Guidelines for the investigation of the impacts of offshore wind farms on the marine environment in the Baltic States

Photo: Vestas Wind Systems A/S

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Compiled by the Baltic Environmental Forum in co-operation with:

List of experts (alphabetic order):

Abersons, Kaspars	Latvian Fish Resources Agency
Bukontaite, Rasa	Coastal Research and Planning Institute, Klaipeda University, Lithuania
Bušs, Agnis	Latvian Ornithological Society
Dagys, Mindaugas	Institute of Ecology, Vilnius University
Daunys, Darius	Coastal Research and Planning Institute, Klaipeda University, Lithuania
Grandans, Gaidis	Latvian Ornithological Society
Jermakovas, Vadims	Latvian Institute of Aquatic Ecology
Järvik, Ahto	Estonian Marine Institute, Tartu University
Jüssi, Ivar	Environmental Board, Estonia
Kartau, Kuido	Hendrikson & Ko Ltd., Estonia
Kontautas, Antanas	Klaipeda University, Department of Biology, Lithuania
Kube, Jan	Institute of Applied Ecology Ltd., Germany
Kuresoo, Andres	University of Life Scienses, Estonia
Kuus, Andrus	Estonian Ornithological Society
Leito, Aivar	University of Life Scienses, Estonia
Ložys, Linas	Institute of Ecology, Vilnius University, Lithuania
Luigujõe, Leho	University of Life Scienses, Estonia
Martin, Georg	Estonian Marine Institute, Tartu University
Minde, Atis	Latvian Fish Resources Agency
Olenin, Sergej	Coastal Research and Planning Institute, Klaipeda University, Lithuania
Peet, Kaile	Hendrikson & Ko Ltd., Estonia
Purina, Ingrida	Latvian Institute of Aquatic Ecology
Raudonikis, Liutauras	Institute of Ecology, Vilnius University, Lithuania
Rostin, Liis	Estonian Marine Institute, Tartu University
Stipniece, Antra	Latvian Ornithological Society
Strake, Solvita	Latvian Institute of Aquatic Ecology
Vetemaa, Markus	Estonian Marine Institute, Tartu University
Volke, Veljo	Environmental Board, Estonia

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INTRODUCTION

Potential negative impacts of offshore wind farm projects have to be investigated as part of the approval procedure through an Environmental Impact Assessment (EIA). Although several effects have been analysed during compliance monitoring in recent years on a project level (Horns Rev and Nysted offshore wind farms in Denmark, Utgrunden wind farm in Sweden, Nordzeewind in The Netherlands), a number of open issues remain to be answered especially in relation to potential cumulative effects, on both national and international scale, respectively. Furthermore, the existing amount of information about the Baltic marine environment is still far too incomplete to be sufficient for a verifiable desk study approach.

Thus a standardised field survey is the key prerequisite for

1. a reliable validation of conservation objectives as part of the EIA,
2. an investigation of potential cumulative effects across projects

Thus the implementation of guidelines for a standard approach, developed in consultation with numerous experts, provides relevant information for applicants on the scope of investigations required by the approval authorities. A thorough baseline approach in accordance to international standards of marine environmental investigations also forms the basis for the compliance monitoring of predicted effects during the operation of an offshore wind farm.

These guidelines only focus on the assessment of impacts on the abiotic and biotic environmental components. The principles of these EIA standards can be easily applied also for many other offshore infrastructure projects.

The current guidelines have been developed in consultation with experts from Lithuania, Latvia, and Estonia. This report has been prepared in the frame of the project "Concept development for an environmental impact assessment for off-shore wind parks in the Baltic States", which is co-funded by the German Environmental Agency (project No 380 01 173).

1. POTENTIAL HAZARDS

A number of potential negative impacts may result from the construction and operation of an offshore wind farm. Different potential hazards must be considered during installation, due to the presence of the installation itself, and during operation.

Construction/De-commissioning

- Displacement of animals resulting from disturbances (noise and light emissions, traffic)
- Emission of pollutants
- Seabed intervention works (impact on seabed morphology and structure, re-suspension of sediment)

Operation

- Change in local oceanography (currents, vertical mixing processes, blocking effects in the vicinity of submarine ridges and shallow lagoons)
- Change in local ice conditions (ice breaking through maintenance traffic, change in drift ice movements, change in freezing performance)
- Creation of artificial hard substrate (reef effect)
- Scour effects at the base of foundations
- Displacement of animals by wind turbines and noise emissions (barrier effects above and below the sea surface, respectively)
- Collision risk for birds and bats
- Electric and magnetic fields at DC-cables
- Heating at AC cables

2. GENERAL EIA & MONITORING REQUIREMENTS

Baseline investigation
A thorough field investigation of the project area is required for the description and validation of the status quo (baseline investigation for the EIA).

