Integrated study on the impact of the Väike Väin double-circuit 110 kV transmission line on birds

Final report

Vers 1.2.

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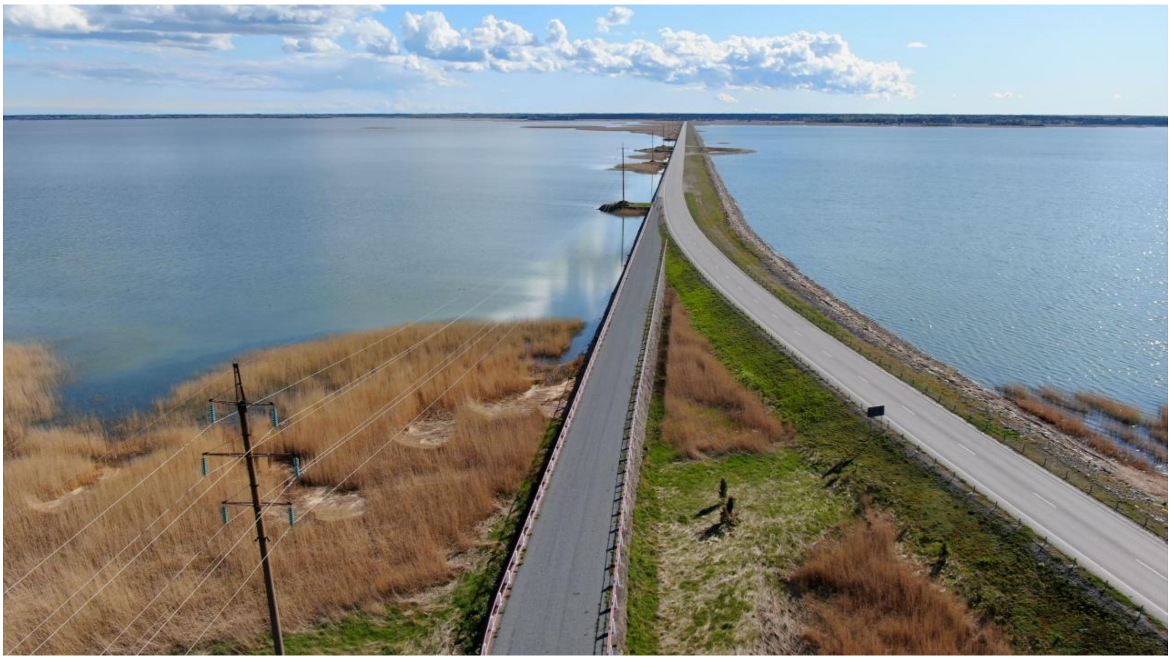

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Introduction

TSO Elering is operating double-circuit 110 kV overhead power line, located next to the Strait Väike Väin dam connecting Muhu and Saaremaa. Power line was reconstructed in September and October 2020 as the function of one 110kV circuit was replaced by submarine cable constructed in 2019. To obtain quantitative data on the impact of the Väike Väin power line on birds and the possibilities to mitigate the negative effects, a study "The impact of power lines on nesting, staging and migrating birds, especially waterfowl – integrated study and recommendations for mitigation" was launched in 2019. Based on the study, recommendations for the possible mitigation and elimination of the negative effects of the power line should be compiled. The terms of reference for the study can be found in Annex 1.

To quantify the impact of power line different methods are used. Field study comprised several modules as follows:

1. Radar study with visual counts and night-time audio study;
2. Searching for collision victims and estimating the mortality;
3. Survey with cameras;
4. Counting of birds staging on wetland in vicinity of the power line;
5. Data analysis, compiling the final report and recommendations to mitigate the impact of the power line.

Progress report summarising field effort and preliminary result of the study was compiled in December 2019 (Volke, Kuus, Luigujõe, 2019). Recommendations to mitigate the impact of the power line – proper positioning of remaining wires, choice between variety of available wire markers to reduce the mortality of waterbirds, and scheme for marking in time of rebuilding – were compiled as a separate report in 2019 (Volke, Kuus, 2019).

This final report begins with an overview of the bird conservation value of the Väike Väin Strait. The methods used in the study are then described. The results section covers the work carried out throughout the investigation period and includes conclusions on the impact of the Väike Väin Strait power line on birds. Further actions are also proposed.

The authors of the report are grateful to the Estonian University of Life Sciences for the possibility of using surveillance radar, training and organizing radar transport, Beta Group OÜ and Omar Neiland for skillful installation and technical support of camera stations, the Road Administration for fast permit procedures and the use of weather station data, Heiki Hanso for logistic assistance on the fieldwork, DVM Madis Leivits from the Estonian University of Life Sciences for providing bird carcasses for scavenger and searcher efficiency test. We thank everyone involved in the field and office for their contribution - Andres Kalamees, Liis Keerberg, Mati Martinson, Rein Nellis, Uku Paal, Agne Peetersoo, Maris Sepp, Karl Jakob Toplaan, Ainar Unus, Martin Vesberg, Uku Volke, Ulla Volke, Kaarel Võhandu.

1. Väike Väin Strait as an IBA and SPA of the Natura 2000 network

The Väike Väin Strait is a unique wetland complex with the diversity of coastal and aquatic habitats including coastal meadows, redbeds, mudflats and islands. The various habitats of the Strait have their specific significance for breeding and migrating birds.

The first comprehensive overview of the birds of the Väike Väin was compiled on the basis of fieldwork carried out in 1994 and 1995 (Kuresoo, Ader, Luigujõe, 1995). The study area covered about 250 km^2, extending from Kõinastu in the north to the Islet Võilaid on the south coast of Muhu and the Kübassaare islets on the coast of Saaremaa. The study registered 153 bird species, including 111 species of breeding birds. The seven species that stopped in the area exceeded the criterion of being designated as a Wetland of International Importance, or Ramsar Site, for at least one season (at least 1% of the species' biogeographical population is present). In 1998, the coastal meadows important for birds were studied in more detail and conservation measures were recommended (Kuresoo & Luigujõe, 1998).

According to the first summary of Important Bird Areas (IBA) (Kalamees, 2000; Skov, 2000) (Kalamees, 2000; Skov, 2000), the Väike Väin Strait was defined as a separate area meeting four different criteria for recognition as a site of international importance (Table 1).

Eight waterfowl species met at least one of the criteria according to the number of non-breeding congregations, and four more species based on the number of breeding pairs. In addition, the site is known to regularly hold at least 20,000 migratory waterbirds, a separate threshold for designation as an Important Bird Area. In 2004, Estonia joined the European Union and data on IBA-s were submitted to the European Commission for inclusion in the Natura 2000 network. Already in the preparatory work (Kuus & Kalamees, 2003) it had been concluded that the entire Väinameri region is very important for nature conservation and it is reasonable to consider it as a large integrated area. Thus, the Väike Väin Strait has been part of the Natura 2000 network as part of the Väinameri SPA and SCI since 2004. A Väike Väin Limited Conservation Area has been established to ensure national protection.

The most comprehensive censuses in the Väinameri SPA, including the Väike Väin Strait, were conducted in 2017, when the fieldwork of the Natura 2000 monitoring project took place (Eesti Ornitoloogiaühing, 2017). Both breeding birds and non-breeding congregations of waterbirds during spring and autumn migration were counted. The census results obtained from the sectors adjacent to the dam and power line are summarized in the last two columns of Table 1.

Table 1. Conservation status of the qualifying species of the Väike Väin IBA and corresponding numbers on 1990s (Kalamees, 2000; Skov et al., 2000), and numbers based on the 2017 census.

Season: P – staging during migration or moulting; B – breeding; number i – individuals, p pairs; cells with blue shading – remarkably high counts from limited area close to the dam in 2017; cells with gray shading – breeders, out of the scope of the present study.

Liik	Pro-tection category	Season	Number (i, p) Min 2000	Number (i, p) Max 2000	Kriteerium	Number (i) Max 2017** spring	Number (i) Max 2017** autumn
Migratory waterbirds total		P		> 20 000	A4iv	7054	17 240
Tundra Swan (Cygnus columbianus)	II	P	500	<3000	A4i, B1i	2255	0
Whooper Swan (Cygnus cygnus)	II	P	<400	<3000	A4i, B1i	204	68
Greylag Goose (Anser anser)		P	400	3500	B1i	62	703
Barnacle Goose (Branta leucopsis)*	III	P	>10 000	>20 000	A4i, B1i	140	1004
Eurasian Wigeon (Anas penelope)		P	>4000	<14 000	B1i	60	6040
Northern Pintail (Anas acuta)		P	1000	>2000	B1i	8	3
Long-tailed Duck (Clangula hyemalis)		P	<20 000	>50 000	B1i	0	0
Goldeneye (Bucephala clangula)		P	<3000	4800	A4i, B1i	583	110
Baltic Dunlin (Calidris alpina schinzii)	I	B		>75 p	B2		
Common Redshank (Tringa totanus)	III	B		<230 p	B2		
Mew Gull (Larus canus)		B		700 p	B2		
Sandwitch Tern (Thalasseus sandvicensis)	II	B		<200 p	B2		

* Barnacle Goose numbers follow Skov et al. (2000);

** only sectors adjacent to the dam and power line.

2. Methods

The fieldwork for the study of the impact of power line took place in November 2019 (Volke, Kuus, Luigujõe 2019) and from March to October 2020 in six-day cycles once a month. The censuses were not carried out during the winter months, because in winter the Väike Väin Strait is usually covered with ice and is not important as a habitat for waterfowl. Working with radar on a state-owned land required a number of permit procedures involving the Consumer Protection and Technical Surveillance Authority, the Health Board and the Road Administration.

Different methods were used to measure the impact of the power line on birds:

1. radar study;
2. visual counts of birds flying near and/or over the power line;
3. monitoring with cameras;
4. night time audio monitoring;
5. ground searches for collision victims;
6. counts of staging birds.

2.1. Radar study

The purpose of the radar survey was to record the flight paths of birds and to measure the flight altitude. The radar survey methodology is based on the previous study with the same type of radar (Kahlert et al., 2012; Leito, 2009).

The study used the Furuno FAR2127BB 2D marine surveillance radar belonging to the Estonian University of Life Sciences. The most important radar parameters are as follows

type: X-ray;
radio frequency: 9410 ± 30 MHz;
pulse: adjustable;
output power: 25 kW;
horizontal beam width: 0.95 degrees;
vertical beam width: 20 degrees.

Portable radar is mounted on a specially adapted trailer. During the survey, the radar was located at the Muhu side of the Väike Väin dam; point coordinates 58° 34.200’ N 23° 10.010’ E (Figure 1).

To meet the objectives of the radar survey, the radar operated alternately in a horizontal and vertical position (Figure 2). Horizontal radar allows to record the flight paths of birds or flocks of birds, vertical radar enables to measure the flight altitudes of birds. The working position of the radar was changed on average once a day. The radar operating radius was usually set on 3 km. The radar operated 24 hours per day, but in some cases the number of working hours was less for meteorological or technical reasons. In April 2020, for technical reasons, it was only possible to make observations in the vertical position of the radar. The actual number of operating hours in the horizontal and vertical positions by counting periods is presented in Table 2.

Table 2. Operating hours of the radar study.

Fieldwork period	Dates	No. of operating hours	
		Horisontal position	Vertical position
November 2019	8.11-13.11	45,3	28,4
March 2020	13.03-19.03	43,0	65,5
April 2020	18.04-24.04		121,0
May 2020	18.05-24.05	71,2	63,9
June 2020	9.06-15.06	70,3	47,0
July 2020	9.07-15.07	66,5	62,0
August 2020	11.08-17.08	70,9	63,9
September 2020	10.09-16.09	64,8	52,4
October 2020	6.10-13.10	65,5	82,6

Figure 1. Study layout: locations of the radar, camera stations and audio recording.

The computer sofware SeaSimul, MaxSea TimeZero Professional v.2 and ScreenHunter 5.1 Pro were used to configure the radar, display the radar data on a computer screen and process it.

Figure 2. Radar in horizontal and vertical position. Visual count.

In November 2019, different options were tested to record the flight paths of birds. Semi-automatic recording of radar signals as *tracks*, as originally planned, did not produce the desired results for technical reasons (frequent cursor jumping from track to track or to stationary objects). Manual capturing of flight paths as *routes* based on the tracks displayed on the screen proved to be more functional. Manual capturing of flight tracks did not always allow to fix absolutely all contacts. Flight altitude data were recorded in an Excel table.

Radar does not detect bird species. The identification of the bird species was originally planned by combining radar and visual survey data, but this work was abandoned due to the labor-intensity and radar operator was focused on capturing as many flight paths as possible.

The detectability of birds is significantly affected by precipitation, which can cover the radar screen with noise (Figure 3) and make it impossible to distinguish the flight paths of birds. Such periods were recorded and subtracted from the actual radar operating time.

The radar was operated by Andrus Kuus, Veljo Volke, Uku Volke and Ulla Volke.

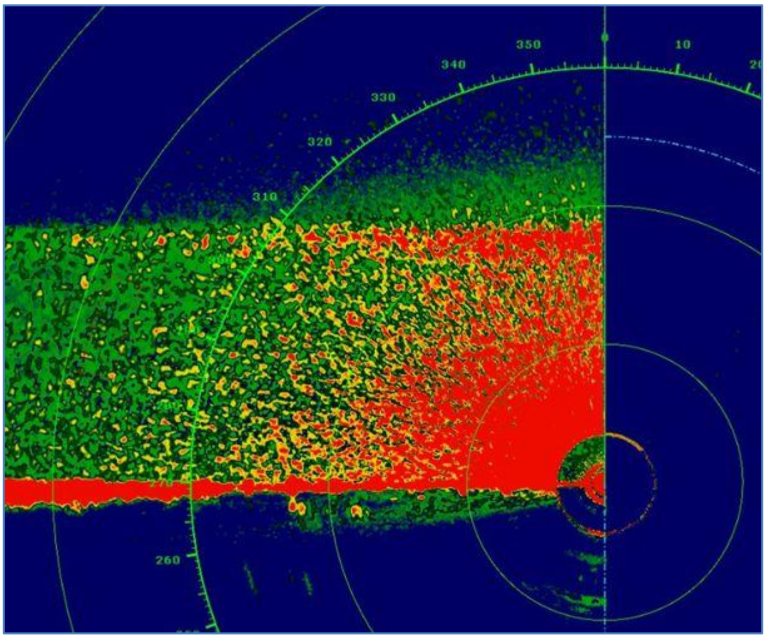


Figure 3. Rain on the radar screen. Radar in vertical position adjusted to measure flight altitudes in upper left sector.

Data anlysis

Depending on the technical possibilities, the horizontal radar tracks were saved in packages of about 50 tracks, each in three different files: filename.txt (track date and time data), filename_rte.csv (track point numbers) and filename_twp.csv (point coordinates). Software R 3.6.3 and ArcMap 10.5 were used to process and visualize the horizontal radar data. Due to the large number of source files, a special computer program was created to compile the files and convert the data to the format used in a standard GIS program.

The density of tracks captured with horizontal radar was determined using the ArcMap tool "Line Density". The resulting track density map shows the density in pixels with the size of 1 hectar (100 x 100m). ArcMap's Linear Directional Mean tool was used to analyze flight directions. The resulting mean flight directions were later grouped in 45° increments.

With vertically operating radar, the direction and distance of the bird/flock were recorded in an Excel table. Heights were found using a trigonometry formula

$$\text{height} = \sin(\text{heading angle}) \times \text{distance}.$$

2.2. Visual observations

The aim of the visual observations was to record the species composition, numbers, flight altitude and behavioural response of birds crossing the power line and flying in its immediate vicinity in daytime. Compared to the radar survey, the results are more accurate (it is possible to determine the species and number of birds), but the possibilities of using visual observations are more limited in time and space. Visual observations were made from the radar location.

Vectronix Vector laser range finder was used for visual observations to measure altitude (and distance). The height was measured at the moment the bird crossed the power line. If the height measurement with laser binoculars was not successful, it was estimated visually.

The following parameters were recorded during the visual observations: date, time, bird species, number of individuals, behaviour, line crossing details, flight height, distance, height and distance measurement method (laser binocular or visually) and observer.

The behavioral response of birds to the power line was classified as follows:

1. No response, no altitude nor heading adjustment;
2. Timely adjustment of altitude;
3. Abrupt change in altitude adjacent to the power line;
4. The individual/flock avoids crossing by changing the flight direction;
5. Flight parallel to the power line;
6. Landing on a tower or wire;
7. Collision, but bird continues to fly;
8. Collision, the bird falls or lands on water or on the ground.

Considering the main objectives of the study, the field "power line" was added to the visual observation database, where the crossing of the power line by birds in relation to the wires was recorded as follows:

1. individual/flock crosses the power line over the upper earth (ground) wire;
2. individual/flock crosses between the wires;
    21 - between the earth wire and the upper conductors;
    22 - between conductors;
3. individual/flock crosses below conductors.

Visual observations took place daytime, usually from sunrise to sunset. In some cases the visual observations were hindered by inclement weather (heavy rain, fog). The number of observation hours is presented in Table 3. Due to the frequent flights of nesting gulls and terns across the line, some species (Black-headed Gull, terns and crows) were recorded for only 10 minutes at the beginning of each counting hour between 9 AM 22nd of April to 15th of July.

Table 3. Field effort during visual observations.

Fieldwork period	Dates	No. of observation hours
November 2019	8.11-13.11	43
March 2020	13.03-19.03	65,5
April 2020	18.04-24.04	84
May 2020	18.05-24.05	100
June 2020	9.06-15.06	95,5
July 2020	9.07-15.07	94
August 2020	11.08-17.08	84
September 2020	10.09-16.09	74,5
October 2020	6.10-13.10	70

Visual observations were conducted by Andres Kalamees, Liis Keerberg, Mati Martinson, Rein Nellis, Uku Paal, Agne Peetersoo, Maris Sepp, Karl Jakob Toplaan, Ainar Unus, Martin Vesberg, Uku Volke, Ulla Volke, Veljo Volke ja Kaarel Võhandu.

