X-shaped Radical Offshore Wind Turbine for Overall Cost of Energy Reduction

D7.11

Seabird distribution, flight behaviour and acoustic cues-Methodology and fieldwork data

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June 2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007135

X-SHAPED RADICAL OFFSHORE WIND TURBINE FOR OVERALL COST OF ENERGY REDUCTION

Project acronym: **XROTOR**
Grant agreement number: 101007135
Start date: 01st January 2021
Duration: 3 years

WP7 Environmental, Socio-Economic Analysis
T7.3 – Undertake Environmental Analysis
D7.11Seabird distribution, flight behaviour and acoustic cues-Methodology and fieldwork data

Lead Beneficiary: UCC
Delivery date: 2022/06/30

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Executive Summary

Deliverable Description: Description of methods implemented to improve Collision and Displacement Vulnerability indices and assess X-ROTOR turbine on seabird acoustic

Responsible: Clairbaux Manon and Jessopp Mark

Outcome Summary:

Environmental Impact Assessments (EIA) conducted during the pre-construction phase of offshore wind farms clearly identified interactions between turbines and marine wildlife, especially seabirds, as a concern requiring further investigation. Displacement and mortality associated with collision could lead to negative impacts on seabird populations, and needs to be assessed on a case-by-case basis irrespective of turbine design.

After conducting a comprehensive review of flight parameters (height, nocturnality, % time spent flying, agility), calculating Collision and Displacement Vulnerability Indices of the 81 seabird species present in European waters and generating vulnerability maps for 12 of them, (see deliverable D7.9 and D7.10), we identified numerous species for which disturbance sensitivity and flight height are highly uncertain due to lack of empirical data, potentially biasing our risk assessments.

This report presents the methods implemented to collect seabird distribution data as well as flight height and sounds experienced by seabird on land/ at-sea in order to 1) refine Collision and Displacement Vulnerability indices and reduce uncertainty and 2) assess the likelihood that the acoustic profile of the X-ROTOR concept turbine can be detected by seabirds and reduce collision risk.

During the previous and upcoming fieldwork seasons, we deployed/ planned to deploy a wide variety of loggers (GPS and microphones, but also accelerometer, camera, temperature depth recorder etc.) from five seabird species (Atlantic puffin, Manx shearwater, Northern gannet, Storm petrel, Lesser Black-backed gull) for which our previous analyses have shown a high vulnerability to Collision/Displacement and/or a high level of uncertainty for flight height and/or displacement sensitivity. In total, more than 170 individuals will have been equipped after the 2022 field season and the excellent recapture rates in 2021 have allowed preliminary analysis. However, most on-board microphones deployed in 2021 malfunctioned providing a limited amount of data that we hope to supplement in 2022.

This work provides a methodological framework and summary of data with on-going analysis being detailed in the next deliverable.

Content

1 Introduction

1.1 Background

Following the IPCC climate predictions (Masson-Delmotte et al., 2021) and in order to reach the Paris Agreement Objectives (United Nations Framework Convention on Climate Change (UNFCCC), 2015), global greenhouse gas emissions must be reduced. Renewable energy has a fundamental part to play in global decarbonisation, and in 2018, targets of the European Union Renewable Energy Directive were revised upward, aiming for at least a 32% share of energy from renewable sources (European Parliament, 2018). In response, many countries are turning to wind energy, with short-term EU targets driving expansion of onshore/offshore wind farms.

To ensure the lowest environmental cost per kW produced, effects of wind farms on ecosystems need to be carefully assessed (May et al., 2017). Environmental Impact Assessments (EIA) conducted during pre-construction clearly identified interactions between turbines and marine wildlife, especially seabirds, as a concern (Bergström et al., 2014). Seabirds are among the most threatened of all bird groups globally (Dias et al., 2019), with effects of offshore wind farms including habitat loss due to barrier effect (Masden et al. , 2010), displacement (Welcker & Nehls, 2016) and mortality by collision (Desholm, 2006), leading to population declines (Searle et al., 2014). Assessment of collision and displacement risks is often a requirement of consenting, and its over or underestimation could have profound effects on the sustainability of populations.