An EIA for an offshore wind farm has to cover the following topics:
- The description of the status quo of the protection objectives (EIA, habitat & bird directives, protection of species)
- Validation of the status quo
- Description of potential impacts/interactions
- Description of potential cumulative effects
- Potential mitigation measures
- Monitoring concept (feed-back, compliance)

An EIA should assess impacts on the following protection objectives:
- Humans
- abiotic environmental components: water, soil, climate
- biotic environmental components: spermatophytes & algae, benthic invertebrates, fishes, seabirds, marine mammals, migrating birds and bats, biodiversity
- landscape
- objects of cultural value (i.e. archaeological sites)

Each protection objective will require a certain evaluation in space and time to enable for a sufficient description of the status quo and its validation. Minor species diversity together with a low inter-annual variability in oceanographic parameter led to conclude that a one-year-investigation is sufficient for the baseline investigation for most conservation objects in the eastern Baltic Sea region. However, annual variability in winter severity (especially ice conditions) is a major source of inter-annual variation in seabird and seal distribution within a certain area during winter and spring. For these conservation objects, therefore, a field survey in two successive years is recommended to obtain a reliable basis for the compliance monitoring during operation. The size of the assessment area will differ between protection objectives according to the scale of potential impacts:

Seabed, Benthos & Fishes
The size of the assessment area corresponds to the project area. The project area should be surrounded by a zone of one nm to cover the range of potential hazards.

Seabirds
The size of the assessment area should cover 150-200 km² (80-100 nm observations on effort) for ship surveys and about 1.000 km² (400 km on effort) for aerial surveys. The baseline investigation has to cover two entire annual cycles as a basis for the compliance monitoring during operation.

Bird migration
Proper project related bird migration investigations can be carried out only for those projects which are located within 15 km distance from the shore (either mainland or island).
A comprehensive baseline investigation combining simultaneous seawatching and radar observations across Lithuania, Latvia, and Estonia as well as an international analysis of short-term recoveries of ringed birds (preferably during the breeding season) is recommended to provide a reliable assessment of the collision risk and potential barrier effects.

Seals
Seals cannot be investigated in relation to a given project area, except during the ice season. Aerial surveys carried out during the ice season should cover an area of about 1000 km^2 (400 km on effort). Aerial seal surveys have to be carried out during the ice season in two successive winters as a basis for the compliance monitoring during operation.
Remote sensing is the only tool which can be used for habitat mapping. About 10 seals should be tagged with telemetry devices, therefore, during the baseline investigation by every application.

Feedback monitoring during construction
A feedback monitoring might be required during construction to ensure maximum acceptable impact thresholds for certain protection objectives (i.e. sediment spills during seabed intervention works, noise emissions during ramming of monopile foundations, etc.).

Compliance monitoring during construction and operation
The before-after-construction-investigation (BACI) forms the basis of the compliance monitoring which aims to demonstrate that the project stays within the predictions about potential environmental impacts drawn in the EIA.

A considerable small scale variability of environmental conditions of the Baltic Sea off Lithuania, Latvia, and Estonia prevents from implementing reference areas into the overall monitoring approach. The implementation of a comprehensive database, gathering raw-data from all offshore EIA (at least at national level), is recommended instead, to provide the indispensable background information on the overall development of the marine ecosystem.

Environmental investigations will be very difficult to undertake during the construction phase within a project area because of safety reasons. Hence, compliance monitoring will start predominantly during operation. However, selected conservation objectives will require a start of the monitoring already during the construction phase (seabirds, seals). According to existing knowledge, succession of marine benthic communities will last for about three years. Field investigations for the compliance monitoring should last, therefore, for three successive years during operation.

Based on current knowledge, it is difficult to provide precise recommendations on investigation tasks, methods, etc. for the compliance monitoring. Due to the technical restrictions someone will face while operating in an offshore wind farm, proper monitoring methods are still under development for most conservation objectives. Thus, this guideline will only provide an outlook for the later obligations of the compliance monitoring.

3. INVESTIGATIONS AND MONITORING OF IMPACTS ON OCEANOGRAPHY

Potential blocking effects of gravity foundations might cause oxygen depletion events in adjacent bays or lagoons, resulting in overall changes in the composition of benthic and fish communities outside the wind farm. Changes in the local ice conditions will probably cause alterations of succession of benthic communities in shallow waters (< 5 m water depth) and of habitat suitability for seabirds and seals.

3.1 Baseline

Oceanographic data (salinity, oxygen, current regime, ice pattern) are required to understand the vertical stratification of marine communities and the spatial distribution of seabirds.
Oceanographic information should be gathered by both direct offshore measurements and desk studies.

3.1.1 Direct measurements offshore

Measurements of salinity, temperature and oxygen should be undertaken during all benthos and fish surveys, both at the sea surface and at the sea floor.

3.1.2 desk studies

To analyse the oceanography of an area under consideration, data from nearby monitoring stations (e.g. HELCOM monitoring programme, national monitoring for the Water Framework Directive) should be compiled.
Hydrodynamic modelling has to be performed for project areas characterised by special current regimes (up-welling, coastal currents).
A compilation of ice conditions has to be carried out (long term variation in regional ice coverage, composition of ice types, and relevance of drift ice movements).
Modelling of project induced changes in local ice conditions (maintenance traffic, drift ice movements, and ice formation) has to be performed for project areas, covered regularly by ice.
Satellite images are generally available for validation of model results, short range ice dynamics models exists for Gulf of Riga (Wang et al. 2003).

