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Validation of a bird radar system

A guidance document

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Preface

This report includes a guidance document to optimize and validate bird radars in the offshore windfarms.

In current practice, collision risk models like the Band model are often used in impact assessments of offshore wind farms. The results of Band model calculations are generally strongly dependent on estimates for a limited number of parameters, and the outcome may vary widely with minor changes in just a few of the input estimates. Therefore, it is important to validate the assumptions used in the collision modelling, in order to improve the confidence around mortality estimates. To achieve this goal, Rijkswaterstaat (RWS) has installed a 3D Fixed Robin Radar in the offshore wind farm Luchterduinen (LUD). This radar is the first radar system in an expected series of six radars that will be placed in offshore wind farms in the near future.

RWS has commissioned Bureau Waardenburg to validate the radars at LUD. This report serves as a guidance document, in which we describe a standardized method for validation of bird radars in future locations. Based on this document, monitoring of these radars can be carried out in a standardized way in other offshore wind farms in the future.

The following persons contributed to the realisation of this report:

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Abel Gyimesi	reporting, project management;
Ruben Fijn	quality assurance.

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1 Introduction

1.1 Background

Recent research in the Ecology and Cumulation Framework (KEC - Rijkswaterstaat 2015, 2019) and the EIAs of various offshore wind farms showed that substantial numbers of casualties are to be expected among different species of seabirds and migratory birds, due to collisions with offshore wind turbines. For some of these species, this additional mortality may be evident at the population level due to their small natural populations, or because a significant proportion of the world population flies over the Dutch North Sea, or because a large proportion of the population flies in concentrated flyways during migration between the Netherlands and the UK.

Within the framework of aforementioned studies, the numbers of collision victims have been calculated with the Band model (Band 2012), currently the most frequently used model for predicting bird collisions in wind farms at sea (Masden & Cook 2016). The results of Band model calculations are generally strongly dependent on estimates for a limited number of parameters, and the outcome may vary widely with minor changes in just a few of the input estimates. Therefore, it is important to validate the assumptions used in the collision modelling, in order to improve the confidence around mortality estimates. This mainly concerns assumptions about avoidance behaviour, fluxes, flight speeds and flight altitudes. Such a validation is carried out by a detailed field study in offshore wind farm Luchterduinen. For this, data collected by specialized bird radars, camera recordings and visual observations is the best available methods.

To achieve this goal RWS has purchased a 3D Fixed Robin Radar, consisting of a horizontal and vertical radar (in short: RWS bird radar). This is installed in the offshore wind farm Luchterduinen (LUD). Currently, Eneco (the owner of LUD) has also an obligation to conduct research into bird collisions and fluxes in the wind farm. The aforementioned two projects complement and reinforce each other and thereby provide new knowledge about bird fluxes, number of collisions and macro-, meso- and micro-avoidance.

The RWS bird radar consists of a horizontal Furuno magnetron-based S band radar and a fixed vertical Furuno magnetron-based X band radar. The aim of the horizontal radar is to detect and track birds within a 6 km scanning range, while the aim of the vertical radar is to detect birds and estimate fluxes within a 1,500 m scanning range. These radars have different characteristics, e.g. in terms of wave and pulse lengths, which means that the detection probability in relation to different sizes of birds differs between the two, and hence settings and validation have to be undertaken separately for the two radars. In addition, the different wavelengths means that the sensitivity to clutter induced by waves and precipitation differs significantly between the two radar types, which again stresses the need to undertake the validations separately. The bird radar in LUD is the first radar system in an expected series of six radars that will be placed in offshore wind farms in the near future.