1.2 Reduce uncertainties when assessing seabird vulnerability to offshore wind farms

Assessing seabird vulnerability to marine energy infrastructures relies on 1) the understanding of the drivers of their at-sea distribution to deduce potential overlaps with marine anthropogenic activities, 2) the knowledge of their at-sea behaviour in response to the marine infrastructures (flight height, attraction and avoidance for example) to assess collision and disturbance risks, 3) the evaluation of risks impacts on local and global populations (through measurements of fitness and/or adult survival) according to species conservation status.

In the context of the X-ROTOR project, we combined those three aspects into Collision and Displacement Vulnerability indices for 81 seabird species present in European waters throughout the year and generate seabird vulnerability maps at the community level (see D.7.10). These indices combine numerous variables (see Critchley & Jessopp, 2019, and D.7.10) and their associated level of uncertainty can dramatically bias the conclusions on species vulnerability. For example, Péron et al. (2020) demonstrated that errors of magnitude of 20m appear when using GPS vertical positioning to describe flight height. These errors, if not taken into account, inflate the variance in flight height and lead to imperfectly quantifying the time spent by birds in the rotor-swept zone of wind turbines, biasing the conclusion of Collision Risk Models. To highlight areas lacking data, identify robust predictions and indicate where caution in interpreting vulnerability indices should be adopted, Wade et al. (2016) developed an uncertainty index that we applied reviewing seabird flight heights available for the 81 species considered (see D7.9). Although uncertainties can be quantified, it's important to collect new data and develop methods to reduce them.

The miniaturization of biologgers has enabled deployment on a growing number of seabird species, including some of the smallest species in Europe such as the European storm petrel (*Hydrobates pelagicus*) making possible the acquisition of increasingly precise data on their physiology (Andrews & Enstipp, 2016), navigation (Yoda, 2019), behaviour (Dunn et al., 2020) and distribution (Davies et al., 2021) during their life cycle. GPS and accelerometers can be used to describe flight behaviour (Collins et al., 2020; Thaxter et al., 2019) and individual habitat use at very fine spatio-temporal scale (Spelt et al., 2019), complementing data obtained through boat/aerial surveys. Those data can be incorporated into Collision Risk Models to determine the likelihood of a bird being in the rotor-swept area, or in vulnerability maps to assess the potential overlap between seabird habitats and wind farm locations (Thaxter et al., 2019) as well as evaluating reaction of seabirds to wind farms (Peschko et al., 2020). However, in the absence of wind turbines during early phase of wind farm development, it is difficult to access wind farm impacts on seabird behaviour, especially on potential attraction/avoidance one.

Previous studies have demonstrated the negative impact of wind turbines on marine mammals through disturbance and displacement (Madsen et al., 2006) notably by masking acoustic signals needed for navigation and communication or by injuring (either temporarily or permanently) their auditory organs. Few studies have looked at the use of acoustic signals in seabirds, but the emission of calls and reaction to noise on land (Mooney et al., 2019), at sea (Thiebault et al., 2019) as well as underwater (Hansen et al., 2017; Larsen et al., 2020; Thiebault et al., 2019) suggests that that anthropogenic sounds may modify seabird behaviour. In a wind turbine context, high levels of disturbance could decrease the collision risk while increasing the displacement of species toward less suitable areas. Because of the unique design of the X-ROTOR concept turbine, high and low frequency noises emitted by the rotor are expected to be more and less frequent, respectively, than for conventional turbines, potentially impacting seabird behaviour. Therefore, better description of seabird acoustic cues and sounds generated by X-ROTOR turbines are needed in order to estimate potential masking, adapt Collision and Displacement vulnerability indices and conclude on potential X-ROTOR impacts.