3.2 Compliance monitoring

Oceanographic parameter should be measured during the operation of the wind farm as part of the compliance monitoring.
Frequent measurements of salinity, temperature and oxygen should be undertaken by remote sensing devices installed either at the transformer platform or at a turbine foundation.
Satellite images should be analysed to describe changes in ice conditions.

4. INVESTIGATIONS AND MONITORING OF IMPACTS ON THE SEABED

Potential impacts on the seabed include re-suspension of fine sand during seabed interventions (trenching, pile driving), scour effects around the foundation, the change in substrate composition by the introduction of artificial hard bottom (gravity foundations, scour protection, etc.).
Severe effects may result from construction works in areas dominated by natural hard bottom, especially limestone.

4.1 Baseline

Geophysical investigations include:

- sediment relief (side scan sonar, resolution 10 cm)
- bathymetry (echo sounder)
- acoustic profiling (sub bottom profiler)
- sediment parameter (grain size, loss on ignition; sampling design in accordance with macrozoobenthos investigations)

One survey during baseline investigations is sufficient.

The geophysical investigation of the seabed has to be carried out (including data analysis and GIS implementation) as the **basis** for the design of all biological investigations.

4.2 Compliance monitoring

A side scan sonar survey should be performed after construction.

5. INVESTIGATIONS AND MONITORING OF IMPACTS ON BENTHOS

Potential impacts on benthos include:

- seabed intervention works during construction
- change in local current regime
- change in ice conditions
- scour effects
- artificial reef effect
- heating by cables (AC)
- electric and magnetic fields at cables (DC)

Benthic communities include macro algae and spermatophytes as well as benthic invertebrates invading soft substrates or settling on hard bottom. Different investigation methods have to be combined, therefore, to cover all compartments.

5.1 Baseline

Measurements of salinity, temperature, and oxygen have to be carried out at a representative number of stations during the survey.
Results of geophysical investigations are a key prerequisite for the investigation programme.

5.1.1 Baseline infauna

Infauna investigations include identification of species, and measurements of abundance and biomass. In addition, the length of bivalves should be measured for a sufficient number of samples (indicator for seasonal anoxia; provides information on harvestable food supply in important sea duck feeding areas < 20 m water depth).

Quantitative grab sampling should be used for investigating soft bottom benthic organisms. Samples of macrofauna (benthic animals which can be caught by a sieve with a mesh size 0.5 mm) are taken with a 0.1 m² Van Veen grab (40-75 kg). Smaller grabs can be applied in case of operating from smaller vessels (e.g. handheld Ekman-Lenz sampler) in shallow waters (< 5 m depth). Alternatively, shallow water soft sediments can be sampled by hand-operated corer via SCUBA diving (diameter 10 cm). The bottom sampler has to be pushed carefully into the bottom to approximately 20 cm depth, upper end has to be closed with a lid and then gently taken out together with the sediment. A minimum of three replicates has to be taken per station when using a corer to obtain a representative number of species per station.

All samples have to be washed through a 0.5 mm gauze and preserved either with 4 % formalin neutralized with Borax ($Na_2[B_4O_5(OH)_4] \cdot 8\ H_2O$) or deep frozen. Further treatment of material has to be performed according to HELCOM, (1988, 1997). Organisms are identified to species level where practicable and counted. Biomass is determined preferably as dry weight (g m^{-2}).

From each Van Veen grab a small tube filled with sediment should be collected for analyses of sediment parameter (grain size, loss on ignition) according to HELCOM standards.

Sampling should be carried out in late summer. One high-resolution survey should be performed. The project area should be investigated by stratified sampling rather than taking parallel samples at a smaller number of stations. The sampling design should be defined based on the results of the geophysical surveys. All depth strata and sediment types have to be covered by a sufficient number of samples for habitat and spatial modeling.

Statistical treatment of data should include community analysis (PRIMER 6, Plymouth Marine Laboratory) and spatial analysis (i.e. kriging).

5.1.2 Baseline epifauna/macrophytes

Epifauna investigations include investigation of species, their abundance and biomass.

sampling by SCUBA divers

On hard bottoms, plants and animals are scraped from the measured surface (20 x 20 cm) of stones using a 0.04 m^2 Kautsky type frame. 4-8 samples are taken per station depending on the heterogeneity of the seabed. All quantitative samples collected by SCUBA divers have to be treated in the same way as indicated for grab samples.

SCUBA diver sampling should be restricted to < 15 m water depth.

Sampling should be carried out in late summer. The sampling strategy should be designed based on the results of the geotechnical surveys and underwater video surveys. Quantitative hard bottom samples aim to assign abundance and biomass values to photos/videos processed by image analyses to obtain closure/abundance and biomass values for algae, blue mussels or barnacles.

video survey

Based on the results of the geophysical survey, representative investigations by underwater video or photo sampling should be carried out especially on hard bottom. A variety of tools are applicable: photo samplers, drifters, sledges, or ROV.

Estimates for abundance and biomass should be derived from image analyses (selected, representative sample video images/photos) combined with results from scratch samples collected by SCUBA divers.