Data analysis

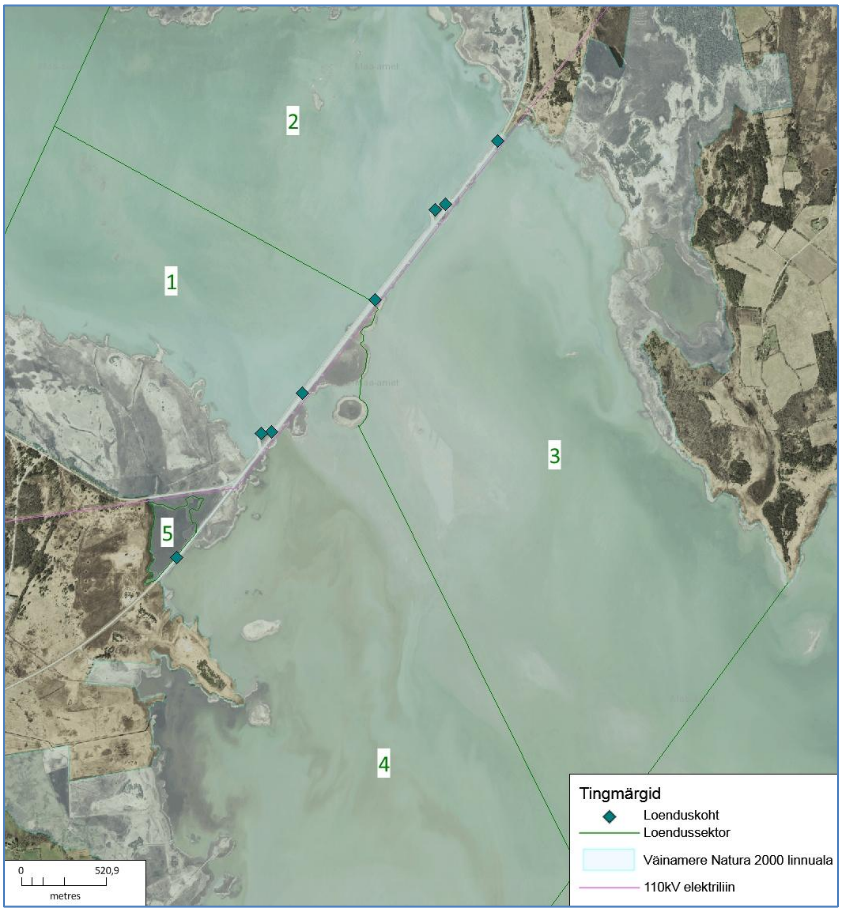
The data of visual observations were wrote on the special data form or entered directly in an Excel spreadsheet. Microsoft Excel 2019 and R 3.6.3 were used for data processing. The R package "mgcv 1.8-31" was used to elaborate additive models.

2.3. Counts of staging birds

Counts of staging waterfowl were conducted at the beginning and end of each 6-days fieldwork cycle, usually on the second (first day of arrival and radar setup) and last day of the cycle, a total of 18 counts.

The entire water area around the dam was covered within visibility range using a telescope and binoculars. The census area was divided into five sectors. The observer recorded the species and abundance of staging waterfowl by census sectors. Eight vantage points were typically used (Figure 4). Due to the high mobility of gulls and terns nesting on islets of the Väike Väin Strait, they were not counted in the summer censuses.

Andres Kalamees, Andrus Kuus, Mati Martinson, Uku Paal, Ainar Unus, Martin Vesberg and Kaarel Võhandu counted the staging waterbirds.



Joonis 4. Census sectors (5) and vantage points (8) used to count staging birds.

2.4. Video recording with cameras

In addition to visual observations, an automatic recording of bird movements with two camera stations mounted to the power line poles was used (locations in Figure 1, main parts Figure 5). Both camera stations were powered by one solar panel (280 W both) and a battery bank (320 Ah) supporting in poor light conditions. Both camera stations were connected to the Orissaare communication tower by radio link, which allowed the distant operation and control over the web. The cameras/recorders can be switched on and off together and individually and the condition of the power supply module can be monitored.

Three camera types were in use during the study:

-Mobotix MX26M (with 6 Mp sensor), sensitivity 0.005 Lux
-Hikvision DS-2CD4A26FVD min sensitivity 0.002 Lux
-Dahua IPC-HFW5442E / 0.002 Lux.

The following data were recorded during the review of the resulting video feeds:

- camera number;
- date;
- time;
- species/group of species;
- behaviour (similar to visual observations);
- power line (similar to visual observations);
- remarks.

Figure 5. Camera station with audio recording system.

Examination of the camera recordings revealed that it takes approximately 2000 hours (one person's one-year working time) to classify all the data suitable for analysis in detail. Thus, one day was selected for detailed analysis from each counting cycle and the rest of recordings were used to find the birds' physical contacts with the line (classes 7 and 8 in visual observations). Class 8 birds were considered as injured or killed. An important additional data identified for these birds was whether or not the bird fell in an area where the searcher for carcasses can find it or not. These results were used in model for estimating the number of collisions (mortality rates).

2.5. Night-time audio monitoring

Audio monitoring was performed to identify the species composition of nocturnal birds. For this purpose, the sounds of birds were recorded. The corresponding devices (directional microphone and recording device) were integrated into the camera station closest to the Saaremaa Island (Figure 1).

The parabolic highly directional microphone was built for year-round use in all weather conditions. The microphone comprises very low noise sensors (sensitivity -28 dB +/- 3dB at 1kHz, 0dB = 1V/Pa). Tascam DR-40 was used as a recorder (Figure 5).

During the first two census cycles of 2020, when there were restrictions for entering Saare County, no audio recording took place, as the system had been dismantled for the winter and its installation would have been difficult for field team.

Data analysis

Audacity audio processing software was used to analyze the audio files.

To check the audio files, the first selection was made on the basis of meteorological information. The quietest night was chosen from the monthly session, as the quality of audio files is negatively affected by both the high background traffic noise and the wind. A total of 53,5 hours of audio recordings were analysed from nights as follows: 11-12 November 2019, 14-15 June 2020, 12-13 July 2020, 14-15 August 2020, 15-16 September 2020 and 11-12 October 2020.

In the analysis of the audio files, the date, time, bird species, number (hereinafter referred to as "number of contacts") and activity were recorded. The following symbols were originally used for the activity:

p - a local bird, sounds can be heard throughout the night. Typically ducks, Greylag Geese, swans, Great Crested Grebe, Eurasian Crane, Water Rail, Common Coot, Northern Lapwing, gulls;
ü - a bird in flight, but difficult to assess whether it is a migratory individual or bird flying from one foraging site to another. It can be assumed that some of them cross the line;
r - migratory bird, an specimen expected to pass through the area on a longer migratory flight. It can be assumed that most of them cross the line;
s - singing bird;
h - sound, unknown whether it is a stationary or a flying bird.

When presenting the final results, the identified birds were grouped into two large groups based on activity: stationary (p, s) and flying birds (ü, r). The number of contacts was used to indicate the approximate frequency of the species. However, the meaning of the size "one contact" can be quite different in different cases - both a one-time flight of an individual or a flock, as well as the singing of stationary bird through the night near the recording point.

Sound files were analyzed by Uku Paal.

2.6. Weather data

Weather can affect both the activity of birds and their detectability in censuses.

In this study, the data stored by Viira Road Weather Station received from the Road Administration were used. Viira Road Weather Station is located on Muhu Island, 3.8 km from the radar location. In November 2019, additional data stored by Muhu Road Weather Station were received from the Road Administration. Muhu Station was located only about 200 m from the location of the radar, but by the beginning of the field work in 2020 it was not in use any more. In addition to the data from the road weather stations, the illuminance was measured with a photometer during visual observations.

Weather station data were recorded at 10-minute intervals. Luminance was measured once an hour. The list of weather parameters is presented in Table 4 and the mean values of weather parameters per day are shown in Annex 2 (Figures L2-1 to L2-3).

Table 4. Weather data

Parameter	Unit
Temperature	^{0}C
Humidity	%
Type of precipitation	dry/rain/wet snow/snow
Intensity of precipitation	mm/h
Visibility	meters
Wind direction	Degrees (0-360)
Wind speed	meters/second
Max wind speed	meters/second
Illuminance	lux

2.7. Carcass searches

According to the methodology, ground searches of dead or injured birds under the power line had to be conducted in the same periods as the radar surveys (two searches in each radar observation period) on the entire power line section between Saaremaa and Muhu. During the study period, 20 carcass searches were performed at the times shown in Table 5. All searches were conducted by Veljo Volke. As the start of fieldwork in autumn 2019 was delayed pending permits for radar operations, an additional censuses (26.09 and 23.10) were conducted to increase the sample. As the reconstruction of the power line started in September 2020, data from September 2019 to August 2020 (incl.) can be used to assess the impact of the unmodified power line.

Table 5. Search dates and search intervals.

Month, year	Date	Search interval
September 2019	26.10.2019	
October 2019	23.10.2019	27
November 2019	8.11.2019	21
	13.11.2019	5
March 2020	15.03.2020	
	19.03.2020	4
April 2020	19.04.2020	31
	24.04.2020	5
May 2020	19.05.2020	25
	24.05.2020	5
June 2020	10.06.2020	17
	15.06.2020	5
July 2020	10.07.2020	25
	15.07.2020	5
August 2020	12.08.2020	28
	17.08.2020	5
Mean longer search interval before reconstruction (n = 7)		**24,9; SD 4,6**
Mean shorter search interval before reconstruction (n = 7)		**4,9; SD 0,38**
September 2020	11.09.2020	25
	16.09.2020	5
Oktoober 2020	7.10.2020	20
	12.10.2020	5
Mean longer search interval during reconstruction (n = 2)		**22,5; SD 3,5**
Mean shorter search interval during reconstruction (n = 2)		**5; SD 0,0**

The search started from the Muhu end of the dam and the observer walked slowly along the southeast side of the dam to the end of the search area. The searcher returned along the northwest side of the dam.

The observer:

- recorded the location of each carcass with a handheld Garmin GPSMAP 66s or a mobile phone using the application Locus Map;

- recorded the condition of each carcass found using the following condition categories: (intact bird, scavenged, feather spot)[1] (Erickson et al., 2000);
- identified the species (and sex and age if possible);
- estimated the time of death and the probable cause of death (power line or car collision).

All carcasses were photographed at their original location. The remains of the dead birds were marked with an environmentally friendly forestry marker spray colour to prevent re-registration during the next search. If the identification of species was not possible in the field, the remains were collected and labelled and identified later at the Sõrve Bird Station by Mati Martinson, using the reference collection of bird feathers.

2.8. Scavenger test, searcher efficiency test and birds outside the search area

Measuring bird mortality from power line collision is mainly carried out by carcass counts on the ground below the lines. However, a high proportion of the birds killed may not be found during these surveys, leading to an underestimation of mortality.

Three to four biases can contribute to underestimating the mortality: (1) the removal by scavengers of carcasses under power lines, that is, carcass persistence (Kostecke et al., 2001) or carcass removal bias, (2) the difficulty for observers to detect carcasses, that is, carcass detection or searcher efficiency bias (Morrison, 2002), (3) the accessibility of sites under power lines for effective prospection, that is, habitat bias (Huso & Dalthorp, 2014), and (4) the flight (or walking, swimming) of wounded birds that die outside the search area, that is, crippling bias (Bech et al., 2012). Sometimes latter two are considered together. Crippling bias is notoriously difficult to estimate experimentally as it requires unbiased monitoring either by direct observation of bird collision with power lines or by telemetry (Borner et al., 2017).

According to the technical description of the study, the data collection required only a test to assess the loss of carcasses to predators and scavengers. In the present study, it is usually called a scavenger test (i.e. corp removal test, carcass persistence trial, etc.).

11 birds of different sizes (from Swift to Mute Swan, but in majority large) were placed at random locations in the search area. For randomization, 20 numbers were generated with a random number generator for the search path (7200 m; equal to twice the length of the power line section being searched as the searcher goes back and forth on either side of the dam). Bird corpses were placed in 11 searchable locations without rearranging the generated numbers (Figure 6). Areas where the south-eastern side of the dam borders the open water were considered unsuitable.

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[1] Condition categories:
Intact - carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
Scavenged - an entire carcass showing signs of being fed upon by a predator or scavenger or portion(s) of a carcass in one location (e.g., wings, skeletal remains, legs, pieces of skin, etc.).
Feather spot - ten or more feathers at one location indicating predation or scavenging. If only feathers are found, 10 or more any kind of feathers or 2 or more primaries must be discovered to consider the observation a casualty.

Figure 6. Locations of bird corpses (scavenger test and searcher efficiency test).

The birds were kindly provided by Madis Leivits, Doctor of Veterinary Medicine, among the birds brought to the Veterinary Department of the Estonian University of Life Sciences for rehabilitation, but who died there. The birds were taken from the freezer the day before the start of the trials.

The persistence of carcasses was checked on days 2, 5, 25 and 56 after placement. The test bird was considered to persist until its remains were detectable in the search area. Similar to Ponce et al. (2010), the “lower limit” of detectability was set so that if less than five (smaller) feathers were found, the test bird was considered missing from the study area. Test results were used in the fatality estimation model.

The technical description of the study did not foresee a searcher efficiency trial, but because the searcher's ability to find dead birds or parts thereof significantly affects the calculated mortality rate and the estimation of fatalities, it was considered necessary to evaluate the searcher’s efficiency. Usually, the searcher's performance is in the range of 30-90% (expressed as a probability of finding 0.3-0.9), depending, among other things, on the searcher's experience (Ponce et al., 2010). To an even greater extent, the recovery rate depends on the size of the bird. For example, in a large-scale experiment, Borner et al. (2017) explained that the mean probability of detection was 0.47 for large birds, 0.18 for medium-sized birds, 0.07 for small birds, and 0.005 for very small birds. In the present study, the carcasses were not divided into size classes, because mainly different waterbird species are of conservation importance in the Väike Väin Strait and these birds are classified as medium (waders, terns) or large (most other waterfowl, eg swans, geese, ducks, etc.). Species of these groups are also mentioned among the conservation objectives of the Natura 2000 Väinameri SPA and and the Väike Väin Limited Conservation Area.

The searcher efficiency trial was performed on the first day of the scavenger test, on October 7th, 2020, using the same 11 birds. After the searcher efficiency test birds remained in the same locations for the scavenger test (see above).

Thirdly, habitat and crippling bias must be taken into account. Some birds fall outside the search area (water, reedbed) after contact with the line and die there, some may be injured but still move out of the search area (crippling bias). Bernardino et al. (2018) still consider the development of methods for the accurate determination of bird mortality (based on the search for remains) and related correction factors to be important, with particular reference to the error caused by 'crippling'. For example, in a study in the United Kingdom, Frost (2008) found that the perpendicular distances over which Mute Swan carcasses were found on the ground from under the overhead power line ranged from 10-351 m (mean 58 m).

In the present study habitat and crippling biases were estimated together, based on the (1) collision events found in the camera recordings, and (2) the collision events registered by visual observations. For each event, it was assessed whether or not the bird fell in the search area. On this basis, a simple formula was used:

a = number of collision events where bird landed in the search area / number of all collision events analyzed.

This is multiplied by the searcher efficiency factor (p) to obtain the carcass detection probability for use in the models, denoted p'.

$p' = p \times a$; Huso (2010) model (and *Se* Jain et al. (2007) model).

The site-specific methodological problem was to take into account the proportion of birds found during the search, but whose death was not caused by a collision with the power line, but by car traffic on the dam. This was mainly related to Black-headed Gulls, who used to walk on the road in spring and summer. The Black-headed Gulls was the most abundant species among the carcasses found (51 individuals), while two collisions of the gull with a power line were recorded on visual observations (one of them during radar setup before regular observations), and twice the remains of the gull were hanging on the earth wire. No good solution was found to the problem, as it is not possible to distinguish between birds that have collided with the power line from those who have hit by car. Thus, only two Black-headed Gull mortality events were taken into account in determining the mortality rates and estimating number of fatalities. This leads to underestimation. One Raven was also found dead. The Raven as a scavenger may have come to the road because of bird remains, it was also considered a traffic victim and its data were not used in the calculation of the mortality rates. There is no reason to suspect that some of other birds than the Black-headed Gulls and the Raven were also traffic victims and thus we used all other data to model the mortality.

2.9. Estimation of fatalities

Various models have been developed to estimate the mortality and the total number of fatalities (Erickson et al., 2000; Huso, 2010; Jain et al., 2007; Kerns et al., 2005; Korner-Nievergelt et al., 2011), but all have their assumptions and limitations (Bernardino et al., 2013).

The Huso (2010) model is used in the present study because it: (1) does not require equal time intervals between two search visits, which many other models assume, but was not followed in the present work; due to the 6-day field work cycles and the terms of reference, the intervals between searches were usually 5 and 25 days. (b) assumes that the disappearance of corpses corresponds to an exponential function (was confirmed by modeling of the empirical data); (c) allow the proportion of unsearched area to be taken into account. The disadvantage of this method is the assumption that birds enter the "population of dead birds" at a constant rate. This may not always be the case. However, Huso (2010) demonstrated the advantages of his method over other previously used models and it is generally considered reliable and robust (Korner-Nievergelt et al., 2011).

3. Results

3.1. Principles of the presentation of results

The results of the study are presented by topics, not by research methods (Table 6). This ensures better understanding of the results.

Table 6. Research topics and methods used to obtain the data.

Topic \ Method	Historical data	Radar (horizontal)	Radar (vertical)	Visual obseravtion	Cameras	Audio	Counts of staging birds	Carcass searches	Wather data
Species composition (+abundance)	x			x		x	x		
Spatial distribution (XY)		x					x		
Flight intensity, temporal variability			(x)	x					x
Flight height			x	x					
Behavioural reactions, collisions				x	x			x	
Mortality, fatality estimations				x	x			x	

3.2. Species composition

The Väike Väin Strait is an important staging and nesting area for waterfowl (Kalamees, 2000; Kuresoo et al., 1995).