1.3 Deliverable details

This report forms part of the Socio-environmental impact work package of the X-ROTOR project and in order to 1) refine Collision and Displacement Vulnerability indices by reducing uncertainty in parameter estimates and 2) assess the potential detectability and response to the X-ROTOR concept acoustic profile and consequent effect on collision and disturbance risk, it aims to improve the knowledge of seabird species distribution, behaviour and acoustic cues. This report presents the methods implemented to collect seabird distribution data as well as flight height, flight speed and sounds experienced by seabird on land/ at-sea needed to improve our understanding of seabird ecology in a wind turbine context. Analysis of the corresponding data will be developed in the next deliverable.

2 Methods

2.1 Seabird species considered

We focused on 5 seabirds species (Figure 1), Atlantic puffin (*Fratercula arctica)*, European storm-petrel (*Hydrobates pelagicus)*, Lesser black-backed gull (*Larus fuscus)*, Northern gannet (*Morus bassanus)* and Manx shearwater (*Puffinus puffinus*) breeding in Ireland.

In Europe, Atlantic puffin is an endangered (IUCN, 2021) alcid species for which collision vulnerability is low (D.7.10) due to its low flight height (D.7.9). Although the collision with turbines doesn't appear as a major concern for the species, Atlantic puffins are vulnerable to disturbance by wind farms and avoid turbine areas. This avoidance could result in an increase of flight time and energy expenditure, leading to a decrease in adult body condition and feeding rate of chicks during the breeding season, potentially impacting survival/fitness and therefore population status. We assessed as "moderate" the uncertainty level of flight height and displacement sensitivity (D.7.9 & D.7.10). Previous studies (Mooney et al., 2020) have shown that Atlantic puffins have a fully functioning aerial hearing ability, despite the constraints of their deep-diving, amphibious lifestyles, potentially explaining their wind turbine avoidance. However further knowledge is required to determine whether turbines may mask important acoustic signals used for foraging.

The four others species have been classified as "Least Concern" by the IUCN, but are highly vulnerable to collision with wind turbines because of their flight height overlaps with turbine swept-zone and/or they exhibit a high percentage of time spent flying per day (D7.9 & D7.10). High uncertainty (D7.10) of flight height as well as sensitivity to disturbance for Manx shearwater and European storm petrel do not allow conclusions to be made with certainty with on collision risk or attraction/avoidance. European storm petrels are one of the lightest seabird species in the North Atlantic Ocean (26g, Cadiou et al., 2010) and only recent GPS miniaturization has allowed researchers to investigate their at-sea behaviour and distribution. In contrast, Northern gannets, are the largest seabird species in European waters (2.9kg, Malvat et al., 2020) and have been extensively tracked and studied. They have been shown to use acoustic cues at-sea while foraging (Thiebault et al., 2019) but the effects of wind turbine noise on perception of these calls remains unknown. Lesser black-backed gulls are opportunistic predators, displaying great behavioural plasticity (Tyson et al., 2015) which results in high uncertainty in distribution models. Empirical data are therefore important to understand their distribution in order to assess overlap with existing or planned wind farms. Given their social behaviour, one can expect that acoustic communication is important for this species, requiring a better understanding of acoustic cues used and potentially masked by wind turbines. All methods for device deployments outlined below were approved by the UCC Animal Experimentation Ethics Committee and conducted under license by the British Trust for Ornithology and the Irish National Parks and Wildlife Service .

Figure 1. The five seabird species studied, from top left to bottom right corner: Atlantic puffin, Manx shearwater, Lesser black-backed gull, European storm-petrel and Northern gannet

2.2 GPS deployment

To better describe distribution and flight behaviour, including flight height of the 5 focal seabird species, we deployed Global Positioning System (GPS) loggers during the summer 2021 and 2022 on breeding adults (see Table 1). Different models and configurations were deployed according to the species body mass and the likelihood of recapture to retrieve and download data. All GPS models recorded flight height as well as parameters (satellite numbers for example) needed to reduce the corresponding uncertainty (Péron et al., 2020) correcting for horizontal and vertical inaccuracies. For some deployments, extra parameters were recorded alongside of locations and flight height data, including flight speed, dive depth, temperature, 3-axis accelerometry. These provide fine scale data to identify different behaviours (Bennison et al., 2018) to contextualise flight height measurements and determine sensitivity to collision and displacement effects. Further, the distribution of individuals equipped can be compered with vulnerability maps based on at-sea surveys (D7.10).