Results from geophysical and benthos surveys are combined to produce a habitat distribution map of the project area. Habitats are designated according to the Natura 2000 and EUNIS systems (by applying national/regional standards).

5.2 Feedback monitoring

A feedback-monitoring of turbidity should be performed in case the EIA predicts significant negative impacts from re-suspension of silt sediments or limestone from drilling operations. Turbidity monitoring includes measurements of concentrations of particulate matter in the water column and image analysis (aerial/satellite images).

5.3 Compliance monitoring

Infauna, epifauna, macrophytes should be investigated by the same methods as applied during the baseline investigation over a period of three successive years during operation to investigate large scale succession of the project area.

The epifauna of artificial hard bottom (foundations, scour protection) should be investigated by ROV and SCUBA divers (< 15 m water depth) as described above for three turbines.

6. INVESTIGATIONS AND MONITORING OF IMPACTS ON FISHES

Potential impacts on fishes include:

- seabed intervention works during construction
- ramming noise for monopiles, noise from ship traffic
- change in local current regime
- change in ice conditions
- scour effects
- artificial reef
- heating by cables (AC)
- electric and magnetic fields (DC)

6.1 Baseline studies

Measurements of salinity, temperature, and oxygen have to be carried out at a representative number of stations during the survey.
Results of geophysical investigations are a key prerequisite for the investigation programme.

Fish investigations include identification of species, and estimation of abundance and biomass. In addition, body length should be measured.

<u>6.1.1 Demersal species</u>

Demersal fishes should be investigated by bottom-set gill net fishing according to national monitoring schemes. Bottom trawling cannot be deployed in many areas because of abundant hard substrates. Furthermore, trawling might not be allowed in certain wind farms during operation (risk of damaging the farm internal cable grid).

The choice of gill net mesh sizes should be similar with those used in the coastal fish monitoring. All basic methods and differences by countries are presented in the guidelines published by HELCOM (Guidelines for HELCOM coastal fish monitoring sampling methods; July, 2008). The fleet of sampling nets consists of bottom set gill nets, which are 1.8 m (6 feet) deep and made of spun green nylon (14, 17, 21.5, 25, 30, 33, 38 mm mesh size) or transparent monofilament nylon (42, 45, 50, 55, 60 mm mesh size). Such net set consisting of many gill nets of different mesh size are referred as "station". The nets may be set in a random sequence in a fishing station. Meshes are measured from knot to knot – it means the bar length (a) are measured (alternatively, it is possible to measure the diameter of the "hole" - A; at that case the result will be ~ 2 times bigger).
Sampling gill net construction: a net piece (bundle) of 60 m length and 3 m height in lap (stretched) is hanged to a 27 m float line (head line) (35 cm between floats, buoyancy of 6 g/m), to a 33 m lead line (weight 2.2 kg/100 m) and to a 1.8 m side (vertical) line. Yarn thickness is no. 110/2 for all mesh sizes, according to the Tex-system (e.g., 110/ 2 means 2 filaments each weighting 110 g per 10 000 m).

The set of nets (further referred as "station") should consist of at least 8 different mesh sizes with the minimum bar length of 14 mm and maximum of

60 mm. The mesh sizes should be selected close to the geometric progression. Nets should be bottom-set (i.e. not pelagic) with the height of at least 1.8 m. Since fishing gill nets amortize rather quickly occasional broken meshes are tolerated.

Gill nets are set directly to the sea bottom, as lightly stretched fleet (line) using the anchors and buoys in both end. The sampling fleet (station) has to be set within the certain sea depths limits. The station grid has to cover the depth layers of the area under consideration (i.e. 20 m (18-22 m), 13 m (12-14 m), 8 m (7-9 m), 5 m (4-6 m), and 3 m (2-4 m), respectively). Within each depths layer, three stations should be sampled per every trip. The minimum number of stations per trip for each certain area sampled, should be not less than 8, despite there may be less than 3 depths layers. The position (longitude, latitude), oceanographic data (see above) and also weather conditions must be registered at the beginning of both, each setting and hauling of gill nets.

Differences occur between the countries in fishing duration in coastal fish monitoring. In Estonia the nets are set between 18 and 21 hrs and collected between 8 and 11 hrs during the following day. Since day-length varies considerably between seasons the setting and lifting times may also vary. However, nets should be always set before the sunset and taken after the sunrise. Timing for setting and lifting should vary as little as possible within a certain fishing campaign.

The baseline fish investigations should cover a complete seasonal cycle and should consist of at least one campaign during the following seasons: spring, summer, autumn.

Presentation of results
In order to enable comparisons with other databases (in which stations do not overlap fully in sense of mesh size selections) catch must be registered by separate nets (for each captured fish: station location, station depth, mesh size, fish length and weight).

- Catch per Unit Effort (CPUE) data by stations and mesh sizes
- Weight per Unit Effort (WPUE) data by stations and mesh sizes
- Dominance ratios
- Length-frequency distribution of dominant species
- Community analysis

<u>6.1.2 Pelagic species</u>
The investigation of pelagic fish will not provide reliable project related information. Thus, investigation of pelagic fish species will not be recommended because of technical reasons.