In this project, a total of 65,689 specimens of 57 species were counted as staging birds (Table 7). The dominant groups were ducks (the most numerous species were Mallard, Wigeon, Common Teal, Gadwall, Tufted Duck, Pochard and Common Goldeneye), swans (Mute Swan), geese (Graylag Goose), Common Coot and gulls (Black-headed Gull).

Comprehensive censuses in the Väinameri bird area, including the Väike Väin Strait, were also conducted in 2017, when the fieldwork of the Natura 2000 monitoring project took place in the Väinameri SPA. The 2017 census results obtained from the census sectors adjacent to the dam (also covered by this study) are summarized in the last column of Table 7.

Of the protected species, specimens of the two highest (I) protection category species were found – Ruff and White-tailed Eagle. There were 10 species of protection category II present, Tundra Swan and Greater Scaup as more numerous. 16 category III species were also registered.

When assessing the impact of the power line, the species that are not protected, but have been mentioned among the conservation objectives of the Väike Väin Limited Conservation Area (or also the Väinameri Natura 2000 SPA), are also important. In protected areas, the status of these species must not deteriorate and, if possible, the status must be improved. The third column of Table 7 lists 29 species found in the censuses of staging birds that are listed among the conservation objectives of the Väike Väin Strait Limited Conservation Area.

Table 7. Bird species registered during the 2019-2020 survey by counting the staging birds and their conservation status; and maximum counting result of 2017 censuses.

Species	Protection category	Conser-vation objective	Total counted, individ.	Max per count, Individ.	Occurence %	Max per count, Individ.
			This study, 2019-2020			2017
Swans						
Mute Swan (Cygnus olor)		×	7996	806	100	1579
Tundra Swan (Cygnus columbianus)	II	×	594	505	16,7	2255
Whooper Swan (Cygnus cygnus)	II	×	128	30	88,9	205
Swans, unidentif.			355	275	11,1	
Geese						
Bean Goose (Anser fabalis)						1510
Grater White-fronted Goose (Anser albifrons)						1000
Greylag Goose (Anser anser)		×	1989	1630	72,2	703
Barnacle Goose (B. leucopsis)	III	×	450	340	16,7	1004
Geese, unidentif.			5530	5500	16,7	
Ducks						
Common Shelduck (Tadorna tadorna)	III		5	4	11,1	2
Eurasia Wigeon (Mareca penelope)		×	5367	2814	55,6	6040
Gadwall (Mareca strepera)		×	1520	488	77,8	45
Common Teal (Anas crecca)			2275	871	61,1	38
Mallard (A. platyrhynchos)			8939	2827	100	3586
Northern Pintail (Anas acuta)	II (h)	×	161	104	38,9	8
Northern Shoveler clypeata)		×	962	742	44,4	14
Common Pochard (Aythya ferina)		×	3959	2387	72,2	4359
Tufted Duck (Aythya fuligula)		×	7988	1312	100	1438
Greater Scaup (Aythya marila)	II (h)		291	288	22,2	5
Long-tailed Duck (Clangula hyemalis)		×	2	1	11,1	1
Common Goldeneye (Bucephala clangula)		×	2777	522	72,2	583
Smew (M. albellus)	II		196	82	38,9	29
Red-breasted Merganser (Mergus serrator)		×	2	1	11,1	1
Goosander (Mergus merganser)			404	82	77,8	87
Ducks, unidentif.			1928	740	27,8	
Grebes						
Little Grebe (T. ruficollis)	III		1	1	5,6	
Great Crested Grebe (Podiceps cristatus)			500	285	94,4	52
Red-necked Grebe (P. grisegena)	III		2	2	5,6	
Cormorants						

Great Cormorant (P. carbo)			76	51	38,9	1
Herons						
Eurasian Bittern (Botaurus stellaris)	II	×	2	1	11,1	1
Great White Egret (Ardea alba)			449	94	66,7	7
Grey Heron (Ardea cinerea)			45	10	55,6	5
Rails and Crakes						
Western Water Rail (Rallus aquaticus)	III		5	3	11,1	1
Common Moorhen (Gallinula chloropus)	III		1	1	5,6	
Common Coot (Fulica atra)			4503	1396	100	1501
Cranes						
Eurasian Crane (Grus grus)	III		73	67	22,2	4
Waders						
Pied Avocet (R. avosetta)	II		35	21	22,2	28
Eurasian Oystercatcher (H. ostralegus)			5	2	22,2	1
Northern Lapwing (Vanellus vanellus)		×	316	165	55,6	177
Common Ringed Plover (Charadrius hiaticula)	III	×	39	37	16,7	
Eurasian Curlew (N. arquata)	III	×				1
Black-tailed Godwit (Limosa limosa)	II	×	11	5	22,2	1
Red Knot (Calidris canutus)			1	1	5,6	
Ruff (Calidris pugnax)	I		2	2	5,6	88
Dunlin (Calidris alpina)		×	1	1	5,6	
Common Sandpiper (Actitis hypoleucos)			3	2	11,1	11
Green Sandpiper (Tringa ochropus)			3	3	5,6	
Spotted Redshank (Tringa erythropus)			11	7	16,7	
Common Greenshank (Tringa nebularia)	III		13	11	11,1	2
Wood Sandpiper (Tringa glareola)	III		3	3	5,6	3
Common Redshank (Tringa totanus)	III	×	7	3	22,2	2
Common Snipe (Gallinago gallinago)			2	1	11,1	
Terns						
Caspian Tern (Hydroprogne caspia)	II		26	20	11,1	3
Black Tern (Chlidonias niger)	III		1	1	5,6	
Sandwich Tern (T. sandvicensis)	II	×				1
Common Tern (Sterna hirundo)*	III	×		45	22,2	9
Arctic Tern (Sterna paradisaea)*	III	×		8	16,7	21
Terns, unidentif.*				48	11,1	
Gulls						
Little Gull (H. minutus)	II	×	10	5	16,7	390

Black-headed Gull (L. ridibundus)*		×		1345	88,9	1750
Mew Gull (Larus canus)		×		6	22,2	17
European Herring Gull (Larus argentatus)				111	88,9	95
Great Black-backed Gull (Larus marinus)			103	14	100	11
Raptors						
White-tailed Eagle (H. albicilla)	I		39	11	72,2	7
Western Marsh-harrier (C. aeruginosus)	III	×	15	4	38,9	2

Visual observations recorded 96482 specimens of 99 species flying above and in the vicinity of the power line (Table 8). The most numerous groups of birds were gulls (Black-headed Gull and Herring Gull as most numerous species), ducks (Tufted Duck, Goldeneye, Mallard), geese (Barnacle Goose, Graylag Goose) and terns (Common Tern). Gulls accounted for one third of the registered birds (Figure 7).

In the night-time, 30 species were identified as sedentary in the **analysis of bird sounds** and 32 species in flight (two last columns in Table 8). The most common birds on the flight were Goldeneye, Whooper Swan and Mallard, whereas Black-headed Gull as sedentary. For species identified as stationary in the dark, a single contact may involve the sounds of bird(s) overnight near the recording point.

Table 8. Birds recorded by visual counts and night-time audio monitoring, and their conservation status.

"Total recorded" and "Max per day" indicate the number of flights over the power line, not necessarily the sum of the number of birds (the same individual may fly over repeatedly);

* - species whose abundance in the spring-summer censuses (22 April - 15 July) was extrapolated based on 10 first minutes of every counting hour;

() - Species with a protected breeding population.

Liigid	Protec-tion cat.	Cons. objective	Total counted, individ.	Max per day, individ.	Occu-rence %	Night-time audio; sedentary birds; No. of contacts	Night-time audio; flying birds; No. of contacts
Swans			1629	135	84,7		
Mute Swan (Cygnus olor)		×	1314	135	84,7	5	
Tundra Swan (Cygnus columbianus)	II	×	77	30	8,5		
Whooper Swan (Cygnus cygnus)	II	×	103	20	25,4	4	12
Swans, unidentif.			135	20	27,1		
Geese			14148	4954	79,7		
Bean Goose (Anser fabalis)			79	40	5,1		1
Grater White-fronted Goose (Anser albifrons)			376	139	8,5		3
Greylag Goose (Anser anser)		×	1618	294	72,9	4	
Barnacle Goose (B. leucopsis)	III	×	9244	4896	25,4		
Brent Goose (Branta bernicla)			2	2	1,7		
Geese, unidenif.			2829	865	28,8		
Pardid			19938	1273	100		

Common Shelduck (Tadorna tadorna)	III		32	11	18,6		
Eurasia Wigeon (Mareca penelope)		×	823	199	30,5	7	
Gadwall (Mareca strepera)		×	229	24	45,8	4	
Common Teal (Anas crecca)			83	34	22	1	
Mallard (A. platyrhynchos)			2802	327	98,3		10
Northern Pintail (Anas acuta)	(II)	×	91	20	20,3		
Garganey (S. querquedula)			1	1	1,7		
Northern Shoveler clypeata)		×	88	20	23,7		
Common Pochard (Aythya ferina)		×	124	98	8,5		
Tufted Duck (Aythya fuligula)		×	7583	667	91,5		2
Long-tailed Duck (Clangula hyemalis)		×	46	46	1,7		
Common Scoter (Melanitta nigra)							11
Velvet Scoter (Melanitta fusca)	III		55	29	6,8		
Common Goldeneye (Bucephala clangula)		×	1332	428	67,8		25
Smew (M. albellus)	II		65	25	15,3		
Red-breasted Merganser (Mergus serrator)		×	275	69	23,7		
Goosander (Mergus merganser)			969	137	57,6		
Ducks, unidentif.			5340	756	98,3		
Divers			262	136	27,1		
Red-throated Diver (Gavia stellata)	III		29	19	11,9		
Arctic Loon (Gavia arctica)	II		99	68	10,2		
Divers, unidentif.			134	96	15,3		
Grebes			4	4	1,7		
Great Crested Grebe (Podiceps cristatus)						6	
Red-necked Grebe (P. grisegena)	III		4	4	1,7		
Cormorants			3218	357	83,1		
Great Cormorant (P. carbo)			3218	357	83,1		
Herons			995	99	89,8		
Eurasian Bittern (Botaurus stellaris)						1	
Great White Egret (Ardea alba)			655	92	72,9		
Grey Heron (Ardea cinerea)			340	70	78		
Rails and Crakes							
Western Water Rail (Rallus aquaticus)						6	
Common Coot (Fulica atra)						6	
Cranes			1314	448	55,9		
Eurasian Crane (Grus grus)	III		1314	448	55,9	3	1
Waders			4733	642	93,2		
Pied Avocet (R. avosetta)	II		7	2	6,8		
Eurasian Oystercatcher (H. ostralegus)			25	5	20,3	1	1

Northern Lapwing (Vanellus vanellus)		×	3276	588	79,7	3	
Common Ringed Plover (Charadrius hiaticula)	III	×	56	16	11,9		1
Whimbrel (N. phaeopus)	III		3	3	1,7		1
Eurasian Curlew (N. arquata)	III	×	27	10	18,6	2	
Black-tailed Godwit (Limosa limosa)	II	×	1	1	1,7	1	
Ruff (Calidris pugnax)	I		23	7	10,2		
Curlew Sandpiper (C. ferruginea)			1	1	1,7		
Dunlin (Calidris alpina)			632	263	16,9		3
Common Sandpiper (Actitis hypoleucos)						5	
Green Sandpiper (Tringa ochropus)			5	3	5,1		1
Spotted Redshank (Tringa erythropus)			8	3	8,5	3	1
Common Greenshank (Tringa nebularia)	III		20	4	20,3		3
Wood Sandpiper (Tringa glareola)	III		59	45	10,2		3
Common Redshank (Tringa totanus)	III	×	17	2	20,3	1	
Common Snipe (Gallinago gallinago)			21	6	10,2		2
Waders, unidenif.			552	73	35,6		
Jaegers			2	2	1,7		
Arctic Jaeger (S. parasiticus)			2	2	1,7		
Terns			10375	880	59,3		
Caspian Tern (Hydroprogne caspia)	II		44	7	22		1
Black Tern (Chlidonias niger)	III		48	8	18,6		
Sandwich Tern (T. sandvicensis)	II	×	3	2	3,4		1
Common Tern (Sterna hirundo)*	III	×	2373	564	16,9		
Arctic Tern (Sterna paradisaea)*	III	×	117	60	11,9		
Terns, unidentif.*			7790	876	42,4	2	
Gulls			32138	1671	100		
Little Gull (H. minutus)	II	×	55	32	10,2		
Black-headed Gull (L. ridibundus)*		×	27825	1566	94,9	8	
Mew Gull (Larus canus)		×	195	24	54,2		1
Lesser Black-backed Gull (Larus fuscus)	II		1	1	1,7		
European Herring Gull (Larus argentatus)			3137	201	98,3	3	
Great Black-backed Gull (Larus marinus)			721	53	93,2	3	1
Gulls, unidenif.			204	59	42,4		
Määramata veelinnud			283	138	8,5		
määramata veelind			283	138	8,5		
Raptors			692	45	100		

White-tailed Eagle (H. albicilla)	I	441	43	91,5		
Western Marsh-harrier (C. aeruginosus)	III	212	22	76,3		
Hen Harrier (Circus cyaneus)	III	1	1	1,7		
Pallid Harrier (C. macrourus)		1	1	1,7		
Montagu's Harrier (Circus pygargus)	III	1	1	1,7		
Eurasian Sparrowhawk (Accipiter nisus)	III	8	3	8,5		
Common Buzzard (Buteo buteo)	III	11	3	13,6		
Rough-legged Buzzard (Buteo lagopus)	III	1	1	1,7		
Buzzars, unidentif. (Buteo sp.)		1	1	1,7		
Osprey (Pandion haliaetus)	I	3	1	5,1		
Common Kestrel (Falco tinnunculus)	III	4	2	5,1		
Red-footed Falcon (F. vespertinus)	III	3	3	1,7		
Eurasian Hobby (Falco subbuteo)	III	4	1	6,8		
Peregrine Falcon (Falco peregrinus)	I	1	1	1,7		
Doves and Pigeons		420	126	45,8		
Rock Dove (Columba livia)		19	8	5,1		
Stock Dove (Columba oenas)	III	3	1	5,1		
Wood Pigeon (Columba palumbus)		277	48	42,4		
Dove/Pigeon, unidentif.		121	88	10,2		
Kingfishers		4	3	3,4		
Common Kingfisher (Alcedo atthis)	II	4	3	3,4		
Crows		5758	492	98,3		
Eurasian Jackdaw (Corvus monedula)*		282	49	37,3		
Rook (Corvus frugilegus)*		283	72	35,6		2
Hooded Crow (Corvus corone)*		4149	480	96,6		
Common Raven (Corvus corax)*		1042	318	81,4		
Crow, unidenif.*		2	1	3,4		
Other passerines		395	71	33,9		
Eurasian Skylark (Alauda arvensis)		12	10	5,1	1	
Barn Swallow (H. rustica)	III	2	1	3,4		
Meadow Pipit (Anthus pratensis)		2	2	1,7		5
Yellow Wagtail (Motacilla flava)						2
White Wagtail (Motacilla alba)		22	7	11,9		7
European Robin (Erithacus rubecula)						1
Redwing (Turdus iliacus)						1
Song Thrush (Turdus philomelos)						5
Fieldfare (Turdus pilaris)		98	60	5,1		

Sedge Warbler (A. schoenobaenus)					2	
Common Reed-warbler (A. scirpaceus)					2	
Great Reed-warbler (A. arundinaceus)					2	
Common Whitethroat (S. communis)		1	1	1,7		
Bearded Tit (P. biarmicus)		36	9	11,9	1	
Blue Tit (Cyanistes caeruleus)		6	2	8,5		1
Great Tit (Parus major)		36	12	16,9		1
Red-backed Shrike (L. collurio)	III	1	1	1,7		
Starling (Sturnus vulgaris)		73	41	15,3		
Common Chaffinch (F. coelebs)		5	2	5,1		1
European Goldfinch (Carduelis carduelis)		2	1	3,4		
Eurasian Siskin (Spinus spinus)		55	55	1,7		
Redpoll (Acanthis flammea)		2	2	1,7		
Eurasian Bullfinch (Pyrrhula pyrrhula)		2	1	3,4		
Snow Bunting (P. nivalis)		15	10	3,4		
Yellowhammer (E. citrinella)		5	2	5,1		2
Reed Bunting (E. schoeniclus)					4	
Passerif., unidentif.		20	5	13,6		
Birds, unidentif.		174	160	11,9		
Bird, unidenif.		174	160	11,9		
Total, waterbird species		59				
Total, waterbird individuals		89039				
Total, bird species		99				
Total, all birds, individuals		96482				

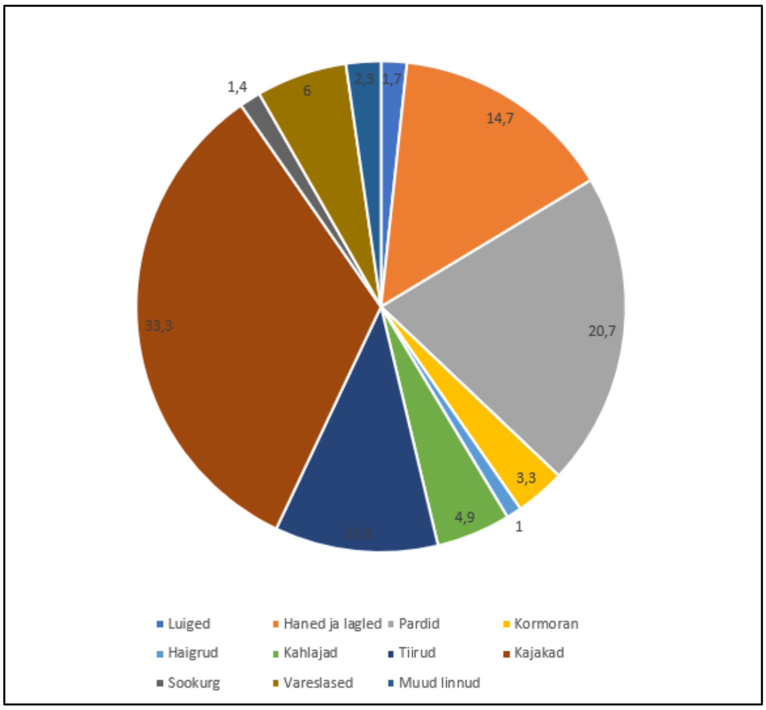


Figure 7. Proportion of bird groups in visual observations.