Table 1. Summary of GPS deployment conducted on the five seabird species studied. Italics numbers correspond to expected deployment during summer 2022. TDR= Temperature Depth Recorder

Species	Location	Dates	Models	Number of individual equipped	Potential Co-Deployments	Parameters
Atlantic puffin	Skellig Michael (-10.54°E, 51.77°N)	10/07/21	PathTrack NanoFix-GEO	10	One on-board microphone (Table 2)	GPS interval: 5 min TDR interval: 2 sec
European storm petrel	Scariff Island (-10.25°E, 51.73°N)	07/2022 & 09/2022	Pathtrack Nanofix GEO mini	*19*	None	Remain to be defined
Lesser black-backed gull	Little Saltee (-6.59°E, 52.14°N)	05/2022	Lightbug Zero	*15*	None	GPS interval: 3 min
Manx shearwater	Little Saltee (-6.59°E, 52.14°N)	07/2021 & 07/2022	Pathtrack NanoFix-GEO or CatLog genII	61 & *27*	On-board microphone (Table 2), Cefas TDR with CatLog GPS	GPS interval: 5 min TDR interval: 2 sec (PathTrack) or 0.25 sec (Cefas)
Northern gannet	Great Saltee (-6.62°E, 52.11°N)	07/2021 & 07/2022	TechnoSmart AxyTrek Remote or IGotU	26 & *20*	On-board microphone or camera (Table 2), Cefas TDR with IGotU GPS	GPS interval: 5 min Accelerometer interval: 0.04 sec (TechnoSmart) TDR interval: 0,25 sec (Cefas)

2.3 Microphones deployment

Microphones were deployed at colony for the five species considered in order to record calls emitted by individuals at the colony. As Manx shearwaters may vocalise inside their burrows rather than outside, microphones were also deployed in nest chambers. Because individuals are also expected to vocalise at-sea, some species were equipped with on-board microphones and GPS to record sounds experienced at-sea and to link vocalisations with specific locations and behaviour. Not all species can be equipped in such a way due to constraints in size or recapture. Northern gannets, Manx shearwaters and one Atlantic puffin were equipped with microphones, details of which are presented in Table 2.

Table 2. Summary of microphone deployment on the five seabird species studied. Italics numbers correspond to expected deployment during the 2022 breeding season.

Species	Location	Dates	Models	Number of individual equipped	Potential Co-Deployments	Parameters
At colony						
Atlantic puffin	Skellig Michael & Little Saltee	07/2021 & 06/2021	Wildlife Acoustic Song Meter SM4	None	None	Sampling rate: 24 kHz Gain: 18 dB
European storm petrel	Scariff Island	07/2022				
Lesser black-backed gull	Little Saltee	07/2021				
Manx shearwater	Little Saltee	07/2021				
Northern gannet	Great Saltee	07/2022				
Inside burrow						
Manx shearwater	Little Saltee	07/2021 & 07/2022	Audiomoth & Audiomoth mini	10 & *20* nests	Partners were equipped with GPS & TDR (Table 1)	Sampling rate: 32 kHz Gain: Medium
On-board						
Atlantic puffin	Skellig Michael	10/07/21	Edic-Miny Weeny A110	1	GPS (Table 1)	Sampling rate: 16 kHz Gain: 24 dB
Manx shearwater	Little Saltee	07/2021	Edic-Miny Tiny B73	5	GPS & TDR (Table 1)	Sampling rate: 22 kHz Gain: unknown
Northern gannet	Great Saltee	07/2021 & 07/2022	Edic-Miny Tiny B73 or Mobius Maxi 4K camera or Audiomoth mini	7 and *20*	GPS & TDR (Table 1)	

Microphone parameters were chosen to find an acceptable compromise between recording duration and sampling frequency. As seabirds seem to detect sounds between 0.5 kHz and 6 kHz (Mooney et al., 2019) we chose a minimum sampling rate of 16 kHz to allow recording of the highest frequencies expected to be detectable to seabirds. Gain allows boosting the input level of the audio signal, with lower gain generally used in loud environments and higher gain used to improve weak signals. We used the default value (16 dB) for most models. On-board microphones were sealed inside foam and heat shrink to keep them dry. As this could decrease the sensitivity of microphones, we quantified any attenuation using with playback experiments for different frequencies with and without foam/heat shrink.