6.2 Compliance monitoring
Bottom-set gill net fishing should be carried out as part of the compliance monitoring during the second and third year of operation of the wind farm (when

sediments are recolonised by benthic invertebrates and fouling communities are established at foundations). Methods and analyses should follow the same procedures as applied during the baseline investigations.
Perhaps, future developments will provide other investigation tools for remote sensing of fish behaviour inside offshore wind farms (echo sounder, video tracking, etc.).

7. INVESTIGATIONS AND MONITORING OF IMPACTS ON MARINE MAMMALS

The potential impacts on marine mammals include

- seabed intervention works during construction
- ramming noise (monopiles), noise from ship traffic during construction
- change in ice conditions
- noise emissions during operation
- maintenance traffic
- artificial reef

7.1 Baseline

A site specific investigation of seals (both grey and ringed seals) is difficult to obtain. Although, knowledge on overall population size and location of important haul out sites has recently improved, little information is available about the offshore behaviour, since seals spend most of the time diving. Visual observations are, therefore, almost impractical. Remote sensing is almost the only tool applicable to investigate the use of offshore habitats.

7.1.1 Remote sensing

Remote sensing by Fastlock® GPS positioning systems has been approved during current investigations in Estonia and elsewhere (see reference list) to provide an excellent data accuracy (30-60 m). Various manufacturers have devised tracking solutions for a wide range of pinniped (seals and sealions) research projects. Dive profiles, foraging trip information and oceanographic data can be obtained by tracking these animals.

Remote sensing of seals from Estonian haul out sites recently revealed that their preferred feeding grounds might be far away from their preferred haul out site. It is still difficult, therefore, to link importance of certain offshore areas to nearest haul out sites.

A validation of offshore habitats can be obtained by establishing a joint database for large-scale offshore infrastructure projects. Each applicant (i.e. project) should tag a minimum of 10 seals with telemetry devices at seal haul-out sites in the vicinity of his project area for baseline investigations. Tracking data have to be processed to provide information on homerange, habitat use of study area throughout the year, migration track routines, etc. The amount of project area specific information will increase with the number of applications. Thus, even if no site specific information might be obtained during a certain application procedure, the situation might have improved until the start of construction (providing than a suitable basis for compliance monitoring).

7.1.2 Aerial surveys during the ice period

Sea ice is the crucial breeding habitat for ringed seals. Also grey seals prefer drifting sea ice for breeding, but seal pups can survive also when born on land. Ringed seal breeding success depends, therefore, on presence of ice

and ice structure. Ringed seals need pack ice and ice ridges with snow hummocks.
Seal distribution on ice during breeding and moulting season should be studied by aerial censuses in March/April twice per winter in two successive years (about 1000 km^2 investigation area, 400 km on effort, 15 % minimum coverage of survey area). Detailed description of line transect method used in Baltic is described by T. Harkonnen and S. Lunneryd (1992).

Telemetry, aerial survey, remote sensing ice data, ice modelling and ice based field data have to be combined for a validation of potential breeding habitats.

Predictive modelling of ice movements should be applied for evaluation of importance of the area for breeding seals.

7.1 Compliance monitoring

Compliance monitoring should implement a replication of tagging 10 seals from nearby haul out sites.
Aerial surveys should be carried out again during the ice season as described for the baseline investigation.
The development/application of image analysis for aerial photography seems will be required for the immediate wind farm area.

8. INVESTIGATIONS AND MONITORING OF IMPACTS ON SEABIRDS

The potential impacts on seabirds include

- Avoidance response (displacement from feeding areas, barrier effects);
- Physical habitat loss/modification;
- Collision risk (mortality)

8.1 Baseline

About 20 different seabird species might use a certain offshore area during the course of a year: divers, grebes, sea ducks, diving ducks, mergansers, gulls, terns, and auks. Some species occur only during the breeding season, some species rest during the migration periods, others stay over winter or moult during summer. Seabird surveys, therefore, will have to be carried out throughout the year.

Two different survey techniques are currently available: ship based surveys, and aerial surveys. International standard routines exist for both survey methods (i.e. Camphuysen et al. 2004). Ship surveys usually provide higher data quality for most species than aerial surveys. However, ship surveys will be difficult in shallow areas (< 10 m water depth) according to the recommended standards (see below). Ship surveys might be impractical during the ice season.

Furthermore, line transect surveys can hardly produce reliable density estimates for species with a clumped distribution pattern (i.e. long-tailed duck concentrations on small ridges). Both methods are likely to be inapplicable during compliance monitoring because of safety reasons. The development of new survey techniques (i.e. image analysis of aerial photographs, Groom et al. 2007) is highly recommended, therefore.

<u>8.1.1 Ship transect surveys</u>

Ship surveys should aim for a spatial analysis of absolute bird densities (including seasonal variation) in the vicinity of the project area.

Ship surveys should be carried out 10 times per year in two successive years. Application documents can be based on the results of the first year, but a second year of investigation is mandatory to obtain reliable results during the operational monitoring.