The number of staging waterbirds (without gulls and terns) at different counting times is shown in Figure 8. The number of staging waterbirds was higher during the autumn and spring migration, with a maximum in October. Due to the difficulty of counting nesting birds, Black-headed Gulls and terns were not registered in all censuses. The maximum number counted was 1358 for Black-headed Gulls (April, 24th, 2020) and 59 individuals for terns (May, 18th, 2020). The high number of nesting gulls compensated for the low number of other waterfowl during the summer months, and the Väike Väin Strait found intensive use by staging and nesting birds throughout the observation period. In the spring, the site holds the largest numbers of swans (all three species), geese (Barnacle Goose, less regularly also Greater White-fronted Goose and Bean Goose) and diving ducks (Tufted Ducks, Goldeneye, also Common Pochard). The number of waterbirds is low in moulting period, from the end of May to the end of July. Then the majority of non-breeders are dabbling and diving ducks and Graylag Geese. The most numerous species is the Mallard. During the autumn migration, the most numerous dabbling ducks are the Wigeon and the Mallard, and the diving ducks are the Common Pochard and Tufted Duck. By November, the number of staging birds will decrease, as the vast majority have continued (or left to) the migration. Species remaining on the strait, are those who also overwinter in the presence of ice-free water, as Mute and Whooper Swan, Mallard, Goldeneye, Tufted Duck, Goosander, Common Coot etc.

The species composition and abundance of birds depend to a large extent on the water level. When the water level in the strait is low in summer and early autumn and extensive mudflats are exposed, the number of waders is also high. In 2020 (as in 2017), there was no longer low-water period and the number of waders remained modest. The number of dabbling ducks is also higher in August and September if the low-water period occurs during the migration stop-over.

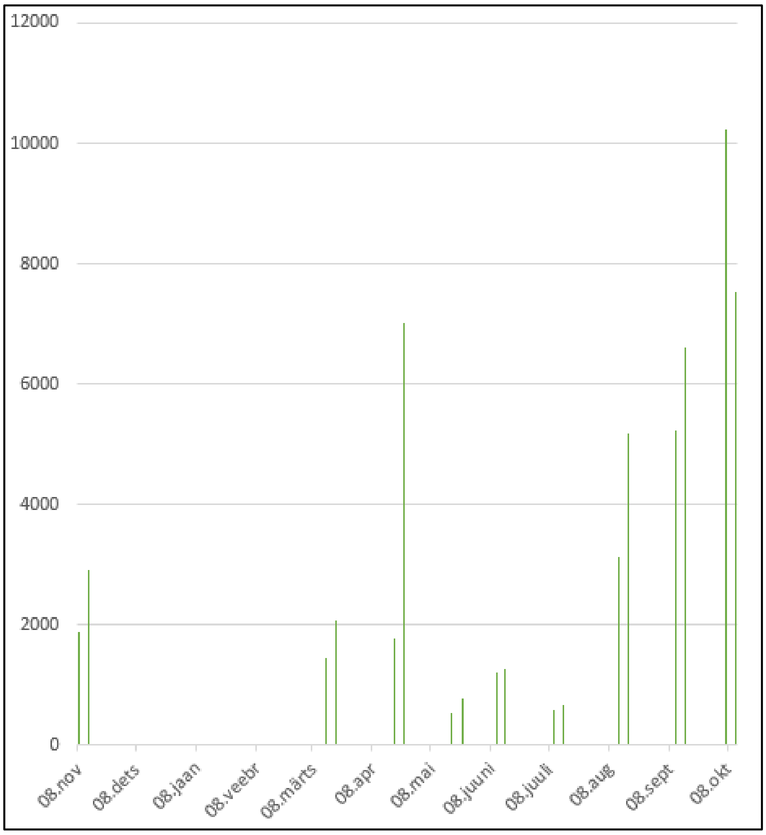


Figure 8. Number (individuals) of staging waterbirds at different census periods (without gulls and terns).

3.3. Spatial distribution of birds

Flight tracks registered by the horizontal radar covered the entire water area around the dam (Figure 9). The lack of tracks in the immediate vicinity of the radar is due to technical disturbances (Figure 10).

The density of tracks by observation periods is shown in Figure 11. The decrease in the density of the tracks in the immediate vicinity of the dam can be noticed - the dam, and especially the power line, act as a barrier to the movement of birds. Manual fixation of tracks did not allow the recording of all flight paths, therefore the absolute values of track density shown in the figures are not accurate. The figures show the differences in track density between the different parts of the strait.

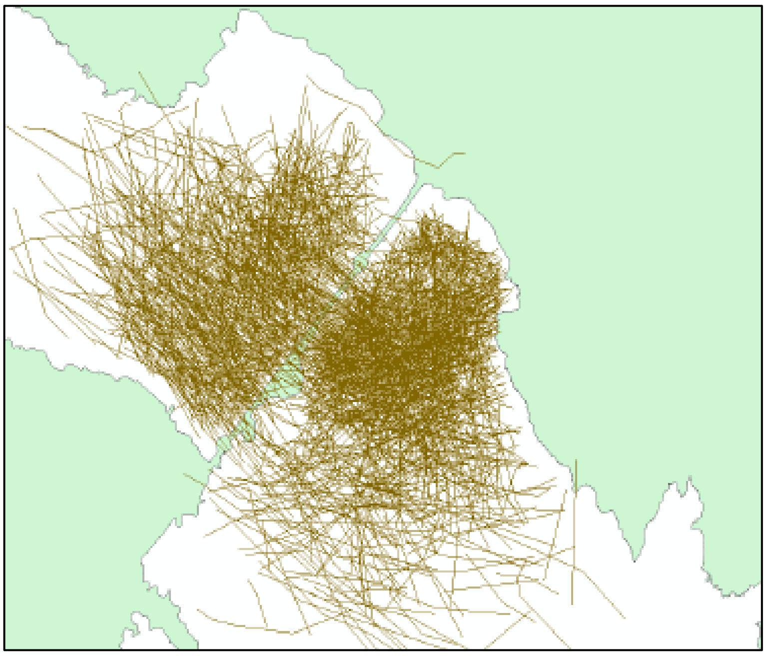


Figure 9. Example of tracks recorded by horizontal radar: November 2019.

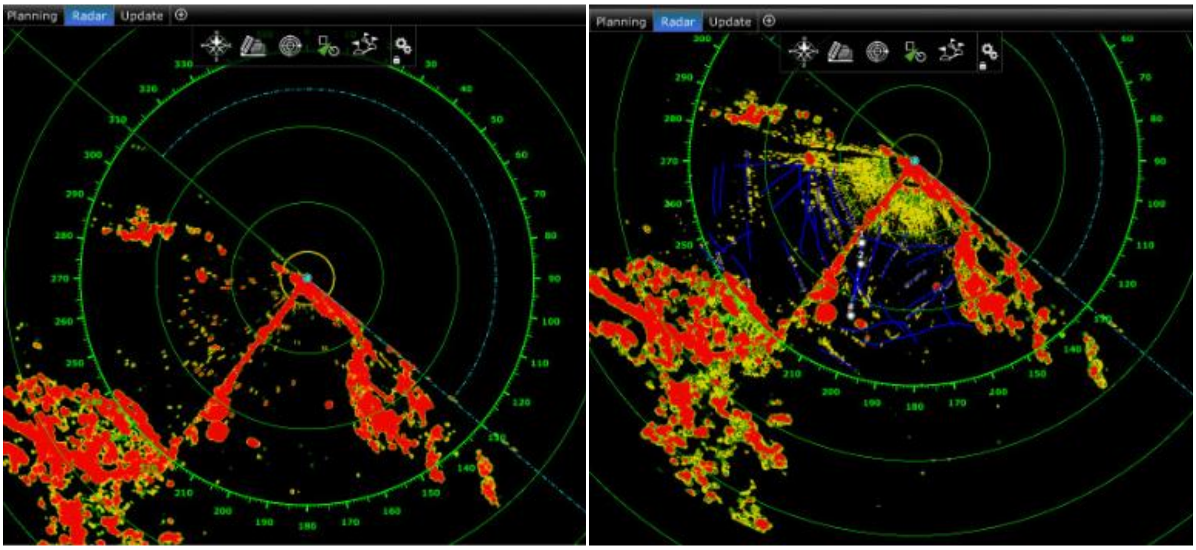


Figure 10. Example of a disturbance that may occur on the radar screen (radar screen recordings on 9 June at 20:30 and 23:30). The blue dot in the center of the screen is the location of the radar, the red area is a land, the yellow spot near the center of the right recording is a technical disturbance.

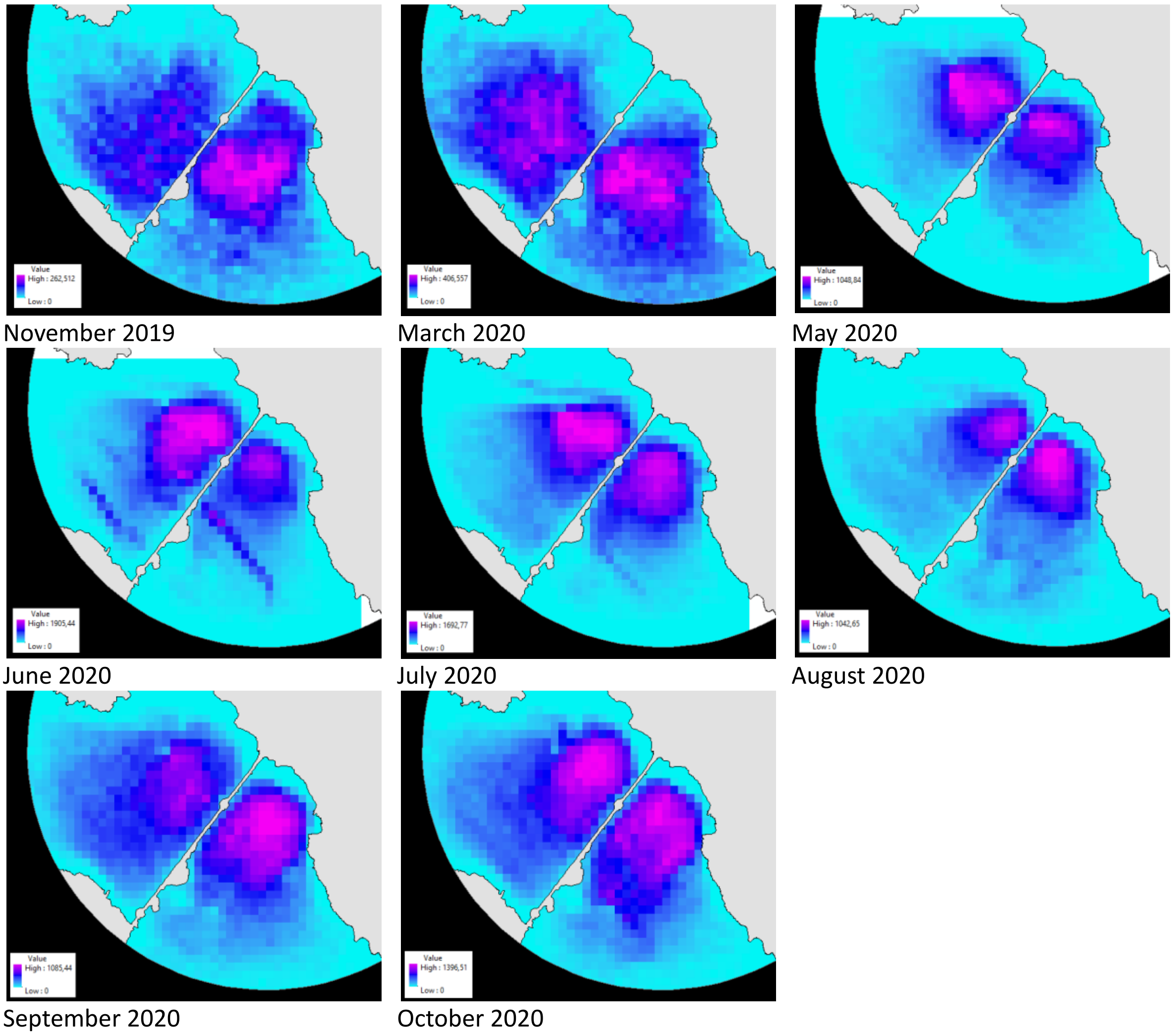


Figure 11. Mean track density per day (km/km²) November 2019-October 2020.

According to the results of the census of staging waterbirds, the water area southeast of the dam (Gulf of Riga) is more important for birds than the sea area facing the Väinameri (Figure 12, Table 9).

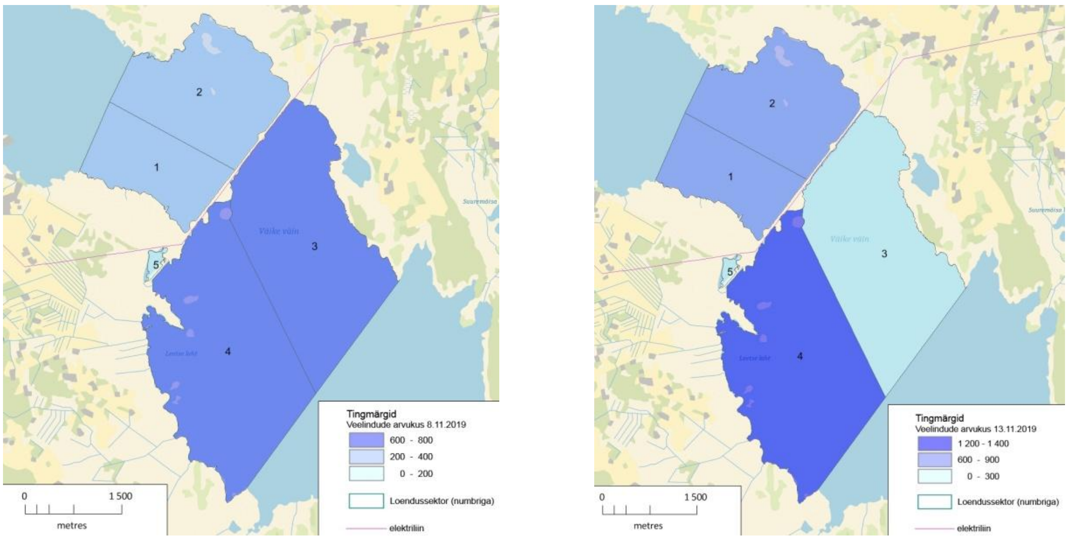


Figure 12. Example of the abundance of waterbirds in the census sectors on 8.11.2019 and 13.11.2019 based on the results of the census of staging waterbirds.

Table 9. Number of staging waterbirds in census sectors (without gulls and terns). Gray background - the highest result of each census.

Sector	Nov 08th	Nov 13.th	March 14th	March 19th	April 19th	April 24th	May 18th	May 24th	June 10th	June 15th	July 10th	July 15th	August 12th	August, 17th	Sept. 11th	Sept. 16th	Oct. 7th	Oct. 12th	Total	Proportion (%)
1	242	620	28	55	70	5	19	19	36		53	84	343	61	380	859	449	785	4 108	6,8
2	357	716	46	445	467	200	80	223	123	185	72	48	89	118	366	321	964	259	5 079	8,5
3	585	137	722	671	422	365	111	130	582	502	196	238	684	22	711	346	5 237	3 730	15 391	25,7
4	653	1 352	402	393	745	6 289	209	364	396	527	51	21	1 605	4 682	3 054	4 321	3 343	2 188	30 595	51,0
5	35	75	242	502	66	153	114	39	70	49	208	270	396	296	715	762	246	570	4 808	8,0

Summarizing the results of all censuses, 76.7% of all counted birds staged in census sectors No. 3 and 4 on the Gulf of Riga side. Adding a small sector 5, the share reaches almost 86%. Despite the differences in the size of these sectors, the important environmental conditions for birds also differ. The water area on the side of the Gulf of Riga is more eutrophic, the reedbed has expanded more into the water area, the average water depth is smaller and mudflats are exposed when water level is low. This creates more favourable feeding conditions for waterfowl, especially for dabbling ducks.

3.4. Flight height

Flight altitude data were obtained using two methods: vertical radar and visual observations. The methods are complementary - radar allows to measure altitudes at night and at high altitudes, but works poorly in the lowest levels. For the comparability, the number of records for both methods has been considered in this chapter, without taking into account the size of the flocks in visual observations.

Although birds can fly at altitudes of several kilometres, most of the flights took place in the lower levels, a few hundred meters above the ground/sea level (Figure 13). The exception is night migration in autumn, and especially in spring.