1.2 Purpose of the validation

Due to the short wavelength of the X-band the vertical radar has increased sensitivity to smaller objects, which affects both the detection probability for small birds and the potential contamination (shading) of bird detections by rain and waves. As the radar antenna is tilted 90 degrees the influence of waves on the vertical bird detections is however, limited to the scanned area near the sea surface. The longer wavelength of the S-band means that the horizontal radar has reduced sensitivity to smaller objects, which then reduces the detection of small birds and the potential contamination of bird detections by rain and waves. The combined effect of the detection and clutter suppression capabilities of the S-band radar is an improved detection of medium- and large-sized birds within the scanned range of 6 km. Both types of radars have a variation of significant detection curves in relation to different sizes of birds or radar-cross sections, which results in an uneven detection at different distances within the scanned ranges. As it is a requirement for both radars to account for this uneven detection, either by applying specific correction factors, or extracting signals from the part of the scanning range with optimal detection for different radar cross-sections, the validation of both detection capacity has to be undertaken in relation to different sizes of birds:

- Single passerine;
- Small gull species, e.g. Black-legged Kittiwake;
- Large gull species, e.g. Lesser Black-backed Gull; Northern Gannet.

1.3 Scope of this report

This report serves as a guidance document in which we describe our methods and experiences for validation of the 3D Fixed Robin Radar. Based on this document, validation of bird radars at other offshore wind farms in the future can be carried out in a standardized way.

2 Measurements

In Eneco Luchterduinen, the RWS bird radars are situated on turbine 42 (figure 2.1; 2.2). To validate and optimize the performance of the **horizontal radar** observations need to be carried out at different distances from the radar. In the case of LUD, the radar turbine and other nearby turbines were used for the field observations including turbine 39 at ±600m, turbine 41 at ±1.1 km and turbine 33 at ±1.6 km distance (figure 2.1). Possibilities for validation observations nearby the radar are limited due to health safety reasons (Bravo Rebolledo *et al*., 2019). However, the extent of clutter at a short distance (± 300 m) around the radars makes such observations really relevant for validation studies. Ideally, validation and optimization of the **vertical radar** should also be conducted at different distances from the radar, but is limited since the observation locations also need to be within the two beams on either sides of the radar, in the case of LUD to the NW and to the SE from turbine 42.