Ship-based surveys should follow a methodology standardised for north-western European sea areas, also known as the ESAS standard (Webb & Durinck 1992). From the compass platform on top or the wings on the side of the bridge, two observers count all flying and swimming individuals within a 300 m wide transect on each side (optimum, requires 5-6 observers; minimum one side survey with 3-4 observers) of the vessel running parallel to the keel line of the observation platform. Simultaneously, the geographic position (at 1 min interval) should be recorded. Birds are usually detected by sight, but in the Baltic Sea the use of binoculars is obligatory. Records include identification of species, number of individuals, and (if possible) age and sex of the sighted individuals. Observations are distinguished between sighted

individuals within and outside of transect to enable calculations of abundance (e.g. individuals per km²). All individuals swimming within transect in a distance of 0-300 m from the ship are recorded as within the sampling transect.
Flying individuals are recorded using the 'snapshot' method. They are only recorded as within transect if they are flying in transect at the time of a snapshot count. All individuals swimming or flying outside the sampling transect as well as all birds flying in the transect area between the times of a snapshot count are recorded as outside transect. The snapshot method is applied to correct for overestimation of particularly mobile species.

Survey routines should follow the recommendations given by **"Standards for the Environmental Impact Assessment"**(German Federal Maritime and Hydrographic Agency).

According to the ESAS standards, observations should be carried out from an observer height > 5 m at a cruising speed from 7 to 16 knots. The recommended effort is 80-100 nautical miles per survey. As in winter there is only 6 hours of sun light two cruising days are needed per survey in winter (requires vessels which can operate 24 hours per day). Transects should run across ecological gradients (from the shore to the open sea). They should run from west to east off Lithuania and Latvia and from north to south off Saaremaa and the Estonian north coast, respectively. Transect spacing should be between 3 and 4 km. The survey has to be interrupted at sea state >4. Visibility should not be less than 2 km.

Survey data (raw densities) should be corrected by applying distance sampling statistics (Buckland et al. 2001, current software: **Distance 5.0**, Thomas et al. 2006) to calculate absolute densities (birds per km²). Densities should be compared between a) the total investigation area, b) the factual project area, and c) a 2 km impact zone around the wind farm, respectively. The method chosen for analysis should take into account the strong spatial variation of bird densities in the Baltic Sea.

For relevant sea duck feeding areas, the harvestable food supply at the start of a wintering season should be documented for monitoring purposes (harvestable fraction of mussels and clams, see benthos section for methods).

8.1.2 Aerial transect surveys
Aerial surveys should aim for a spatial analysis of (relative/absolute) bird densities (including seasonal variations) in a larger area. Analysis will be partly restricted to genus level because of identification problems (divers, auks, gulls, grebes).

Aerial surveys are an alternative for the ice period and shallow areas where ship surveys are not applicable. Aerial surveys should be carried out four times per year and in two successive years.

Line transect surveys should be conducted by using a twin-engined high-winged aircraft with bubble windows flying at an altitude of 250 ft. and 100 kts (180 km/h) speed. According to the standard line-transect protocol (described by Noer et al. 2000, Diederichs et al. 2002, and Camphuysen at al. 2004), one or to two observers on each side of an aircraft record every bird swimming or flying together with the time of observation (to the nearest second) on a voice recorder. Observations are made without binoculars in a 397 m wide transect which is subdivided into 2-3 zones (Fig. 1). The outer limits of these zones are identified using a protractor (see Pihl & Frikke 1992 and table 1). While the published standard uses two zones, recent work in Denmark and Germany has shown that a division into three zones increases the reliability of density estimates. Note that three zones may be difficult to apply when birds occur in very high densities.

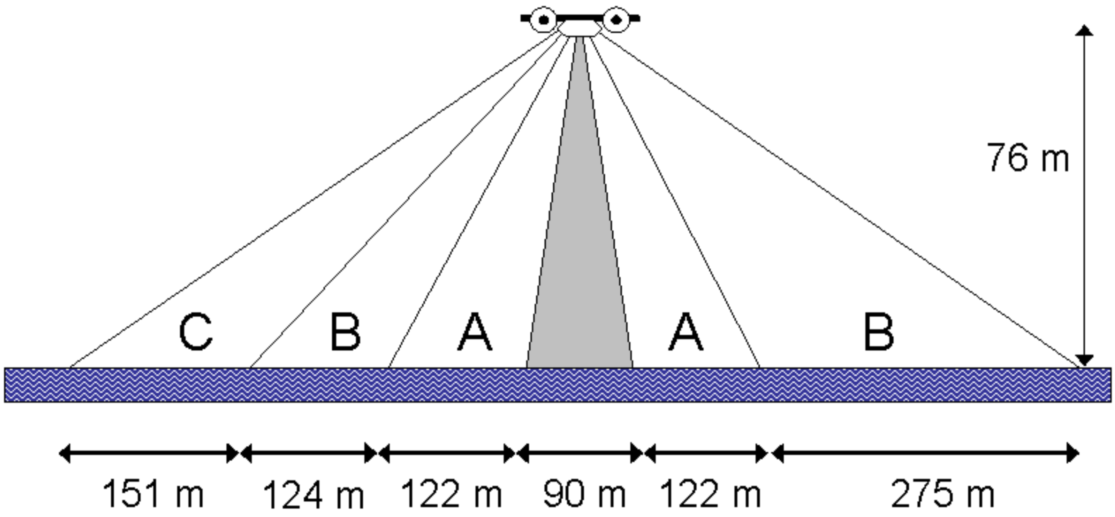

Figure 1: Transect division for aerial seabird surveys: published standard (right side), and recommended division (left side) (from Diederichs et al. 2002, adapted).