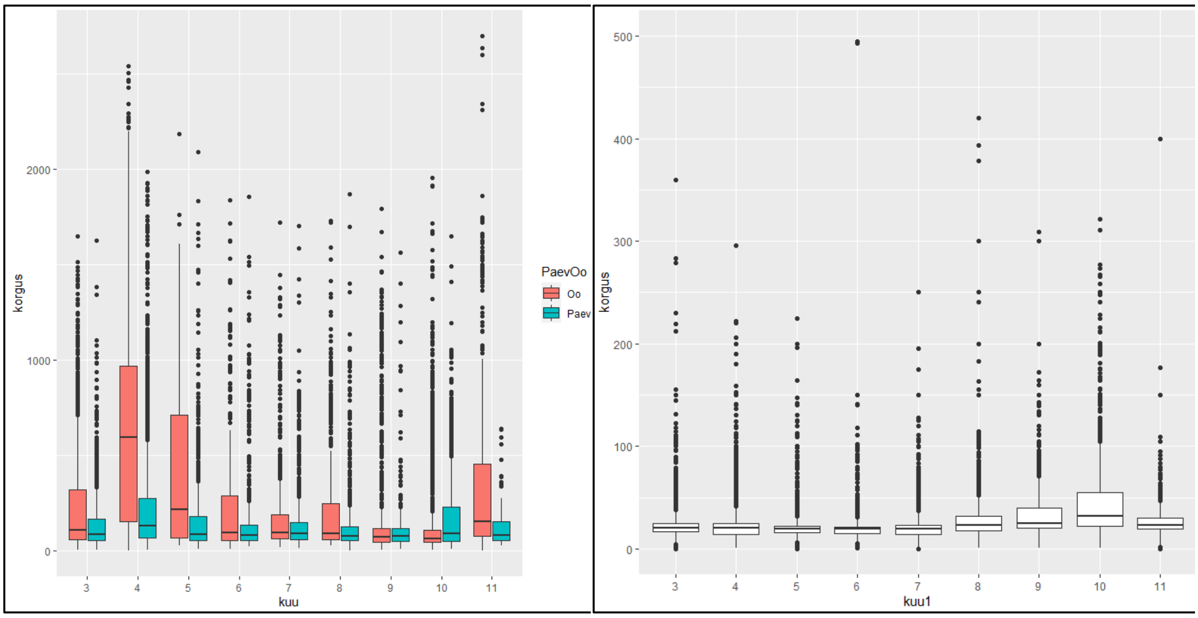


Figure 13 Flight altitude based on vertical radar data (left) and visual observations (right).

Similar to the flight intensity, the flight altitude also depends on various factors: season and time of the day, weather conditions, bird species. The effect of time (month, hour) on flight altitude based on additive models is shown in Figure 14.

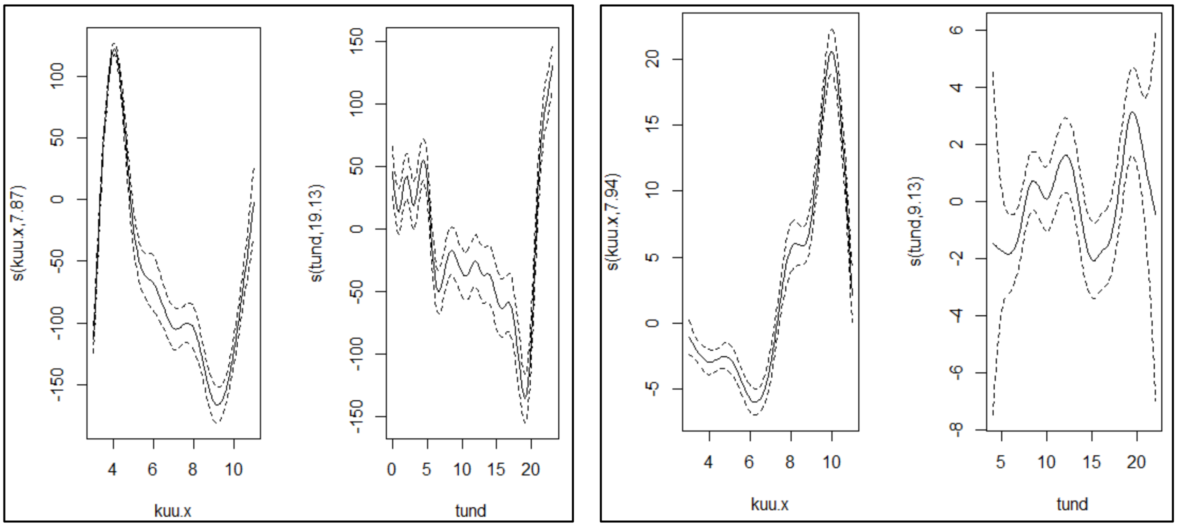


Figure 14. Dependence of flight altitude on season (month) and time (hours) based on data from vertically operating radar (left) and visual observations (right). In all cases, the 95% confidence interval of the additive model is shown.

Seasonally, there is a significant increase in flight altitude during migration periods. In the upper air layers and at night (vertically operating radar data) the flight altitude increased in both migration periods, during the day in the lower air layers (visual observation data) mainly in autumn.

Both the additive model (p <0.001) and the non-parametric test (Wilcoxon test, p <0.001) show a statistically significant difference in flight altitude between day and night. The flight altitude is higher at night (Figure 15), and the differences in altitude are especially noticeable during the spring and autumn migration periods (Figure 13). The flight altitudes by hours are shown in Figure 16.

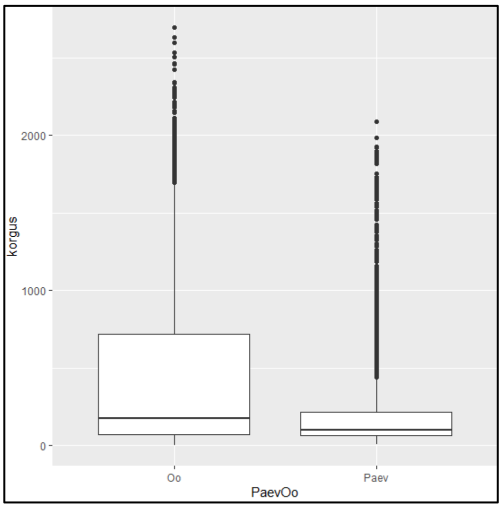


Figure 15. Flight altitudes at night and day according to vertical radar data.

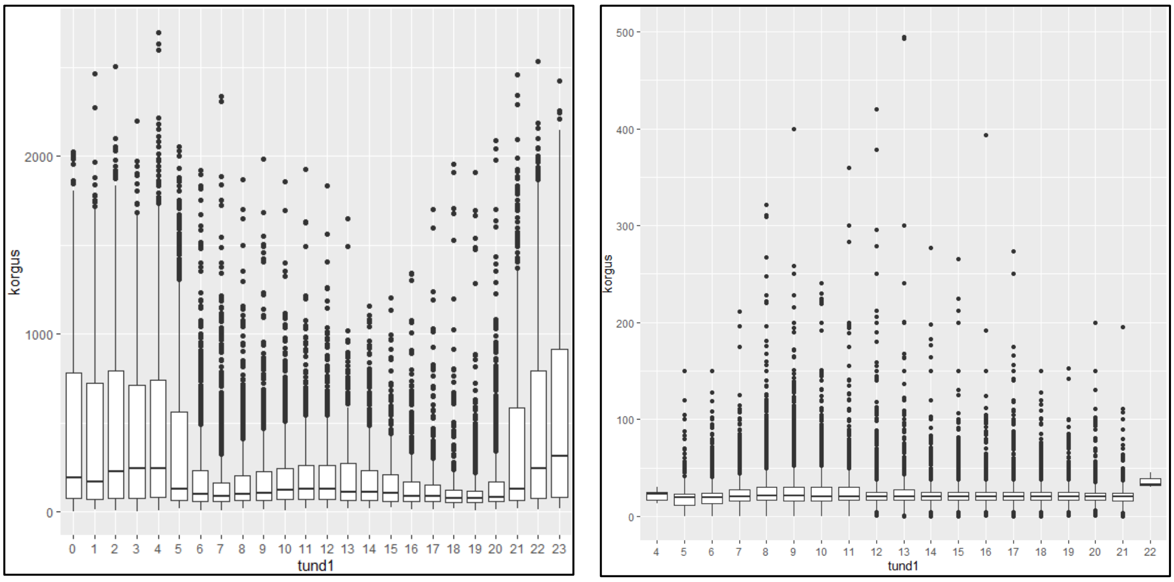


Figure 16. Flight altitudes by hourly data from vertically operating radar (left) and visual observations (right).

During the day in the lower air layers, different species prefer different flight altitudes (Figure 17). The lowest flight altitude in the area directly affected by the power line is the preferred flight altitude for swans, terns, gulls and crows. The mean flight altitude of ducks, geese, herons and waders is higher. The cormorant and cranes flew at the highest altitude.

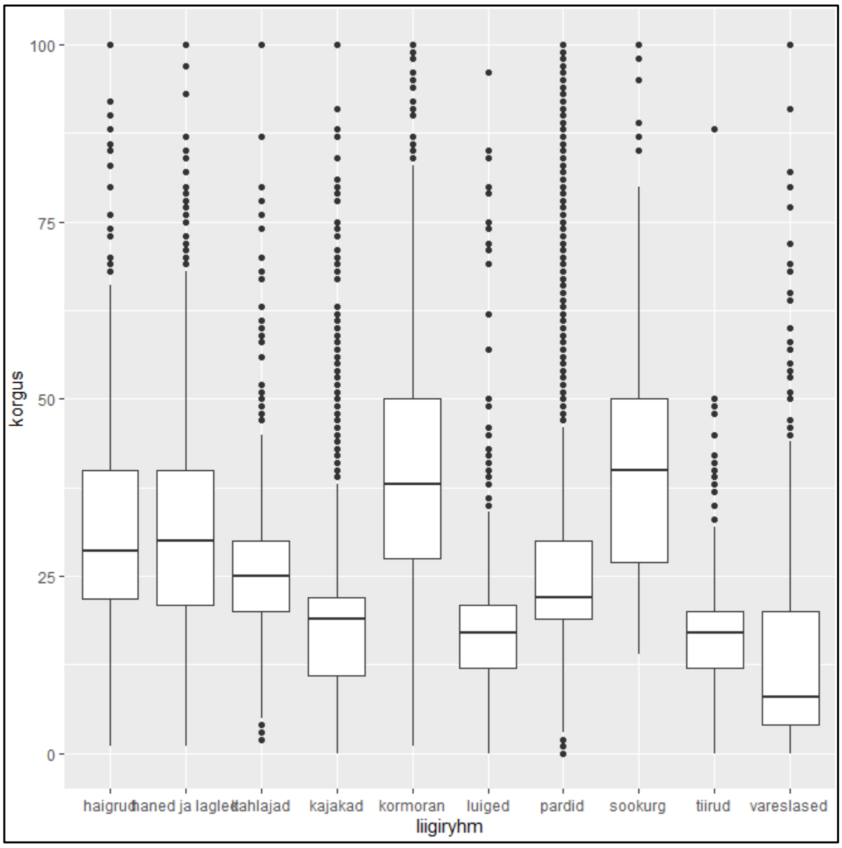


Figure 17. Flight altitude of different species groups according to data of visual observations.

A thorough analysis of the relationships between altitude and weather conditions is beyond the scope of this study. Additive models show the relationship between flight altitude (at night and in higher air layers) and air humidity, wind direction and wind speed (p <0.001).

3.5. Flight intensity above the power line and its dynamics

Both local birds, staging or nesting in the strait, and birds from elsewhere (flying over non-stop) fly above and in the vicinity of the power line. Bird flight intensity and its dynamics were analyzed using visual observations and vertical radar data. The data of the first method characterize the flight intensity during the day in the lower air layers, the data of the second method characterize the flight intensity in the higher altitudes and dark times. The data of visual observations are more accurate and allow us to take into account the number of individual birds, in the case of vertical radar we can only use the number of tracks (the number of individuals in flocks cannot be distinguished). In both cases, the data show the number of flights, not necessarily the sum of the number of individuals crossing the line (birds staging and nesting in the strait may have crossed the line repeatedly).

3.5.1. Seasonal dynamics

The number of birds recorded per day during visual observations is shown in Figure 18. Only data from complete census days (censuses lasted approximately from sunrise to sunset) are taken into account.

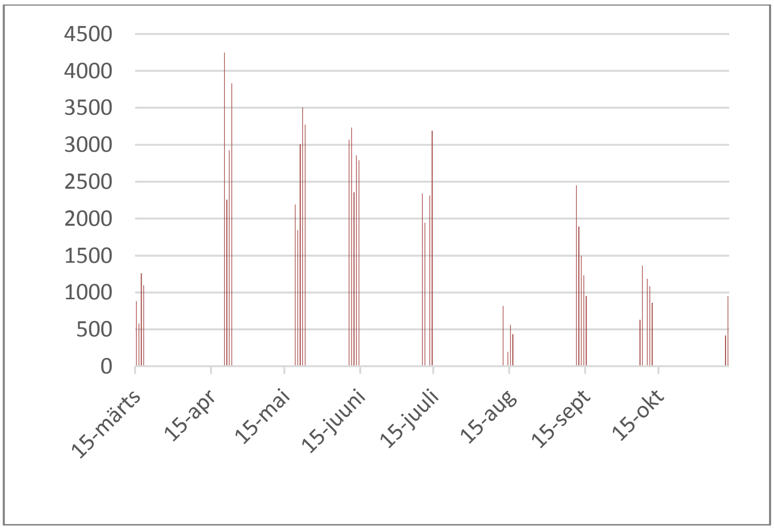


Figure 18. Number of birds registered during visual observations per day.

The number of birds registered per day is affected by both the hourly flight frequency and the number of observation hours. As expected, the increase in the number of observation hours lead to an increase in the number of birds recorded (Figure 19).

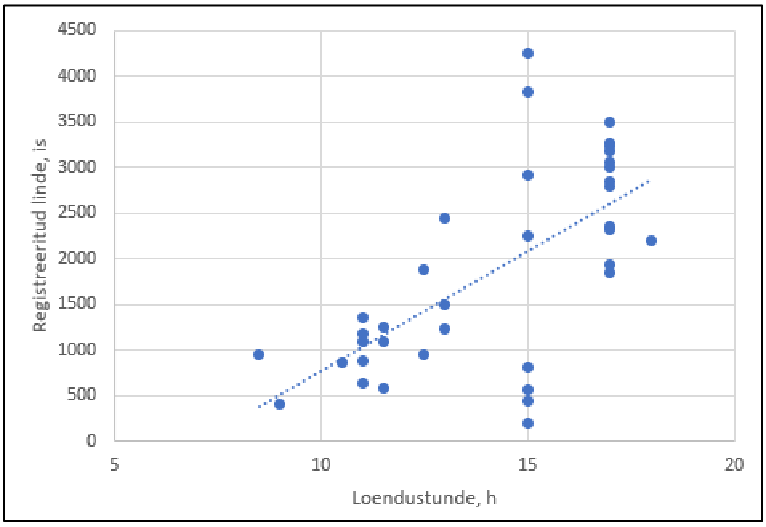


Figure 19. Relationship of the number of counted birds (Y axis) and the number of counting hours (X-axis) (full counting days only).

Describing the flight intensity hourly allows, in addition to taking into account the possible impact of the length of the census day, also the use of all available data (for census days, only complete census days are comparable).

The intensity of the flight per hour depends on the season, time and weather conditions. Based on the additive model, the month, time, and their combined effects were statistically significant in visual observations (all p <0.001) and explain approximately three-quarters of the variability in flight intensity (Figure 20).

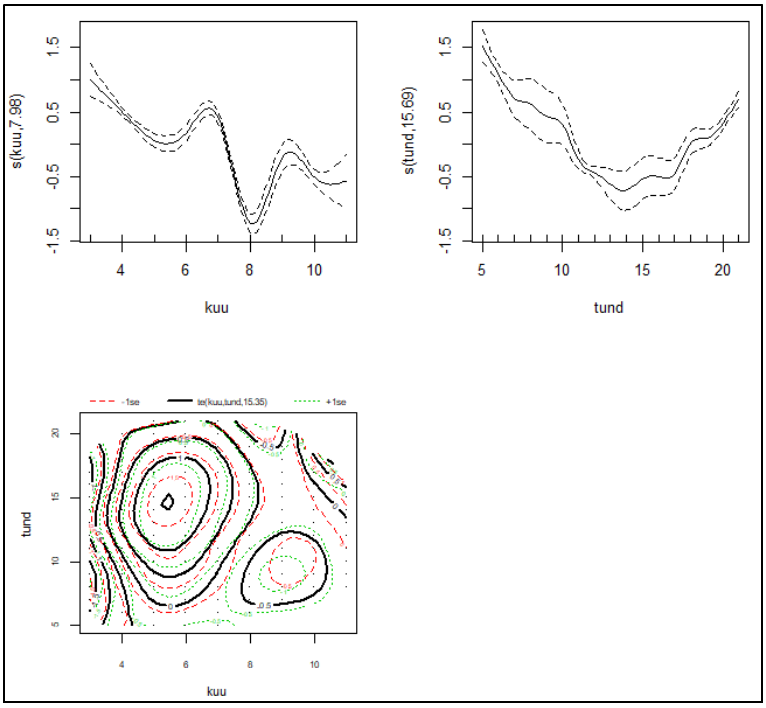


Figure 20. Dependence of bird flight intensity on the month and time as recorded by visual observations (the upper figures show a continuous line of the additive model with a 95% confidence interval, the lower figure illustrates the combined effect of the month and time).

The average daily and hourly flight intensity of birds during visual censuses in different census cycles is shown in Figure 21. Based on both the additive model and average census results, flight intensity was high in spring and first half of the summer, and decreased to minimum in August (and increased again in the fall).