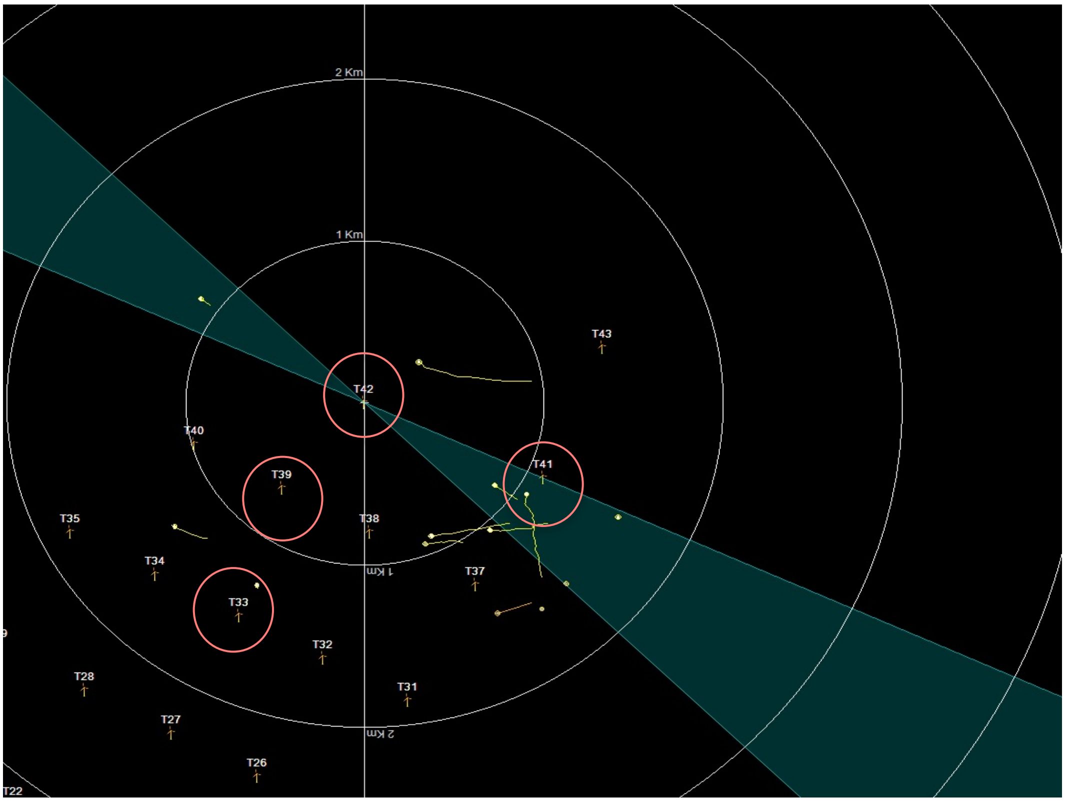

Figure 2.1 Radar image from Luchterduinen indicating the vertical beam of the bird radars, with turbine 42 where the radars are installed in the middle of the beams. Other turbines from which validation observations were carried out are indicated by a red circle.

Possibilities to carry out observations at different distances may be limited in offshore situations, due to the lack of structures that can serve as an observation platform. Therefore, in some cases all validation observations may need to be carried out from the location where the radar is installed. Here, further limitations may hold due to restricted safety areas where no radar radiation occurs (see figure 2.3 for an example).

Nevertheless, validations should ideally only be carried out from a fixed platform and not from e.g. boats, in order to have an exact location from where measurements can be repeatedly conducted. These fixed platforms must be reachable in all seasons under a range of different types of weather conditions, in order to collect validation measurements under varying conditions.

Figure 2.2 RWS bird radars on turbine 42.

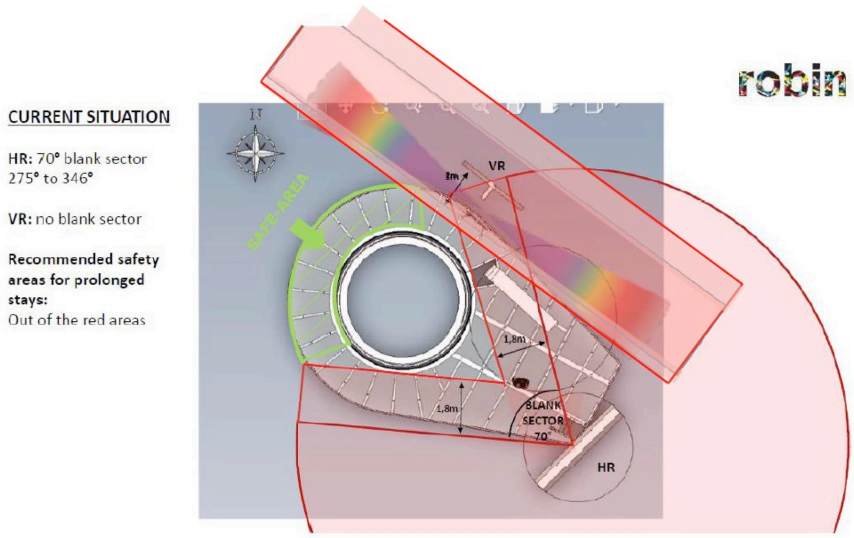

Figure 2.3 Location of the HR and VR on the platform of turbine 42 in Luchterduinen wind farm. The red part is the area with radar radiation. The green part is the area without radiation; the so called "safety-area".

Bird radar data can be incorrect in different ways: either by recording birds when there are none present (false positive, see chapter 2.2) or missing birds when they do occur (false negatives, see chapter 2.3). Also recorded locations (horizontally and/or vertically) can be different than the actual locations (see chapter 2.4). In order to collect accurate measurements on these potential issues, validation of bird radars should consist of separate measurements on these different parameters. Thus, these measurements should be carried out in separate sessions, which should ensure the collection of an adequate amount of data for each type of discrepancy of the radar measurements. Moreover, we advise to stick to one type of measurements in sessions with a minimum duration of half an hour.