Table 1: Recommended division of the transect band for aerial surveys

Zone	D *	A	B	C	E (outside)
published standard					
outer limit, protractor angle (degrees)	60	25	10		4
outer limit, distance from platform (m)	45	167	442		1115
zone width (m)	45	122	275		673
total transect width (m)				397	
recommended change					
outer limit, protractor angle (degrees)	60	25	15	10	4
outer limit, distance from platform (m)	45	167	291	442	1115
zone width (m)	45	122	124	151	673
total transect width (m)				397	

* invisible (below aircraft)

Survey routines should follow the recommendations given by **"Standards for the Environmental Impact Assessment"**(German Federal Maritime and Hydrographic Agency). During flight position of the aircraft should be recorded by GPS tracking at 5 sec interval (minimum). Observations have to be assigned to position (by using observation time record).

Transects should run across ecological gradients (from the shore to the open sea). They should run from west to east off Lithuania and Latvia and north south off Saaremaa and the Estonian north coast, respectively. Transect spacing should be between 3 and 6 km. Surveys are only possible when the water surface is calm and there are no breaking waves, with a maximum sea state of 3 (see Garthe et al. 2002). Visibility should be at least 5 km, and analysis of data recorded with glare (usually only on one side of the platform) should be avoided.

Survey data should be corrected by applying distance sampling statistics to calculate absolute densities (birds per km²). This method relies on the assumption that **all** birds close to the transect line (i. e. zone A of the transect) are detected (Buckland et al. 2001). This assumption is usually not met in aerial surveys (although observers should concentrate on detecting birds in zone A). In order to correct for the birds missed in zone A, a double observer design should be applied, with two observers count the birds simultaneously on the same side of the aircraft. Detection probability for each species can then be estimated using mark-recapture distance sampling statistics (implemented in Distance 5.0, Thomas et al. 2006).

Densities should be compared between a) the total investigation area, b) the factual project area, and c) a 2 km impact zone around the wind farm, respectively.

8.2 Compliance monitoring

Surveys should be carried out in two successive years during operation. The compliance monitoring should aim to compare the density of seabirds inside a wind farm, in a circumventing 2 km impact zone, and in the baseline study area, respectively.

Whether ship-based or aerial surveys as described above can be applied inside a given wind farm area depends on the spacing of turbines. An alternative method based on aerial photographs should be further developed to enable for a promising BACI design of the compliance monitoring.

Aerial photography from an altitude of 1,640 ft (app. 500 m, i.e. above the turbines) has important advantages:

- it will not disturb seabirds (currently Common Scoters are frequently chased from the transect by the approaching aircraft)
- risks to pilots, observers, etc. in the vicinity of a wind farm are avoided
- Aerial photographs provide raw data which can be reanalysed at a later stage.

Automatic image analysis tools will allow for:

- Calculation of absolute densities
- Calculation of absolute densities for species with a clumped distribution

High resolution digital SLR cameras (> 15 megapixel) mounted on twin-engined planes equipped for routine vertical aerial photography should be able to produce pictures of sufficient resolution for seabird detection and identification. However, software solutions for automatic image analysis are currently under development and not commercially available (Groom et al. 2007). They will have to be developed by seabird specialists together with software experts. Regional solutions are likely to be beneficial since treatment of ice will be a special feature of aerial images from the Baltic States.

9. INVESTIGATIONS AND MONITORING OF IMPACTS ON BIRD MIGRATION

The validation of potential risks to migrating birds predominantly refers to the collision risk of nocturnal migrants. Attraction by artificial light might increase the risk. Barrier effects might be of relevance for waterfowl migration at low altitude (e.g. divers and sea ducks). Both effects might be negligible when focussing on a single wind farm project but they potentially cause severe hazards to populations when considering several thousand turbines from different applications.

9.1 Baseline

About 200 bird species migrate across the Baltic Sea twice annually. More than 500 Mio. individuals might pass the Baltic States during autumn migration. Different bird species exert a variety of different migration strategies:

- waterfowl (flapping; diurnal/nocturnal)
- raptors/cranes (flapping/soaring; diurnal)
- diurnal passerines (flapping)
- nocturnal passerines (flapping).

Birds migrate up to an altitude of about 3000 m. Only about 5-10 % of the birds fly below 100 m altitude during daytime. About 50 % of all birds migrate at night. Hence, all methods which can be applied to investigate bird migration are highly selective (table 2). Several methods are difficult to apply from vessels.

Table 2: restrictions in quantitative/qualitative detectability of birds aloft offshore.