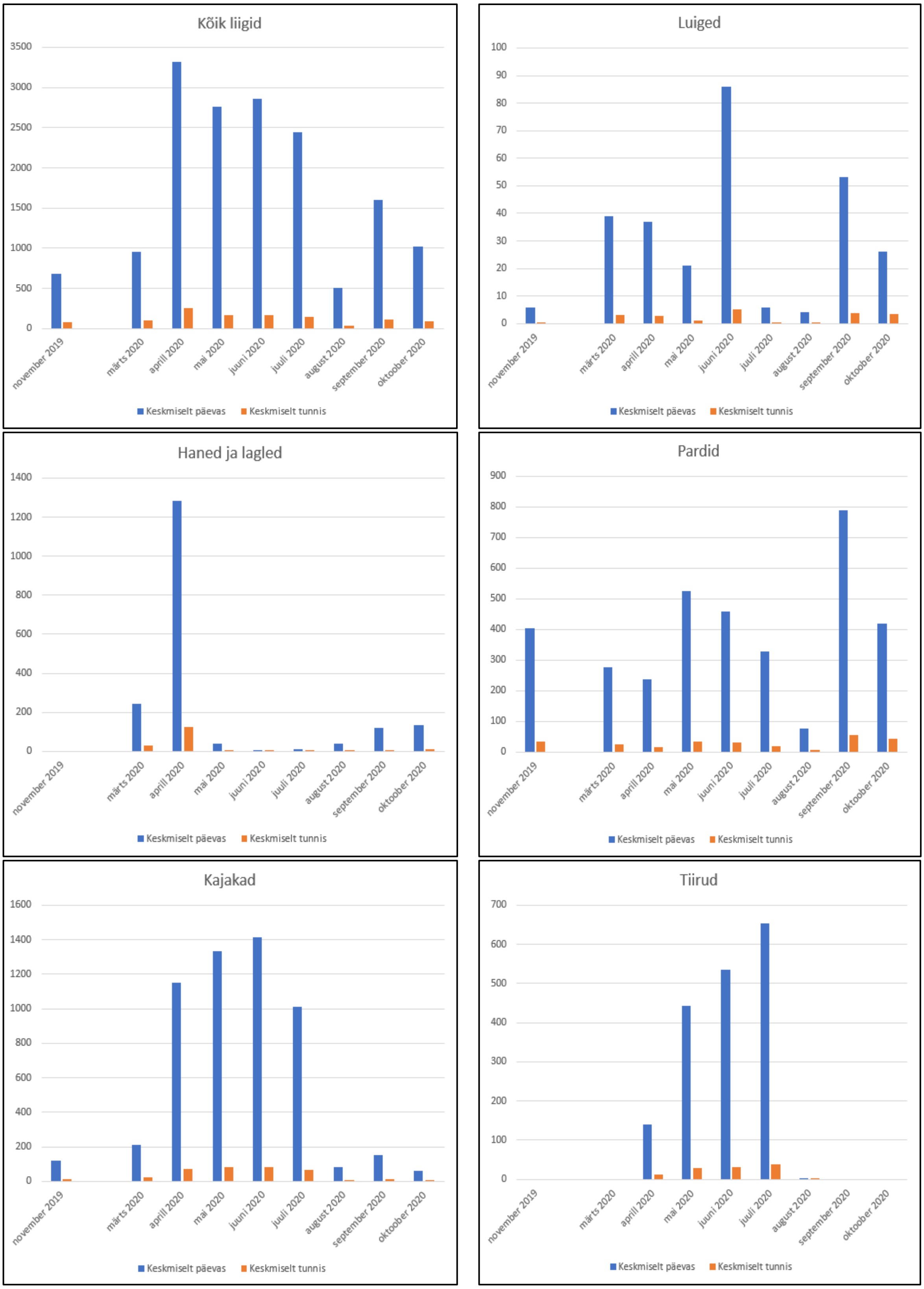


Figure 21. Mean flight intensity (per day- blue, per hour- orange) of birds by visual observations (all birds, swans, geese, ducks, gulls, terns).

Seasonal differences in flight intensity during daytime (visual observations) are different for different species groups (Figure 21). The flight intensity of swans was highest in June, and that of geese in April. The flight of gulls was more intense from April to July and the flight of terns from May to July. In both groups, it coincides with the breeding season. The flight intensity of ducks was the most even in different months, the maximum was reached in September and the minimum in August.

In the higher altitudes and at night, the month and time were also statistically significant, the flight intensity during the day differed from at night (all $p < 0.001$; Figure 22)

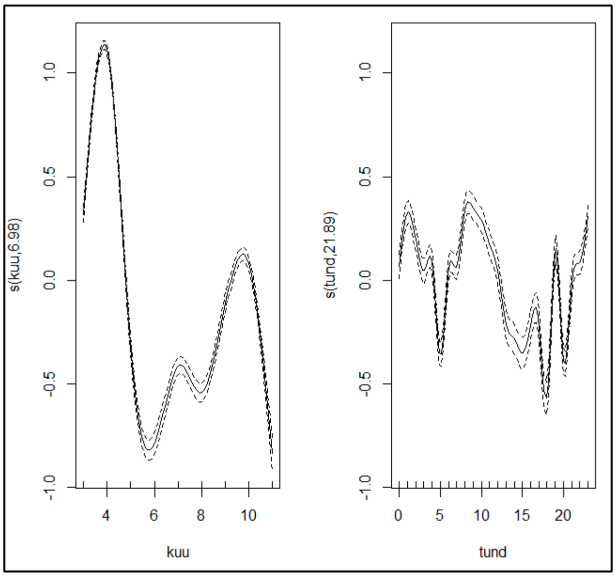
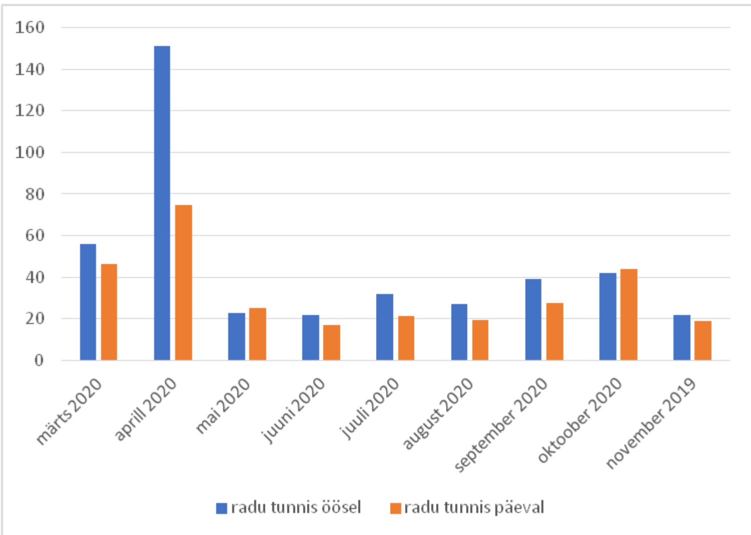


Figure 22. Dependence of the flight intensity of birds on the season (month; left) and time of the day (right) according to the vertically operating radar data (additive model with 95% confidence intervals).

The average hourly flight intensity of birds according to vertical radar data is shown in Figure 23. Based on both the additive model and the average census results, the flight intensity peaked in April, decreased in early summer and then started to increase again.



Joonis 23. Mean flight tracks per hour from vertically operating radar; blue – night; orange – day.

3.5.2. *Diurnal dynamics*

During the day, the general pattern was the high intensity of the flight in the morning, the decrease of the intensity to a minimum in the afternoon and the new increase in the evening (Figure 20). The mean flight intensities per hour for visual observations grouped by month and season are shown in Figure 24.

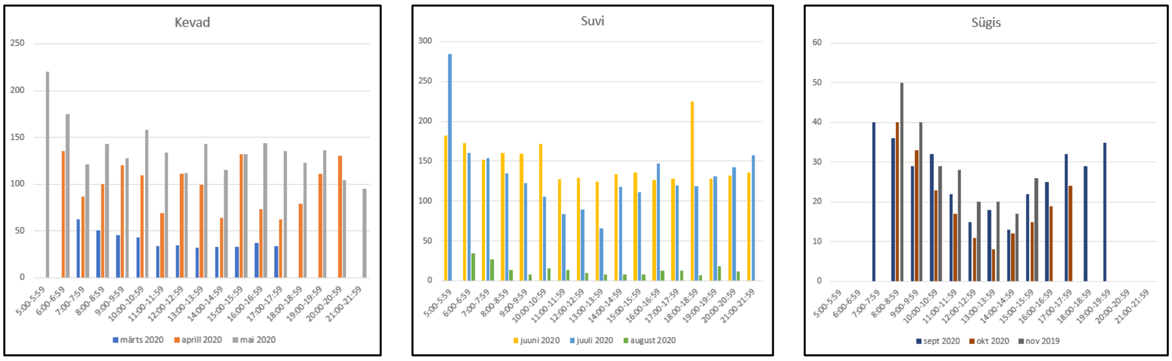


Figure 24. Mean number of individuals counted per hour during visual observations in spring, summer and autumn.

According to the data of the vertically operating radar, the morning and evening maximum and the midnight and noon minimum can also be observed during the day (Figure 22). The average number of flight paths per hour for vertically operating radar is shown in Figure 25 (night and day are not distinguished as this would split the morning and evening hours in half and give the impression of an apparent decrease in the number of tracks). The number of tracks registered at night and day differed the most in April due to intensive night migration (Figure 12). A maximum of 263 tracks per hour at night (April 22, 23:00-23:59) and 209 tracks during the day (April 20, 10:00 - 10:59) were recorded using vertically operated radar.

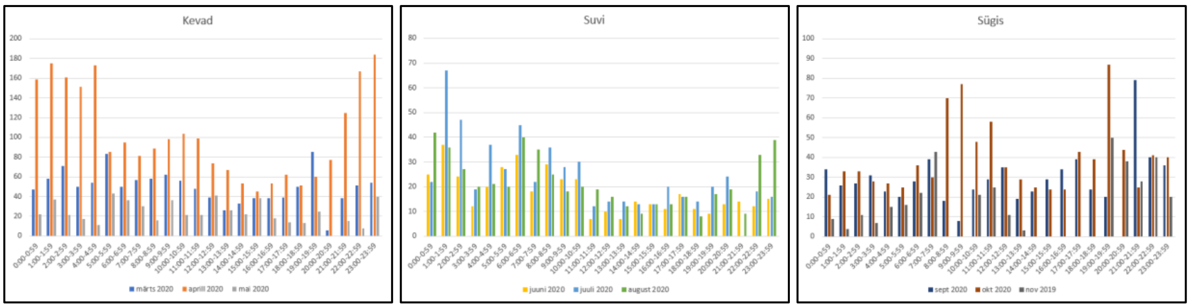


Figure 25. Mean number of flight paths per hour according to vertical radar data in spring, summer and autumn.

3.5.3. *Impact of the weather*

A detailed analysis of the relationship between flight intensity and weather conditions is beyond the scope of this work. Additive models show the relationship of flight intensity with air temperature, humidity and wind speed, in the lower altitudes and during the day also with wind direction (p <0.001 in all cases).

3.6. Behavioural reactions close to the power line, collisions

A power line is an artificial structure that differs from natural objects. While bird can distinguish the towers as an analogue of trees, the wires have no natural counterpart. There is a particular conflict with normal natural conditions when the line is located in the open landscape, where birds do not normally expect natural obstacles and the airspace should be free. In this case, the bird's sensory abilities, in particular vision, must help to avoid the collision.

When approaching a line, the need to respond to it depends on the bird's initial flight altitude and the flight direction relative to the power line. It is not necessary to increase the flight altitude for birds crossing the line high above. Birds (such as crows) that are constantly operating in the area can successfully avoid the line by flying from below the conductors.

The frequency distribution of different behavioural reactions of birds recorded by visual observations is presented in Table 10. September and October 2020 are not included in the sample, as the power line was already (partly) reconstructed at that time - some wires were removed in September and line markers were installed in October.

Table 10. Behavioural responses of birds to the power line by species group based on visual observations between November 2019 and August 2020 (number of individuals).

Behaviour	Herons	Geese	Waders	Gulls	Cormorant	Swans	Other species	Ducks	Common Crane	Terns	Crows	Total	Proportion %
No response	161	328	224	4694	667	117	514	1708	47	662	785	9907	51,3
Adjusting flight height in distance	105	125	137	2106	156	198	164	2546	10	684	146	6377	33,0
Adjusting flight height close	13	45	34	1021	32	80	51	552	2	336	42	2208	11,4
Avoiding power line with adjusting horizontal flight direction	4	11	8	132	8	59	18	110	3	34	16	403	2,1
Flight parallel to the power line	7	12	1	62		10	22	35	6	6	60	221	1,1
Landing on tower or wire				4			6				171	181	0,94
Collision, but bird continue to fly				5		2	1	5		1	1	15	0,08
Collision, bird falling or landing			1	1		11		2				15	0,08
Proportion of collision events	0	0	0,25	0,07	0	2,7	0,13	0,14	0	0,06	0,08	0,16	

In half of the cases (51.3%) the birds did not respond to the presence of the power line. Most of them were individuals crossing the line at a safe height. One third of the birds that originally flew at or below the level of the line or started flying from the water level adjusted their flight altitude in time. This shows that they saw the power line early and prepared carefully to cross it. The rapid change of flight altitude near the power line took place in slightly more than a tenth of the cases (11.4%). This is dangerous, but proved to be mostly successful, as only 0.16% of the birds came into physical contact with the wire. The majority of birds showing dangerous behaviour were gulls and terns. The usual habit of gull(s) was to approach the power line at the height of wires and change the altitude quickly, "jumping" over the earth wire or manoeuvre between wires.

The breakdown of different options chosen by birds is presented in Table 11.

Table 11. Options for crossing the power line by monthly visual observations from November 2019 to October 2020 (number of individuals). Dangerous choices are on the shaded background.

Way of crossing the power line	**November 2019**	**March 2020**	**April 2020**	**May 2020**	**June 2020**	**July 2020**	**August 2020**	**September 2020**	**October 2020**	**Total**	**Proportion, %**
Crossing over the earth wire	1019	2030	3100	2453	2399	2045	1012	1626	1370	17054	77,6
Between earth wire and upper conductor	11	40	185	209	358	210	53	46	15	1127	5,13
Between conductors	26	57	95	100	219	109	29	5	6	646	2,94
Between wires (details unclear)	14	6	2	28	15	38	5	2	1	111	0,51
Below lower conductors	85	348	638	571	612	517	94	102	50	3017	13,7
Proportion of dangerous flights	4,4	4,2	7,0	10,0	16,4	12,2	7,3	3,0	1,5		8,58

As expected, more than three-quarters (78%) of birds were flying over the power line and also avoided the thinner ground wire. 8.6% of birds flew between wires, which is more dangerous way to get to the other side of the power line than other options. Seasonal dynamics are clearly observable. The share of dangerous flights was the largest between May and July. This coincides well with the breeding season of terns and gulls. Flight data by species group are presented in Table 12.

Table 12. Options for crossing the line by species group based on visual observations November 2019 to August 2020 (number of individuals). The dangerous choices are on the shaded background.

Way of crossing- the power line	**Herons**	**Geese**	**Waders**	**Gulls**	**Cormorants**	**Swans**	**Other species**	**Ducks**	**Common Crane**	**Terns**	**Crows**	**Total**
Crossing over the earth wire	269	487	373	5278	854	270	581	4504	61	1007	374	14058
Between earth wire and upper conductor	5	4	9	488	1	64	27	166	1	277	24	1066
Between conductors	2	3	2	305	2	50	44	48		115	64	635
Between wires (details unclear)	2	2	4	36	1	5	4	22		23	9	108
Below lower conductors	3	5	11	1777		41	85	113		267	563	2865
Proportion of dangerous flights	3,20	1,80	3,76	10,5	0,47	27,7	10,1	4,86	1,61	24,6	9,38	9,66

On average, every tenth bird (9.7%) flew between the wires when heading to the other side of the power line. Swans performed the most dangerous flights between wires, as much as 28%. This also explains the high mortality of swans. About a quarter of the flights of terns also passed through the airspace between the wires, but their frequency of collisions remained relatively low (Ch 3.7.).

3.7. Power line victims and fatality estimation

A summary table of collision victims is presented in Annex 3, collided birds grouped by ecological or systematic group in Table 13.

A web-based calculator (Bioinsight, 2018) was used to calculate the mortality and total number of fatalities and the associated correction factors, following models with known properties published in the scientific literature (Bernardino et al., 2012). References are provided for each model used.

3.7.1. Number of found carcasses

A total of 145 dead birds belonging to 19 species were found with 20 searches in the entire study period from September 2019 to October 2020 (Table 13). The table distinguishes the period before the start of the power line reconstruction activities.

Table 13. Number of found carcasses.

Group of birds\ season (No. of searches)	**Autumn 2019** (4)	**Spring 2020** (6)	**Summer 2020** (6)	**Total before reconst-ruction** (16)	**Autumn 2020** (4)	**Grand total** (20)
Swans total	5	18	5	28	3	31
Ducks total	18	21	4	43	4	47
Ciconiformes total	0	0	0	0	1	1
Gruidae total	1	0	0	1	2	3
Waders total	1	0	1	2	0	2
Gulls and terns total*	17 (3)	10 (3)	31 (4)	58 (10)	2 (1)	60 (21)
Corvidae total*	1 (0)	0	0	1 (0)	0	1 (0)
Total	43 (28)	49 (42)	41 (14)	133 (84)	12 (11)	145(105)

* Gulls, terns and crows – number of found carcasses used in models is in brackets, all other individuals found were classified as traffic victims.

Ten individuals of five protected species were found as follows:
Common Shelduck (protection category III) - 1 individual;
Greater Scaup (breeding population: prot. category II) - 2 ind.;
Smew (protection category II) - 2 ind.;
Baltic Dunlin (subspecies schinzii I category) - 1 ind.;
Common and/or Arctic Tern (both III protect. category) - 4 ind.

3.7.2. Results of the scavenger test, carcass persistence

The empirical results of the scavenger are shown in the left graph of the Figure 26. During the first two days, the predators did not remove any placed birds from the study area. After five days still 82% and after 25 days 64% of carcasses persisted. Other studies have found that after the placement predators reduce the number of test corpses logarithmically - faster in the first days of the trial and at a decreasing rate as the test progresses (Costantini et al., 2016; Ponce et al., 2010).

According to Bispo et al. (2013) model, the *S(t)*, the survival probability of bird carcasses[2] placed in the Väike Väin Strait study best corresponded to the exponential function (*AIC*

[2] $S(t) = P(T > t)$ function represents the probability that a subject survives from the time origin to some time beyond t.