Validation observations should ideally be carried out by using a **Laser Range Finder** in order to collect spatially accurate data. Modern Laser Range Finders (LRF) can use the laser beam not only to determine the distance between a target and the LRF, but also collect information on the angle between the horizon and the target. This can be used to determine the altitude of a bird. These observations are useful for all validation measurements, but specifically for testing the location accuracy of the radar. As the LRF measurements are regarded as the 'truth' for the validation of the radar measurements, it is essential to calibrate the LRF at the start of each field campaign. This concerns the compass calibrations of the LRF carried out according to the standard calibration procedure described in the rangefinder manual. In addition, LRF measurements should be calibrated in the field with known objects, such as other wind turbines and buoys. Calibration data should be collected once every hour by measuring the individual distances and heights to three known points using the LRF. The calibration points need to be used to spatially adjust the location of records.

In addition, another essential tool to record validation observations is a remote viewer of the generated tracks by the 3D Robin Radar. Robin Radars are standard delivered with a Visualizer tool that can be run on a laptop and on which all radar tracks can be labelled to species, including their number. There is also "comment" field to include additional remarks, such as the flight altitude measured by the LRF or estimated by the observers. Using this field is also the most convenient way to record the ID number of the LRF measurements, in order to be able to couple these measurements to certain radar tracks. Note that running the Visualizer needs Internet connection or a direct connection to the radar computers, and the laptop needs power supply, either in the form of (spare) batteries or access to the power grid. Due to the handling of different instruments (binoculars, LRF, laptop), and simultaneously tracking birds in the air and on the radar screen (see below), it is advised to carry out the validation measurements by a minimum of two experienced radar ornithologists working together.

In summary, the following materials or tools are required for validating a radar system offshore:

- Laser Range Finder and accompanying heavy tripod
- Binoculars
- Laptop with functional Robin Visualiser (or another type of remote viewer), spare batteries, internet access
- Tablet with GPS and data-enter application
- Power connection

2.1 True positives

Obviously, the purpose of a bird radar is that the radar detects the bird around the radar up to a certain distance. These so-called ‘true positives’ can be verified in the field when both radar and visual observer can locate the same bird.

As mentioned above, all validation measurements should be conducted at different distances from the radar, in order to evaluate the detection loss of the radars with distance. In case of an offshore wind farm, this can be done by using turbines at different distances from the radar (see figure 2.1). Recording true positive measurements are all records that are both detected by the radar (and are visible in the Visualizer, see figure 2.4) and the bird observers. Confirmation of observing the same bird by the radar observer and the bird observer should rely on describing the location of the bird, the flight path, the flight behaviour and if possible the flight height of the bird. If both observers are convinced that they have a matching bird, the track is tagged in the radar Visualizer as true positive. In some cases, the observers can be convinced that they have a matching bird based on the flight path, despite the altitude measured by the radar obviously deviates from the reality. In these cases, a true positive observation may be entered in the Visualizer, with entering an altitude measurement by the LRF or a visual estimate in the ‘comments’ field. Besides that, always place a remark to the record in the Visualizer that the observation is not unambiguous.