Species group	Method	Spatial range	Diurnal limitations	Applicability (species restrictions)
Waterfowl quantitative	Seawatching	2-5 km (according to observer height) 100 m altitude	Only during daylight	Only diurnal migrants (which pass by during daylight)
Waterfowl quantitative	Horizontal radar (platform required)	10 km	Only up to 3 Bft (sea clutter hides echoes on radar screen)	species identification only possible during daylight in combination with telescope
Waterfowl qualitative	Acoustic registration	?		Only some waders
Waterfowl qualitative	Vertical radar (platform required)	?		Impractical, because waterfowl comprises only for about 5 % of the migratory volume

Species group	Method	Spatial range	Diurnal limitations	Applicability (species restrictions)
Waterfowl qualitative	Fixed beam radar (platform required)	5 km		Impractical, because waterfowl comprises only for about 5 % of the migratory volume
Raptors/cranes quantitative	seawatching	2-5 km (according to observer height) 300 m altitude	Only during daylight (cranes migrate also at night)	all
Diurnal passerines quantitative	seawatching	100 m, 50 m altitude	Only during daylight	Only diurnal migrants (which pass by during daylight), Only 5-10 % of the migratory volume
Diurnal passerines qualitative	Vertical radar (platform required)	1.5 km		Only recognition of flocks
Diurnal passerines qualitative	Fixed beam radar (platform required)	3 km		Only recognition of flocks
Nocturnal passerines quanitative	Vertical radar (platform required)	1.5 km		No qualitative approach
Nocturnal passerines quanitative	Fixed beam radar (platform required)	3 km		Recognition of species groups
Nocturnal passerines qualitative	Acoustic registration	?		Highly selective

As a consequence, one has to consider that field investigations carried out offshore from a vessel will not provide sufficient information for a reliable risk assessment, especially when considering potential cumulative effects.

A proper validation of potential (cumulative) negative effects to migrating birds is difficult to obtain for a single project. It is recommended, therefore, to investigate potential negative effects on an international level (across all three Baltic States). Such an approach should include:

- A joint analysis of short term recoveries of ringed birds (preferably ringed at the breeding ground) including the Baltic States as well as Finland and western Russia to identify populations migrating across the eastern Baltic Sea.
- Simultaneous standardised seawatching (from sunrise to sunset) in Lithuania, Latvia, and Estonia (in ideal also including southern Finland) at selected appropriate sites (peninsulas and islands) to identify migration bottlenecks and to evaluate diurnal migration traffic rates.

- Simultaneous quantitative investigations of nocturnal migration by the use of fixed beam radar at representative sites across Lithuania, Latvia, and Estonia (2-3 devices in parallel) to evaluate migration traffic rates.
- Population modelling to establish species/population specific thresholds for additional adult mortality caused by collisions at offshore wind turbines.

The result of such an approach would enable authorities to plan the overall capacity for the erection of offshore wind turbines in the eastern Baltic Sea.

9.2 Compliance monitoring

Information on collision rates of nocturnal migrants at offshore wind farms is still missing on a worldwide perspective. Thus, the implementation of a monitoring of collisions is highly recommended. At present, there are no tools available to quantify collisions. However, the collision risk model of Band et al. (2006, http://www.snh.org.uk/) allows calculating collision rates if relevant model input data can be provided. These data include:

- mean traffic rates outside the wind farm (at risk altitude)
- mean traffic rates in the vicinity of the turbine (avoidance/attraction).

There is still no method to measure attraction or avoidance by artificial light for nocturnal migrating birds to be considered in this model.
Methods to obtain these data are currently under development:

- Fixed beam radar monitoring at wind farm (mean traffic rate estimate)
- Automatic video recording of birds in the vicinity of the rotor (quantification of avoidance/attraction behaviour).

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10.2 Relevant homepages

Helsinki Commission (Manual for Marine Monitoring in the COMBINE Programme of HELCOM):
http://www.helcom.fi/groups/monas/CombineManual/en_GB/Contents/

German Federal Maritime and Hydrographic Agency (Standards for offshore EIA):
http://www.bsh.de/en/Products/Books/Standard/index.jsp

RUWPA (Distance homepage, statistical analyses of line transect data):
http://www.ruwpa.st-and.ac.uk/distance/

Plymouth Marine Laboratory (Primer-E Ltd):
http://www.primer-e.com/

Scottish National Heritage (collision risk model of Band et al. 2006):
http://www.snh.org.uk/
http://www.snh.org.uk/pdfs/strategy/renewable/COLLIS.pdf

Sirtrack (seal tracking devices):
http://www.sirtrack.com/
http://www.smru.st-andrews.ac.uk/Instrumentation/pageset.aspx?psr=274

Swedish Environmental Protection Agency (results from Vindval research programme 2005-2007):
www.naturvardsverket.se

Noordzeewind (monitoring at offshore wind farm Noordzeewind, The Netherlands 2006-2012):
http://www.noordzeewind.nl/

Danish Energy Authority (results from offshore wind farm monitoring in Denmark):
http://www.ens.dk/graphics/Publikationer/Havvindmoeller/index.htm

EUROBATS (Guidelines for consideration of bats in wind farm projects):
http://www.eurobats.org/publications/publication_series.htm