3 Deliverable outcomes

3.1 Retrieval rates

During the breeding season 2021, we managed to retrieve most of the on-board devices deployed on the four seabird species equipped. While we obtained highly detailed location data from all species, unfortunately, most of the on-board microphones deployed malfunctioned. Alternative acoustic recorders have been sought to deploy in the 2022 breeding season.

Table 3. Summary of GPS and microphone retrieval during the breeding season 2021

Species	Location	Dates	Models	Number of individual equipped	Number of individual retrieved
GPS deployments					
Atlantic puffin	Skellig Michael	10/07/21	PathTrack NanoFix-GEO	10	10
Manx shearwater	Little Saltee	07/2021	Pathtrack NanoFix-GEO or CatLog genII	61	43
Northern gannet	Great Saltee	07/2021	TechnoSmart AxyTrek Remote or IGotU	26	24
Microphones deployments					
Atlantic puffin	Skellig Michael	10/07/21	Edic-Miny Weeny A110	1	1 (malfunctioned)
Manx shearwater	Little Saltee	07/2021	Edic-Miny Tiny B73	5	3 (malfunctioned)
Northern gannet	Great Saltee	07/2021	Edic-Miny Tiny B73	7	6 (malfunctioned)

3.2 Example data

Significant GPS data was collected during summer 2021, enabling us to process tracks to identify key metrics including foraging dript range, duration and important foraging areas and transit routes (see Figure 2 for example with Atlantic puffins), showing a reasonable agreement with vulnerability maps previously produced under the X-ROTOR project (D7.10).