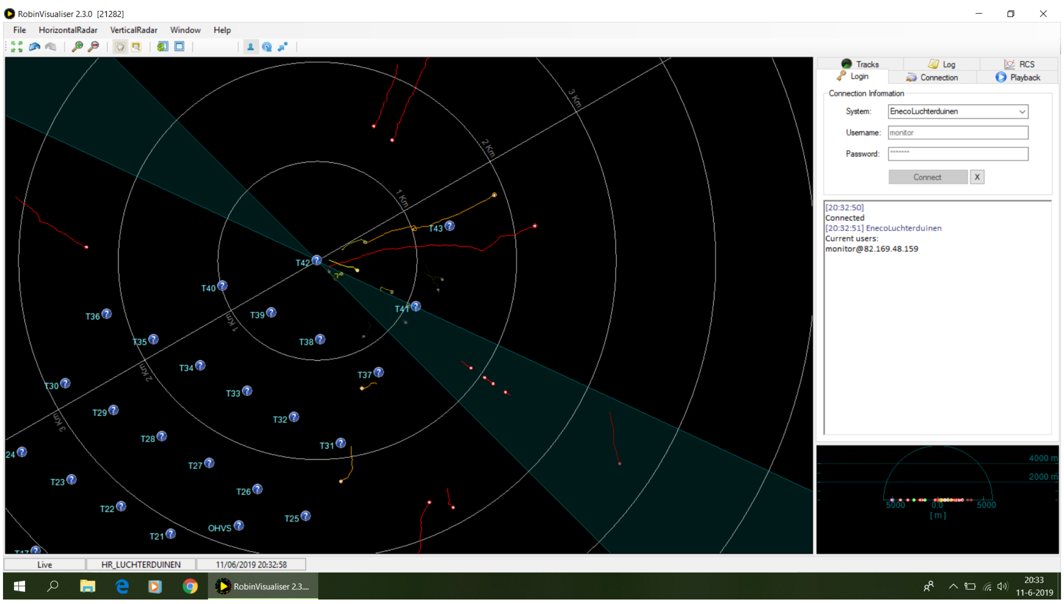

Figure 2.4 Example of the Robin Visualizer showing the horizontal radar image on the left side and the vertical radar image (small) on the right side. The centre of the distance-circles shows the position of the RWS bird radar. East of the RWS bird radar are two clear bird tracks visible displayed in red and orange.

2.2 False positives

One of type of error in radar-ornithology is that the radar records a bird, whilst there are no birds flying. Such errors are called 'false positives'.

These measurements rely on the capacity of the bird observer to be 100% sure that the bird indicated by the radar does not exist. As the horizontal radar is not capable of measuring altitude, tracks of the horizontal radar can concern a bird at any height in the air, and making it virtually impossible for visual observers to be confident that a certain radar track is not a bird. Therefore, validation measurements on false positives should only be conducted at locations where birds can be detected both by the horizontal and vertical radar.

Furthermore, the radar observer and the bird observer should define a 'detection zone' where they are looking for birds. This detection zone should allow the bird observer to have 100% certainty of detection, both in the horizontal and the vertical plane, which may depend on the size of the bird. We advise to use a detection zone up to 100m for large birds, and maximum 50m altitude for small birds. In the horizontal plane the following distances are advised:

- 500 m for large birds;
- 300 m for medium birds;
- 200 m for small birds.

The field observations should be carried out according to the following sequence:

- the radar observer looks at the screen for bird tracks within the pre-defined detection zone;
- once a track is detected and selected within this zone, the radar observer warns the bird observer;
- the bird observer tries to find the bird in the field based on the description of location and track characteristics by the radar observer;
- if the bird observer is absolutely sure that within the detection zone no bird is passing by, the track is tagged as false positive in the Visualizer.

In situations with a lot of sea clutter (figure 2.5) it is helpful to agree on a line transect along which the radar observer looks for bird tracks. Then it is easier for the bird observer to identify whether a real bird is crossing the same line.

