the case of the cumulative barrier effect, does not significantly increase the energy expenditure associated with the flight from the wintering grounds to the nesting grounds, because many other natural factors constantly affect the course of migration. These are mainly weather-related factors, but it may be also affected by local phenomena such as fog or even getting scared away by predators.

Table 5.1. The importance, resistance, and sensitivity of species and species groups included in the analysis of collision risk and barrier effect

No.	Species/group of species	Latin name	Value/significance of the receptor	Disturbance resistance (barrier effect)	The receptor's sensitivity (barrier effect)	Disturbance resistance (collision risk)	The receptor's sensitivity (collision risk)
1.	Greylag goose	*Anser anser*	Low	High	**Insignificant**	Moderate	**Low**
2.	Greater white-fronted goose	*Anser albifrons*	Low	High	**Insignificant**	Moderate	**Low**
3.	Common wood pigeon	*Columba palumbus*	Low	High	**Insignificant**	High	**Insignificant**
4.	Common swift	*Apus apus*	Low	High	**Insignificant**	High	**Insignificant**
5.	Eurasian curlew	*Numenius arquata*	Low	Moderate	**Low**	Moderate	**Low**
6.	Whooper swan	*Cygnus cygnus*	Low	High	**Insignificant**	High	**Insignificant**
7.	Long-tailed duck	*Clangula hyemalis*	High	High	**Low**	High	**Low**
8.	Common scoter	*Melanitta nigra*	Moderate	High	**Low**	High	**Low**
9.	Little gull	*Hydrocoloeus minutus*	Moderate	Moderate	**Low**	Moderate	**Low**
10.	Lesser black-backed gull	*Larus fuscus*	Low	Moderate	**Low**	High	**Insignificant**
11.	Black-throated diver	*Gavia arctica*	Low	High	**Insignificant**	High	**Insignificant**
12.	Common merganser	*Mergus merganser*	-	High	**Insignificant**	High	**Insignificant**
13.	Greater scaup	*Aythya marila*	Low	High	**Insignificant**	High	**Insignificant**
14.	Eurasian skylark	*Alauda arvensis*	Low	High	**Insignificant**	High	**Insignificant**
15.	Eurasian wigeon	*Mareca penelope*	Low	High	**Insignificant**	High	**Insignificant**
16.	Red-breasted merganser	*Mergus serrator*	-	High	**Insignificant**	High	**Insignificant**
17.	Velvet scoter	*Melanitta fusca*	High	High	**Insignificant**	High	**Insignificant**

No.	**Species/group of species**	**Latin name**	**Value/significance of the receptor**	**Disturbance resistance (barrier effect)**	**The receptor's sensitivity (barrier effect)**	**Disturbance resistance (collision risk)**	**The receptor's sensitivity (collision risk)**
18.	Common crane	*Grus grus*	High	Moderate	**Moderate**	Moderate	**Moderate**
19.	Auks (razorbill, common guillemot, black guillemot)	*Alcidae (Alca torda, Uria aalge, Cepphus grylle)*	Low	High	**Insignificant**	High	**Insignificant**
20.	Accipitriformes (common buzzard)	*Buteo buteo*	Moderate	Moderate	**Moderate**	Moderate	**Moderate**
21.	Geese (greylag goose)	*Anser anser*	Low	Moderate	**Low**	Moderate	**Low**
22.	Swans (whooper swan)	*Cygnus cygnus*	Low	High	**Insignificant**	High	**Insignificant**
23.	Divers (common diver)	*Gavia arctica*	Low	High	**Insignificant**	High	**Insignificant**
24.	Terns (Arctic tern)	*Sterna paradisaea*	Low	High	**Insignificant**	High	**Insignificant**
25.	Charadriiformes (northern lapwing)	*Vanellus vanellus*	Low	Moderate	**Low**	Moderate	**Low**
26.	Owls (long-eared owl)	*Asio otus*	Low	Moderate	**Low**	Moderate	**Low**
27.	Passerines (song thrush)	*Turdus philomelos*	Low	High	**Insignificant**	High	**Insignificant**
28.	Skuas (Pomarine skua)	*Stercorarius pomarinus*	Low	High	**Insignificant**	High	**Insignificant**

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