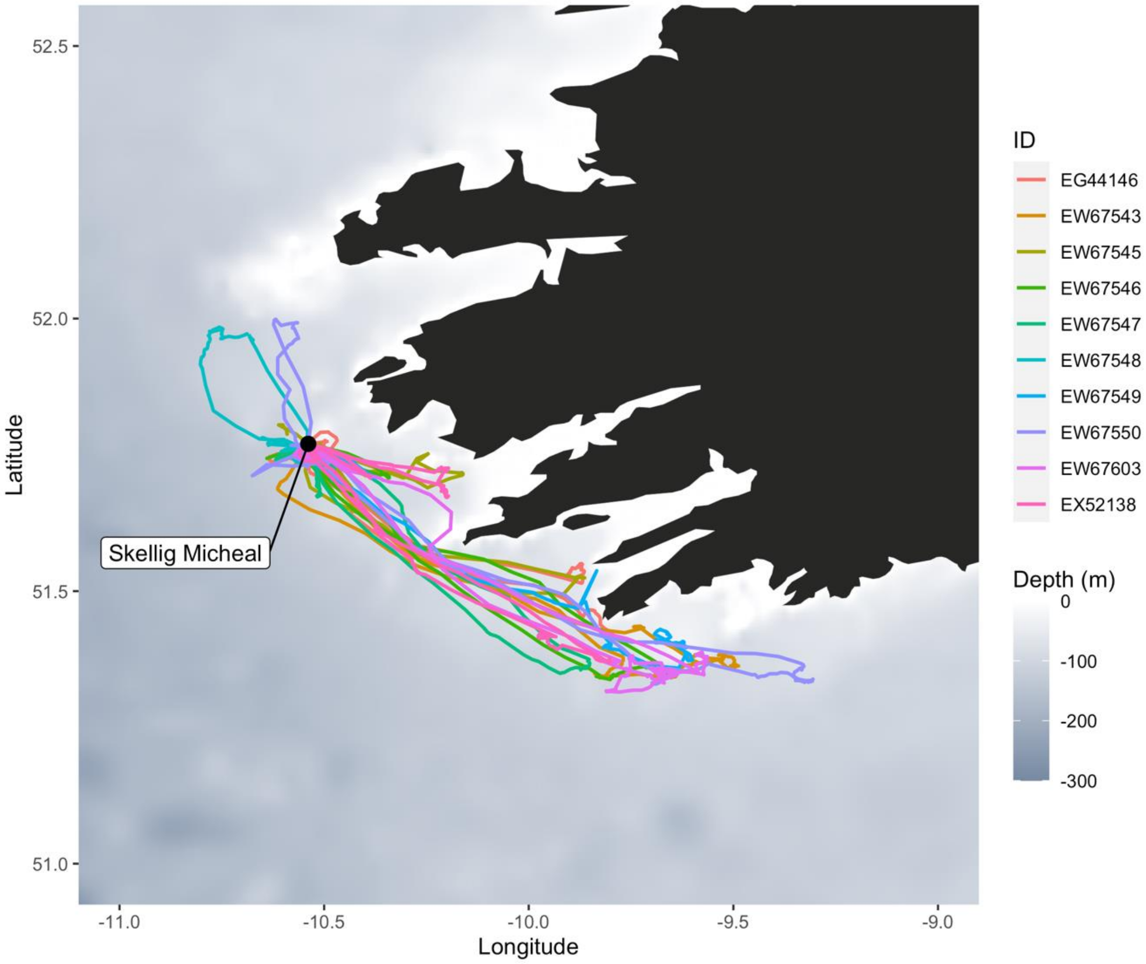

Figure 2. GPS tracks of the 10 Atlantic puffins equipped on Skellig Michael, Co Kerry, during the breeding season 2021.

Determination of flight height using raw GPS data should account for inaccuracies in the vertical plane (Péron et al., 2020) using state-space models (Ross-Smith et al., 2016). These will form the bulk of future analysis, so are not included in this report. Although most on-board microphones malfunctioned, we obtained sonograms linked to GPS locations and accelerometry or dive data (Figure 3). Frequencies emitted and received by individuals will be analysed, however, we require more information on the design of the X-ROTOR turbine and predicted noise signature to determine whether individuals may detect and respond to the noise from the turbine.