Exponential 72.65859, *AIC Weibull* 73.15702, *AIC Log Logistic* 77.28310, *AIC Log Normal* 76.90557)[3] (Figure 26).

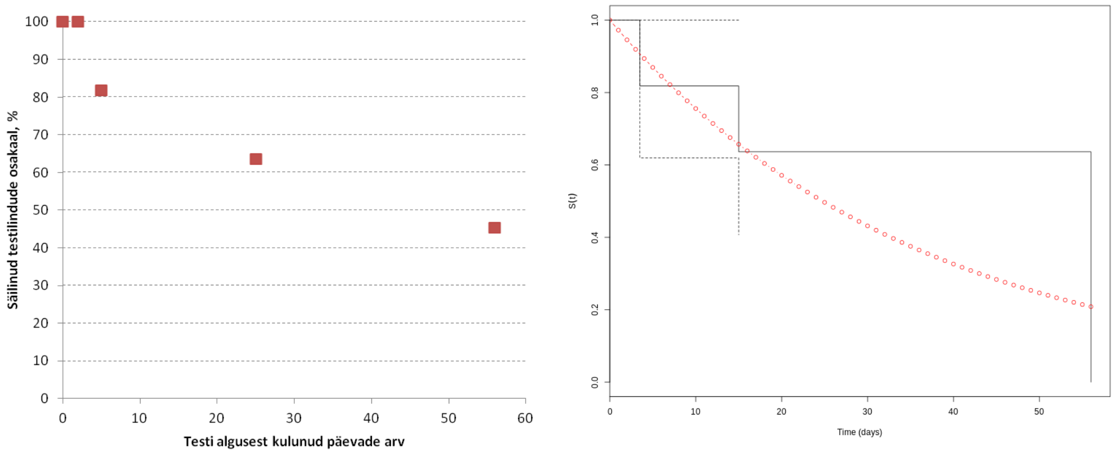


Figure 26. Carcass persistence probability. Empirical proportion of persisting carcasses (left graph) and modeling carcass removal times using parametric survival analysis with the best fitting parametric exponential model (Bispo et al., 2013) (right).

The average probability of carcass survival was 0.92 for the 5-day search interval and 0.71 for a 25-day search interval.

The mean survival time was 56 (SE ± 15; lower 95% confidence limit 26.6, upper 95% confidence limit 85.4) days.

Unusually long detectability of bird carcasses on study site is likely to be due to two factors: (1) the scavenger test used predominantly large and medium-sized birds, parts of which remain detectable longer; (2) the road embankment bounded by the sea on both sides has less mammal predators than is normal in natural habitats. The survey of the Tartu-Viljandi-Sindi 330/110 kV power line took place in an agricultural landscape where predation pressure was higher and resulted with the mean detection time of test carcasses 23 days in autumn (Volke, 2017).

3.7.3. Search detection probability

In the searcher efficiency test, the searcher found three of the 11 carcasses placed. The result was calculated using binomial mixed models and 95% confidence limits were found based on the beta distribution (Korner-Nievergelt et al., 2014).

Searcher performance (detection probability) p = 0.27 (LCL 95 = 0.09; UCL95 = 0.57).

As only part of the area was searched (the rest was reedbed and water), the probability that bird will fall into the searched area (a) must be calculated. In this case, the probability of finding the animal is $p' = p \times a$;

[3] The values for Akaike's Information Criterion (AIC) were used to compare the models' relative fit. The best parametric distribution assumption was taken according to the lowest AIC value.

Visual observations and camera recordings revealed on the basis of 16 collision events that 7 birds fell in an area where the searcher could find them, in 9 cases the birds fell into reeds or water. Therefore:
a = number of birds in the search area / number of all events analyzed = 7/16 = 0.4375;

a is multiplied by the searcher efficiency factor to obtain the carcass detection probability (denoted p') for use in the models;

$p' = p \times a = 0.27 \times 0.4375 = 0.118$.

3.7.4. Fatality estimations

The Huso (2010) model was used to estimate the number of fatalities. The estimates are presented in Table 14 and the daily mortality rates generated by the model in Figure 27.

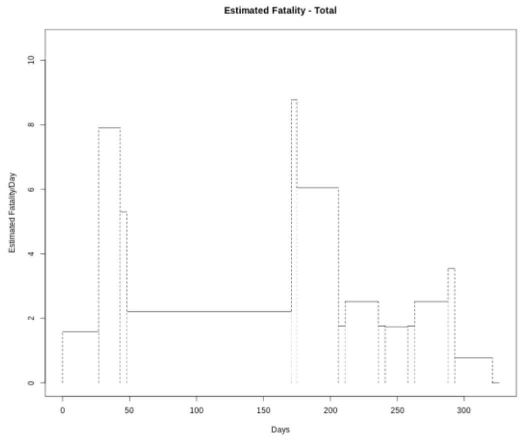
Table 14. Fatality estimates according to Huso (2010) before the reconstruction of the power line (original power line configuration).

	Number of searches Sept 2019 - Aug 2020	Carcasses found	Estimation of fatalities according to Huso (2010)
All birds	16	83	996
Swans	16	28	384
Ducks	16	43	472
Other species (swans, ducks, Lesser Black-headed Gull and Raven excluded)	16	11	119
Protected species*	16	10	103
Species listed as conservation objective of the Väike Väin Limited Conservation Area**	16	43	548

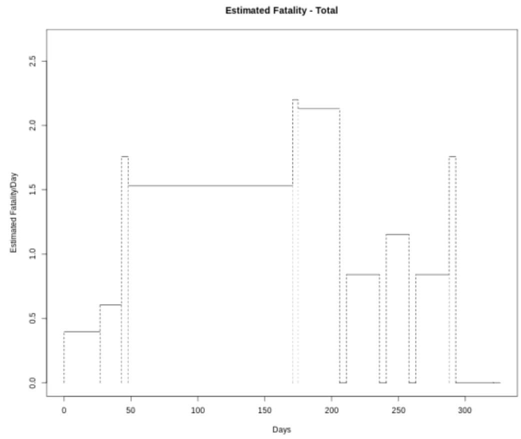
* protected species: Shelduck (Cat III), Greater Scaup (breeding population Cat 2), Smew (Cat. II), Dunlin (subspecies *schinzii* CAT. I), Common Tern (Cat. III);

** Species listed as conservation objective of the Väike Väin Limited Conservation Area: Mute Swan, Wigeon, Tufted Duck, Long-tailed Duck, Goldeneye, Lapwing, Dunlin, Common Tern, Black-headed Gull.

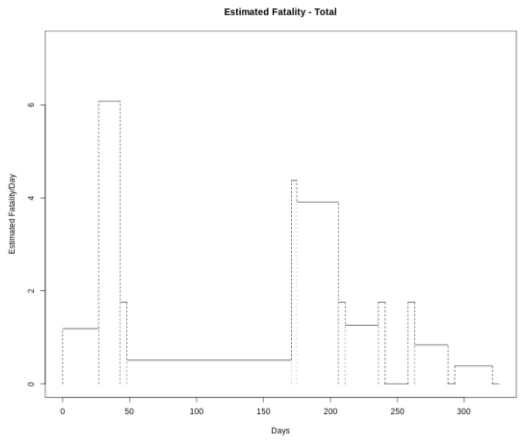
According to the model used, in the pre-reconstruction period, about a thousand waterbirds died on the 3.6 km long 2*110 kV overhead line section of the Väike Väin Strait per year. Ducks and swans were most seriously affected. Approximately 100 individuals of protected species were estimated to die annually, as well as more than 500 individuals of species listed as conservation objectives of the protected area.



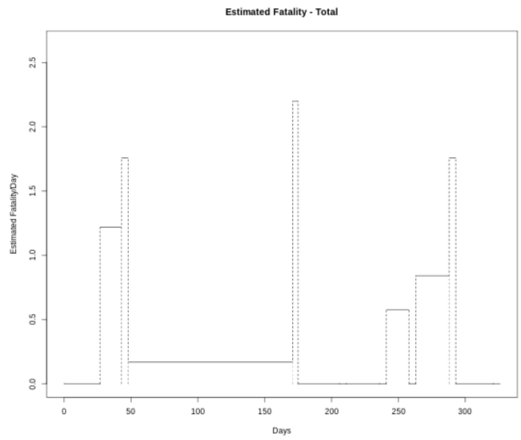
All species



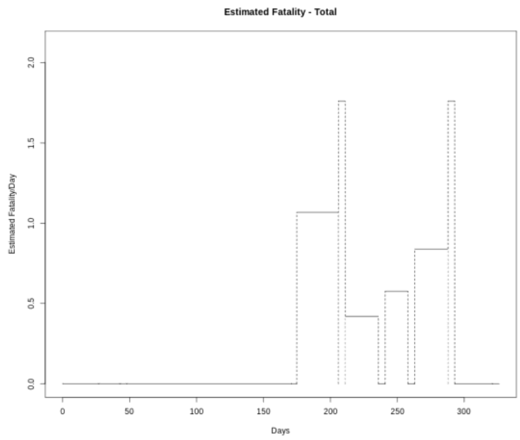
Swans



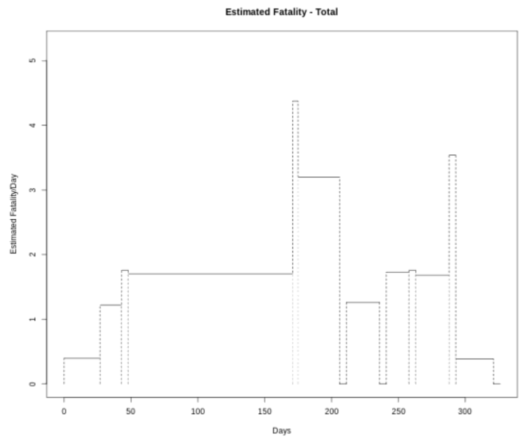
Ducks



Other species



Protected species



Target species - conservation objectives of the site

Joonis 27. Daily fatality estimations according to Huso (2010) (No. of collisions per day).

Summary, conclusions and recommendations for next steps

From September 2019 to December 2020, the Estonian Ornithological Society conducted a study "Integrated study on the impact of power lines on the Väike Väin Strait dam on birds" on the basis of a procurement contract concluded with AS Elering. The aim of the study was to explain the impact of the high-voltage overhead line crossing the Väike Väin Strait on the birds and to plan science-based mitigation measures, which can be taken into account during the reconstruction of the power line.

The main results and conclusions of the study are as follows:

1. In 2019, taking into account the data of the scientific literature and the results of the first fieldwork period, the report "Recommendations for the reconstruction of the power line with the aim to reduce the mortality of birds" was prepared (Volke, Kuus, 2019).

2. The Väike Väin Strait is an important staging and nesting area for waterbirds. The site has retained its international importance. In this project, a total of 65,689 individuals of 57 species, including 28 protected species, were counted as staging in the vicinity of the dam and power line. The number of staging birds was higher during the autumn and spring migration periods, with a maximum in October. The sea area southeast of the dam (Gulf of Riga) was more important for waterfowl.

3. The 2*110 kV overhead power line is located on regular flight paths of birds. Visual observations recorded 96,482 individuals of 99 species flying above and in the vicinity of the power line. Both the radar survey and the visual observations confirmed that the power line acts as a barrier to the movement of birds. The flight altitude of birds was higher at night than during the day, the differences in altitude were especially noticeable during the spring and autumn migration periods. The lowest flight altitude in the area directly affected by the power line was the preferred flight altitude for swans, terns, gulls and crows. The flight intensity of birds was high in spring and the first half of summer, decreased to a minimum in August and increased again in autumn.

4. The behavioural responses of birds when approaching the power line were different. Dangerous behaviour, which we considered a sudden change in flight altitude near the power line, occurred in about a tenth of the cases (11.4%). 0.16% -of the birds came into physical contact with the wire, half of latter died. 8.6% of birds used the most dangerous way to cross the power line and flew between wires. Considering only the pre-reconstruction period, the highest risk events constituted 9.7%.

5. The direct impact of the overhead power line on birds was assessed by periodic searching for bird carcasses. During the study period (September 2019 to Oct 2020), a total of 145 dead birds (or their remains) of 19 species were found with 20 searches.

6. Using correction factors and data modeling, it was found that about a thousand waterbirds, including about 100 individuals of protected species have collided and died annually on the 3.6 km stretch of the 2*110 kV power line crossing Väike Väin Strait.

7. The high mortality rate of waterbirds caused by the power line has a significant negative impact on the integrity of the Väike Väin Limited Conservation Area and the Väinameri Natura 2000 SPA, and on the species listed as conservation objectives of abovementioned sites. The work did not address the negative effects of the power line barrier effect, which causes the prolongation of bird flight paths and the additional energy consumption associated with repeated crossing of the line.

8. In the autumn of 2020, the power line was reconstructed (one 110 kV circuit removed) and the ground wire and lower level conductor wire were marked with two types of line markers (FireFly Bird Flight Diverters and RIBE markers) in accordance with the guidelines prepared in 2019 (Volke, Kuus, 2019). As the reconstruction of the power line section was completed only in October, at the end of the last fieldwork phase, the post-construction impact of the power line (and efficiency of line markers) cannot be assessed in this study.

Recommendations for further action

1. In order to quantify the post-construction impact of the power line on birds, it is appropriate to carry out a follow-up study in 2021 or 2022, lasting six months (March to August). The methodology must not be changed substantially.

2. The follow-up study will provide important information on the effectiveness of the line markers and the layout scheme used on the Väike Väin Strait power line. This knowledge can be used when planning to reduce the bird mortality in other critical sections of the transmission network in the future.

3. Given the high nature conservation value of the Väike Väin Strait and the high frequency of waterbird's flights over the power line, the presence of the power line itself is unfavourable to birds (barrier effect) and deteriorates habitat quality, even with (possibly) low mortality rates. Therefore, it is also justified to remove the power line without follow-up study.

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Annexes

Annex 1. Terms of reference (technical description)

Elering AS lihthange „Kompleksuuring Väikese Väina tammil paiknevate elektriliinide mõju kohta lindudele II“ (viitenumber 212251)

Elektriliinide mõju Väikese väina pesitsevatele, peatuvatele ja läbirändavatele lindudele eriti veelindudele - kompleksuuring ja soovitused mõjude leevendamiseks.

Tehniline kirjeldus

1. Eesmärk

Kompleksuuringu eesmärgiks on kvantitatiivselt hinnata Elering AS-ile kuuluvate 110 kV elektriõhuliinide mõju Väikese Väina linnustikule nii peatuvate kui läbi rändavate lindude osas, hinnata elektriliinide poolt põhjustatud lindude suremust Väikese Väina tammi piirkonnas kasutades erinevaid metoodikaid (radaruuringud, laserkaugusmõõtmine, visuaalvaatlused, hukkunud lindude otsingud ja kaamerauuringud). Uuringu alusel tuleb koostada soovitused elektriliini negatiivsete mõjude leevendamiseks linnustikule.

2. Töö kirjeldus

Uuring tuleb läbi viia Elering AS-i omandis olevale kaheahelalisele 110 kV õhuliinile, mis asub riigimaantee nr 10 osaks oleva Muhu ja Saaremaad ühendava Väikese Väina tammi kõrval (vt. Lisa 1. Asukohakaart). Uurimisalaks on eelnimetatud veekoguga ristuv 3 km pikkune elektriliini lõik ja seda ümbritsev veeala. Õhuliini puhul on tegemist kaheahelalise 110kV õhuliiniga, mille tammipoolsel küljel paiknev ahel on L172A Tusti – Orissaare ning tammist väljapool paiknev ahel on L173 Võiküla – Orissaare.
Töös tuleb elektriliini mõju mõõtmiseks linnustikule kasutada erinevaid metoodikaid ning töö jaotub järgmisteks mooduliteks:

1. Radaruuring koos visuaalvaatlustega ning öise audioseirega;
2. Õhuliinides hukkunud lindude otsingud koos õhuliini poolt põhjustatud suremuse hindamisega;
3. Õhuliini seiramine kaameratega;
4. Õhuliini ümbritseval märgalal peatuvate veelindude visuaalsed loendused;
5. Andmeanalüüs, koondaruande ja soovituste koostamine elektrikõrgepingeliini mõju leevendamiseks.

2.1 Radaruuring koos visuaalvaatlustega ning öise audioseirega

Kasutatava radarsüsteemi abil peab olema võimalik tuvastada ja klassifitseerida lendavad linnud õhuruumis. Kasutada tuleb rahvusvaheliselt aktsepteeritud metoodikat[1], kasutades radarit nii horisontaalses kui vertikaalses positsioonis eri sessioonide kaupa[2]. Lennukõrguste registreerimiseks kasutatakse laserbinoklit (näiteks *Rangefinder Vector* või analoogsed seadmed). Horisontaalses positsioonis olev radar peab suutma salvestada lindude teekondade trajektoorid ning vertikaalasendis üle lendavate lindude lennukõrgused. Lindude lennukauguse ja –kõrguse määramine radariga võib toimuda samaaegselt kui radari tehniline lahendus võimaldab üheaegset tööd nii vertikaal- kui ka horisontaalteljel.