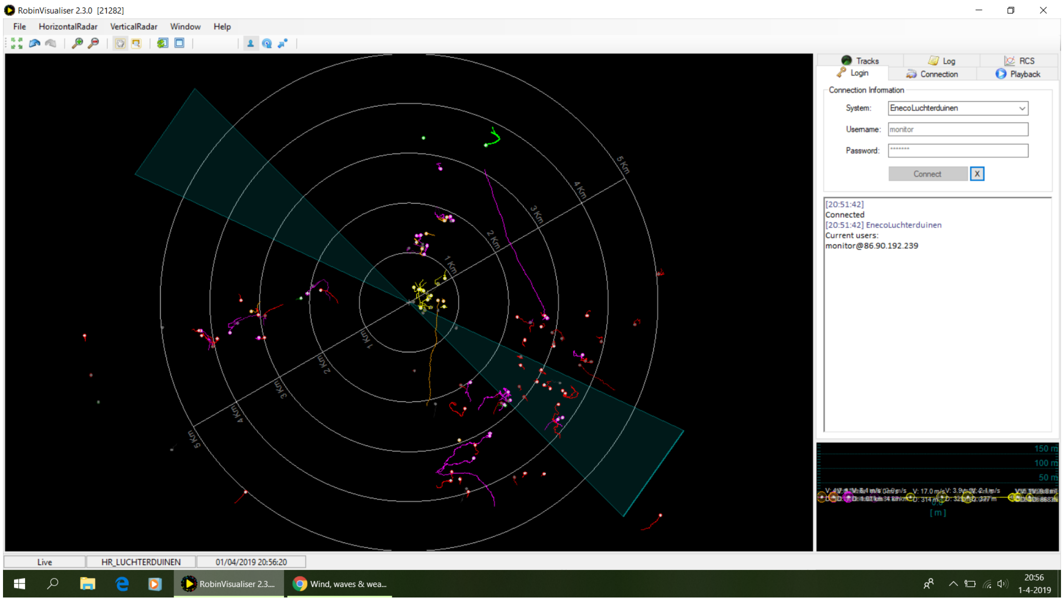

Figure 2.5 Example of the Robin Visualiser showing the horizontal radar image on the left side and the vertical radar image (small) on the right side. In the vicinity of turbine 42 a lot of sea-clutter is visible.

2.3 False negatives

False negative radar measurements concern birds that are not detected by the radar but are identified by visual observers. These measurements can be conducted both for the horizontal radar as for the vertical radar. The essence of these measurements is that any bird a field observer sees in the range of the radars, should be detected by the radar too. Therefore, limitations regarding the distance within which the observer looks for birds in the field is less limited than in the case of false positive measurements. Nevertheless, it is sensible to pre-define a spatial zone within which both the bird observer and the radar observer are operating, i.e. looking for birds and radar tracks, in order to enhance finding matching observations. However, it is advised that the bird observer carries out observations alternating with the naked eye and the LRF (figure 2.6), in order to detect birds both close by and far away.

Figure 2.6 Example of a view seen trough the Laser Range Finder while searching for birds.

Horizontal radar
The field observations should be carried out according to the following sequence:

- The bird observer looks for birds within a detection zone pre-defined together with the radar observer.
- If the bird observer sees a bird, warns the radar observer with an indication of the distance and direction.
- If there is no radar track is to match the observation, the radar observer enters in the Visualizer a false negative observation.
- If the radar observer is unsure of the observation, nothing is entered and the search for the next focal bird can continue.

In situations with a lot of sea clutter it is helpful to agree on a line transect along which the bird observer looks for birds. Then it is easier for the radar observer to identify if a track is crossing the same line.

Vertical radar
The validation of false negative measurements of the vertical radar should obviously only be conducted from locations where the vertical radar has coverage.

The protocol for field observations is similar to the horizontal radar false negative measurements. However, in case of the vertical radar, the bird observer should also look for birds by also scanning the sky high up alternating with the naked eye and LRF, in order to detect birds just as well close by, at low altitudes, and far away or at higher altitudes. Procedure for the rest is the same as for horizontal radar;

- The bird observer looks for birds within a detection zone pre-defined together with the radar observer.
- If the bird observer sees a bird, warns the radar observer with an indication of the distance and direction.
- If there is no radar track to match the observation, the radar observer enters in the Visualizer a false negative observation.
- If the radar observer is unsure of the observation, nothing is entered and the search for the next focal bird can continue.

2.4 Accuracy of radar measurements

Radar data can also vary in their accuracy. In order to test for this, LRF measurements can be carried out and coupled to bird radar tracks. Hence, for these measurements only true positive radar measurements can be used, but without a spatial limitation on the whereabouts of the bird. The intention is to collect as many tracks as possible, high and low, far and close by to the observers. For observations with the LRF one observer is operating the rangefinder and the other is documenting the data by in the LRF tablet and the radar Visualizer. Once the radar observer and the bird observer agree to have the same focal bird on the radar screen and in the field, an LRF measurement is initiated. If that succeeds, species information is entered into the Visualizer along with the ID number of the LRF measurement in the 'comments' field. Time, positions and altitudes are automatically logged in the tablet of the LRF. This can provide long series of recordings for an individual focal bird or bird flock.

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