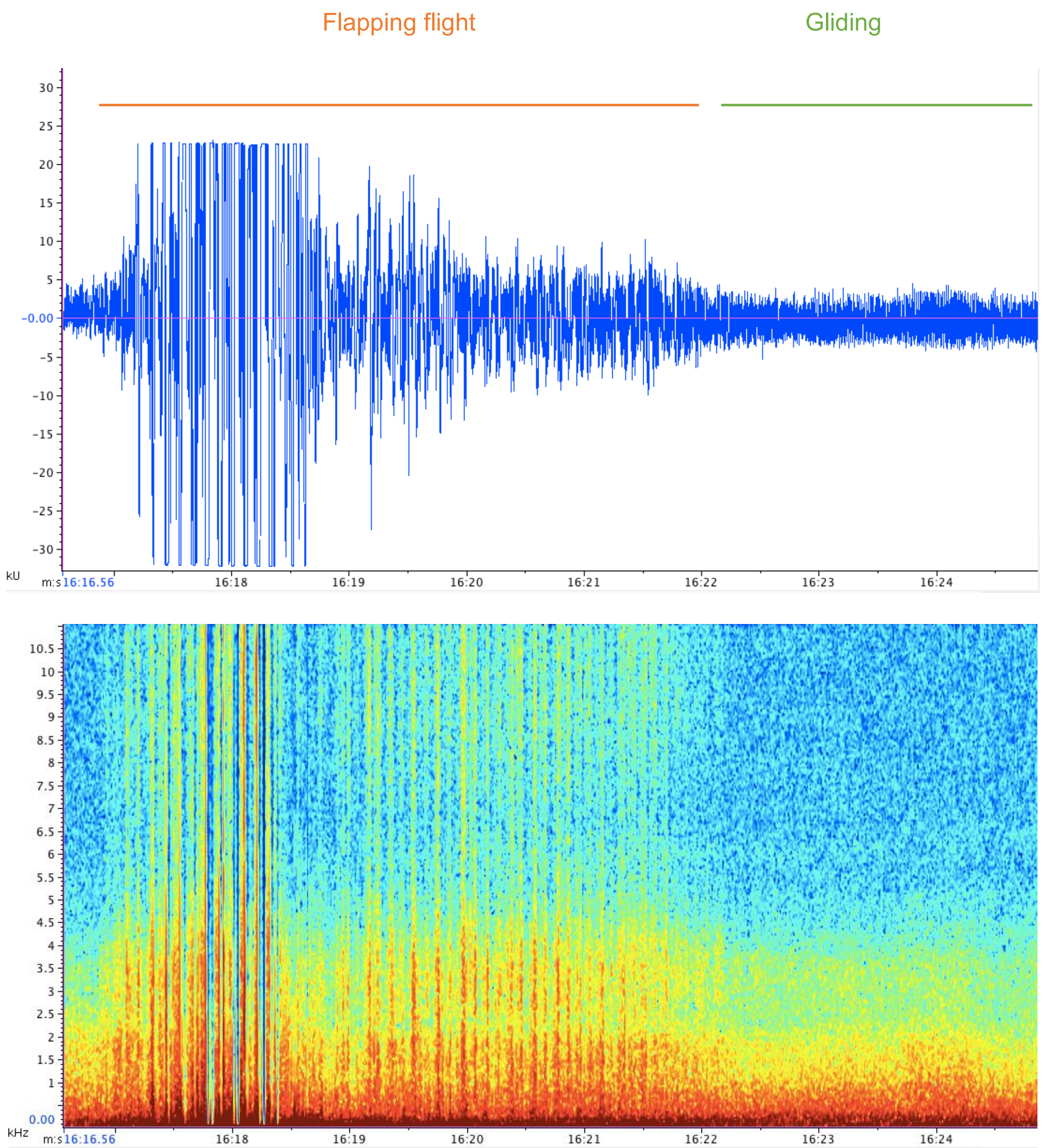

Figure 3: Oscillogram (top) and sonogram (bottom) from an on-board microphone during a segment of gannet flight. Wing beats were clearly identifiable and audible, enabling distinction between flapping and gliding flight.

4 Conclusion

This report presents methods to collect distribution, flight behaviour and acoustic cues for 5 seabird species for which collision and/or displacement risk assessment required more knowledge to reduce associate uncertainty. Preliminary analysis has begun on the data, but further deployments will be conducted during the 2022 seabird breeding season to increase sample size and address the failed acoustic recordings from the 2021 fieldwork season.

Some limitations inherent to our methods need to be taken into account. Péron and colleagues (2020) show that flight height measurements from GPS could be subject to inaccuracies and that the full distribution of flight height should be considered rather than the mean when assessing collision risk with turbines. However, Wade and colleagues (2016) consider flight heights based on GPS or radar as less subject to uncertainties than those based on direct observations, and state-space models provide satisfactory results when applied to GPS data (Ross-Smith et al., 2016). Given the logistical, cost, and ethical constraints on large-sacle seabird deployments, our data are from a small number of individuals equipped at a small spatio-temporal scales and therefore may not be fully representative of the wider population. Furthermore, deployments may affect the behaviour of the equipped birds. We have taken care to reduce handling times, and limited deployment weight to <3% of the bird's body mass, as recommend for tracking studies. Data obtained are consistent with other studies in terms of foraging range and duration providing confidence that we have recorded natural behaviours. Further analyses of tracking and acoustic data will be conducted within the X-ROTOR project in the following year and reported in the next deliverable (D.7.12). Previous assessments of Collision and Displacement Vulnerability (D7.10) will be reviewed in light of this analysis as well as information on the particular characteristics of the X-ROTOR turbine design.

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