Kasutatav radarsüsteem peab tuvastama lindude lennuaktiivsuse reaalajas, suutma ühendada tuvastatud lindude asukohapunktid automaatselt nende ajalises järgnevuses üheks

[1] Kahlert, J., Leito, A., Laubek, B., Luigujõe, L., Kuresoo, A., Aen, K., 2012. Factors affecting the flight altitude of migrating waterbirds in Western Estonia. Ornis Fennica, 89 (4), 241–253.
[2] Leito, A., 2010. Sõitjate ja veoste üle Suure Väina veo perspektiivse korraldamise kava koostamine ja keskkonnamõjude strateegiline hindamine. Linnustiku uuring. Eesti Maaülikool, 119 lk.

lennuteekondadeks ja salvestama need andmebaasi vektorobjektina (lennuteekond ja selle teekonnapunktid) ja andmetabelina, milles on salvestatud mõõdetud parameetrite väärtused. Iga üksiku tuvastatud linnu või linnuparve kohta tuleb salvestada järgmised parameetrid: lennukiirus (m/s), tuvastatud lennuteekonna pikkus (m) ja lennusuund (kraadides). Andmeside abil peab olema võimalus kõik vastaval ajahetkel tuvastatud lindude lennuteekondade kuvamine välioludes kasutatavale arvutikekraanile võimaldamaks teekondade kasutamist visuaalvaatlusi tegevate ornitoloogide poolt. Võimalikult paljude lennuteekondade puhul püüda binoklit ja vaatetoru kasutades tuvastada radarjälgitava linnu liik, isendite arvukus ja käitumuslik reaktsioon elektriliinide suhtes. Öisel perioodil toimub liikide tuvastamine audioseire abil kasutades suundmikrofoni ja salvestusseadet. Radarvaatluste ajal tuleb kasutades automaatjaama koguda andmed õhurõhu [hPa], õhutemperatuuri [°C], tuule kiiruse [m/s] ja -suuna kohta [asimuudi kaarekraad]. Linnuradari abil tuleb salvestada ka andmed sademete kohta, mis väljendakse radari tööraadiusest sademetega kaetud ala osakaaluna üldpinnast. Vastav näitaja tuleb arvutada iga radari töötunni kohta. Kogu radarvaatluste perioodi jooksul tuleb mõõta keskkonna valgustaset [lux] kasutades luksmeetrit.

Radaruuringu periood peab katma perioodi alates märtsist (kaasa arvatud) kuni novembrini (kaasa arvatud). Ühes kuus tuleb radarvaatlused koos visuaalvaatluste ja öise audioseirega läbi viia vähemalt kuuel (6) ööpäeval. Rändeperioodil on soovitav võimaluse korral valida radarvaatluste periood eeldatavalt rändeks sobiva ilmastikuga päevadele. Kahe radaruuringu perioodi vaheline intervall peab olema vähemalt 6 ööpäeva.

2.2 Õhuliinides hukkunud lindude otsingud

Õhuliiniga seotud hukkunud või vigastatud lindude loendus-otsingud elektriliini all tuleb korraldada soovitavalt radaruuringutega samadel perioodidel (kahel päeval igal radarvaatluste perioodil) kogu Saaremaa ja Muhu vahelise lõigul. Otsingu käigus peab vaatleja märkima leiu asukoha koordinaadid, liigi, surma põhjuse (kokkupõrge elektriliini või autoga jne) ja muud selles kontekstis olulised tähelepanekud. Hukkunud linnu laip tähistatakse värviga ning fotografeeritakse.
Andmete kogumisel tuleb läbi viia test röövloomade poolt vaatlusperioodil hukkunud isendite kao hindamiseks. Analüüsil tuleb kasutada analoogsetes uuringutes kasutatavaid modelleerimise meetodeid.

2.3 Õhuliini seiramine kaameratega

Kameraseire eesmärgiks on välja selgitada tegelik lindude kokkupõrke ala elektriliinidega. Detailne automaatne avastamine tuleb läbi viia 2 kaamerajaamaga ühes visangus kogu radarvaatluse perioodi vältel 24h ööpäevas. Kaameraseire peab sisaldama süsteemi paigaldust ja seadistust, kaamerate töös hoiu ja hooldamise kulusid, IT rakenduse kulusid ja andmete järeltöötlust ning statistilise analüüsi ning lõpparuande koostamist. Kaameraseire andmed tuleb integreerida radar-, visuaal- ja audiovaatluste tulemustega.

2.4 Õhuliini ümbritseval märgalal peatuvate veelindude visuaalne loendused

Elektriliini ümbritseval märgalal peatuvate veelindude visuaalne loendused viiakse läbi soovitavalt igal radarvaatluse perioodil kahel päeval. Loendusel tuleb kasutada töös „Natura 2000 kaitsealade võrgustikku kuuluvate linnualade linnustiku seire ettepanek ja seirekava aastateks 2013-24“ (Eesti Ornitoloogiaühing, 2013) peatuvate veelindude rannikuloenduste metoodikat.

2.5 Andmeanalüüs, koondaruande ja soovituste koostamine elektriliini mõju leevendamiseks.

Andmeanalüüsi käigus tuleb kvantitatiivselt hinnata elektriliinide mõju Väikese Väina linnustikule nii peatuvate kui läbi rändavate lindude osas, hinnata elektriliinide poolt põhjustatud lindude suremust Väikese Väina tammi piirkonnas kasutades erinevaid metoodikaid (radaruuringud, laserkaugusmõõtmine, visuaalvaatlused, hukkunud lindude otsingud ja kaamerauuringud). Elektriliinide poolt põhjustatud suremust tuleb hinnata erinevatele liikidele, sarnase ökoloogia ja morfoloogiaga liigirühmadele erinevatel eluperioodidel (kevadränne, pesitsemine, suvised rändeliikumised ning sulgimisperiood, sügisränne). Eraldi tuleb hinnata elektriliini rekonstrueerimisega kaasnevat efekti ning alles jääva elektriliini poolt põhjustatud lindude suremust.
Uuringu alusel tuleb koostada soovitused elektriliini negatiivsete mõjude võimalikuks leevendamiseks ja likvideerimiseks.

3. Töö tegemise eeldus, üleandmine ja teostamise aeg

Töö teosaja peab olema varasemalt läbi viinud lindude rändealase uuringu või seire. Töö teostaja peab pakkumuses kinnitama vajalike tehniliste vahendite (radar, kaamerajaamad) olemasolu.

Töö tulemusena kogutud algandmed, koostatava analüüsi ja kaardikihtidega seotud kõik õigused antakse üle Tellijale. Aruanded, algandmed ja kaardikihid võib Tellijaga eelnevalt kooskõlastades (Tellija kirjalik nõusolek) teha kõigile kättesaadavaks avaandmetena KESE riikliku seire andmebaasis või Eesti Looduse Infosüsteemi (EELIS) keskkonnas. Ilma Tellija kooskõlastuseta on eeltoodud informatsioon konfidentsiaalne.

Koondaruanne tuleb tellijale esitada nii eesti kui ka inglise keeles.

Töö on jaotatud kaheks etapiks. Esimese etapi järgselt tuleb koostada ja Tellijale üle anda lihtsustatud vahearuanne (vaid eesti keeles), mis kirjeldaks etapi jooksul läbi viidud uuringuid, kogutud andmeid ning esmaseid järeldusi. Esimese etapi seiret (september-oktoober 2019) on lubatud korrata vastavalt vajadusele kuude kaupa ka 2020. aastal. Kordusseire teostamine 2020. aasta sügisel on lubatud vaid Tellija kirjalikku taasesitamist võimaldavas vormis nõusoleku olemasolul juhul, kui seire alguses esimestel kuudel kogutud andmete kvaliteet ei vasta loodetule ning andmekogumise metoodikat on tarvis kohendada või täiendada.

Töö eest tasumine toimub kahes osas vastavalt Lepingule.

Töö tuleb üle anda lõplikul kujul hiljemalt 15 kalendrikuu jooksul pärast hankelepingu sõlmimist.

Annex 2. Weather data (Viira Road Weather Station, Estonian Road Administration)

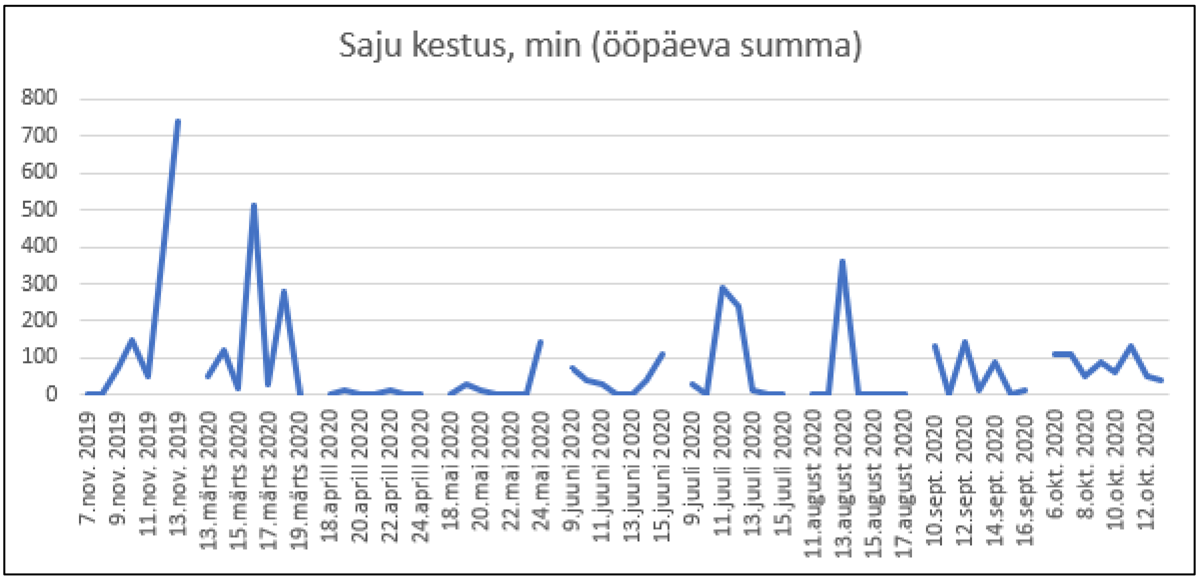

Figure L2-1. Duration of rain/snow during fieldwork cycles.

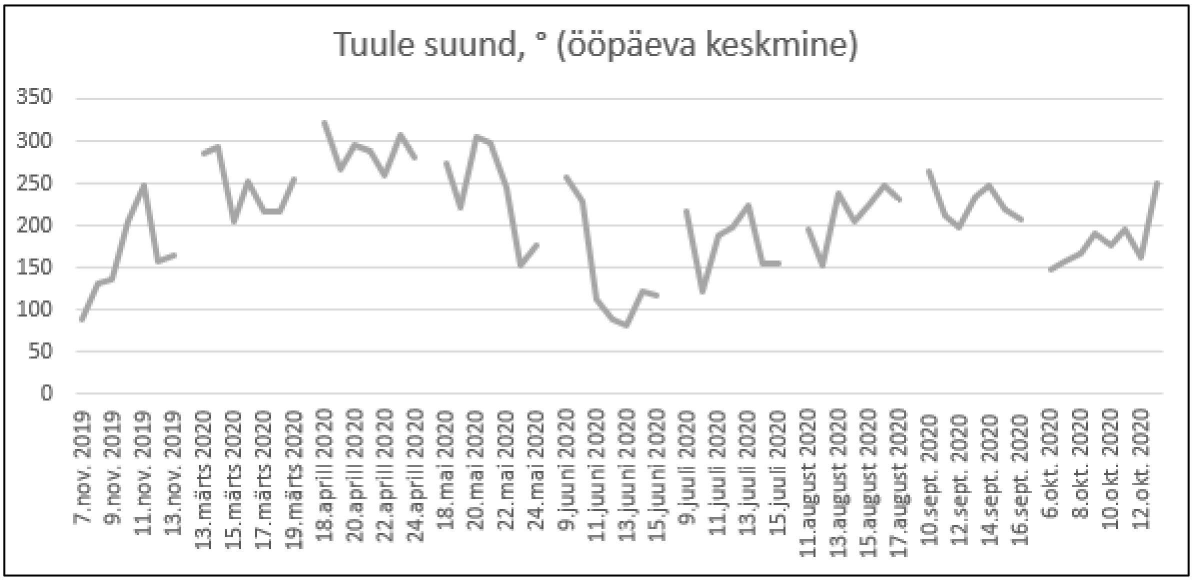

Figure L2-2. Average wind direction during fieldwork cycles.

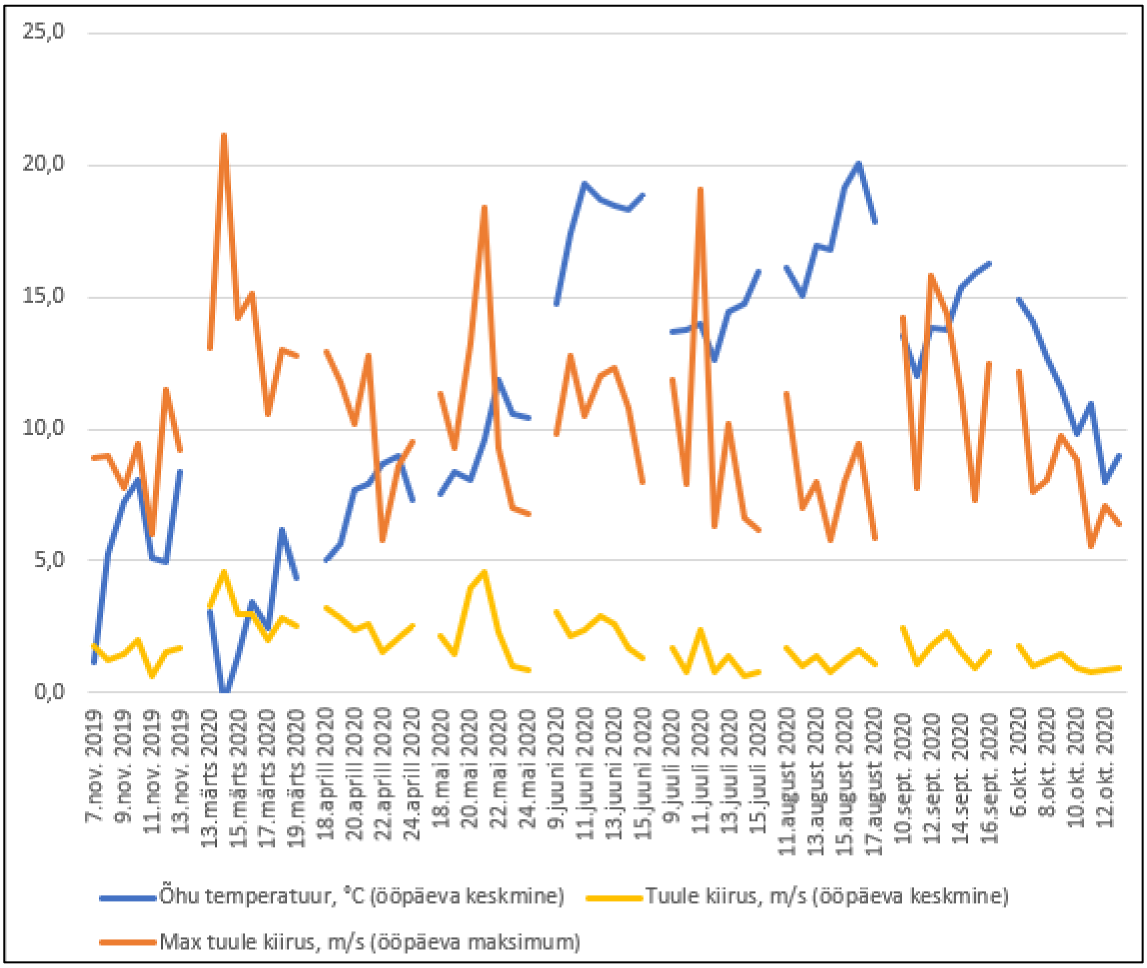

Figure L2-3. Values of weather parameters during fieldwork cycles.

Annex 3. Results of the carcass searches.

Species/Group	26.09. 2019	23.10. 2019	8.11. 2019	13.11. 2019	15.03. 2020	19.03. 2020	19.04. 2020	24.04. 2020	19.05. 2020	24.05. 2020	10.06. 2020	15.06. 2020	10.07. 2020	15.07. 2020	12.08. 2020	17.08. 2020	Total Before rec.**	11.09. 2020	16.09. 2020	7.10. 2020	12.10. 2020	Grand total
Mute Swan	1				1		1				2		1	1			7	3				10
Swan unidentif.	1	1	1	1	8	1	5		2				1				21					21
Swans total	2	1	1	1	9	1	6	0	2	0	2	0	2	1	0	0	28	3	0	0	0	31
Shelduck									1								1					1
Wigeon	1					1	1										3		1	1		5
Teal									1						1		2		1			3
Mallard	2	2	9	1	1		2		1								18	1				19
Dabbling ducks total	3	2	9	1	1	1	3	0	3	0	0	0	0	0	1	0	24	1	2	1	0	28
Tufted Duck	1		1				2			1		1	1				7					7
Greater Scaup							1	1									2					2
Long-tailed Duck							2										2					2
Goldeneye					1								1				2					2
Smew							2										2					2
Diving ducks total	1	0	1	0	1	0	7	1	0	1	0	1	2	0	0	0	15	0	0	0	0	15
Duck unidentif.		1			1	1	1										4					4
Ducks total	4	3	10	1	3	2	11	1	3	1	0	1	2	0	1	0	43	1	2	1	0	47
Grey Heron																	0			1		1
Ciconiidae total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Common Coot			1														1	1		1		3
Gruidae total	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	3
Lapwing	1																1					1
Dunlin														1			1					1
Waders total	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	2
Common Tern											1						1					1
Tern unidentif.	1												2				3					3
Black-headed Gull*	14						2		4	2	4	2	4	3	11	4	50	1				51
Herring Gull					1	1											2			1		3
Greater Black-backed Gull			1														1					1
Herring/Gr Bl-backed Gull				1													1					1
Gulls, terns total	15	0	1	1	1	1	2	0	4	2	5	2	6	3	11	4	58	1	0	1	0	60
Raven*		1															1					1
Crows total	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
TOTAL	**22**	**5**	**13**	**3**	**13**	**4**	**19**	**1**	**9**	**3**	**7**	**3**	**10**	**5**	**12**	**4**	**133**	**6**	**2**	**4**	**0**	**145**

* numbers of Black-headed Gull and Raven were not used in mortality calculations; ** period before reconstruction and during reconstruction is distinguished because the impact on birds is different.