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Species-specific inventory of tracking device usage, user experience and legal requirements

A. Potiek
S. Duijns

Bureau Waardenburg
Ecology & Landscape

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Bureau Waardenburg
Ecology & Landscape

Bureau Waardenburg, Varkensmarkt 9, 4101 CK Culemborg, the Netherlands
0031 (0) 345 512 710, info@buwa.nl, www.buwa.nl

Preface

The North Sea is home to large numbers of seabirds, and the proposed construction of multiple offshore windfarms might interfere with these species by indirect (e.g., avoidance), or by direct effects (e.g., collisions). Knowledge on the distribution and behaviour of these species is essential to estimate these indirect and direct effects and requires detailed recording of the movement of individuals. Tracking movements of individual seabirds have until recently been challenging, but advances in technology during the last decades have now enabled researchers to deploy a wide range of tracking devices on species with a wide range of body masses. Here, we present an inventory of the availability and applicability of these tracking devices for 13 seabird species of special interest in the North Sea.

The work would not have been possible without the help and assistance of all dedicated researchers, policy makers and tag manufacturers that helped with this study by providing relevant information and by filling out the online survey. We thank the following researchers: Jean-François Rail, Judy Shamoun-Baranes, Lorraine Chivers, Rahel Borrmann, Bernd Vorneweg, Brian D. Uher-Koch, Emeline Pettex, Ibrahim Alfarwi, Jonas Hentati-Sundberg, Kane Brides, Nina Dehnhard, Peter Rock, Phil Atkinson, Rowena H W Langston, Ulrik Lötberg, Victoria Warwick-Evans, Aevar Petersen, Ib Krag Petersen, Morten Frederiksen, Olivier Gilg, Risto Juvaste, Stefan Garthe, Liz Humphreys, Eric Stienen, Ewan D Wakefield, Francis Daunt, Hallvard Strøm, Keith Hamer, Lucy Wright, Martin Baptist, Ramunas Zydelis, Willem Bouten, Richard Phillips, Frederic Robin, Freydis Vigfusdottir, Grigori Tertitski, James Grecian, Kyle Elliot, Mark L Mallory, Morten Helberg, Natalie Isaksson, Sandra Bouwhuis, Thierry Boulinier, Rory Wilson, Emily Shepard, Christian Rutz, Anette Fayet, Tim Guilford, Francesca Cagnacci, Akiko KATO, Mary-Anne Lea, Sara M. Maxwell, Yan Ropert-Coudert, Akinori Takahashi, Lucy Hawkes, Jean-Baptiste Thiebot, Chris McKnight, Kentaro Kazama, Niall Burton, Samantha Cox, Jonathan Green and Aurore Ponchon for their help and willingness to fill out the survey or provide us with additional information. Ruben Fijn and Rob van Bemmelen (both Bureau Waardenburg) provided helpful comments on a previous version of this report. We thank the manufactures for providing us the requested information about the different tagging devices. In random order these companies are: Cellular Tracking Technologies, Druid Technology and INTERREX-RINGS, Ecotone, GeoTrak, GPS Collars AS, Hangzhou Yuehai Technology Co, HQXS, Hunan Global Messenger Technology Co. Ltd, Lotek, MigrateTech, Milsar, Movetag telemetry, North Star, Ornitela, Pathtrack, Technosmart, UVA bits and Wildlife computers. We also thank the Danish Energy Agency, the Bundesamt für Seeschifffahrt und Hydrologie (BSH), the Royal Belgian Institute for Natural Sciences (RBINS), the France Energies Marines, the JNCC and Marine Scotland for providing their insight in offshore wind energy and the relation with seabirds. We also thank our colleagues Mark Collier, Abel Gyimesi, Rob van Bemmelen and Ruben Fijn for contacting their network to participate in the online survey. Eric Stienen is thanked for his critical view and effort to review this report. This project is commissioned by Rijkswaterstaat Water, Verkeer en Leefomgeving (case number 31154272) and is being executed by Bureau Waardenburg. Maarten Platteeuw is supervising the project on behalf of Rijkswaterstaat Water, Verkeer en Leefomgeving and we thank him and Jos de Visser for the feedback and guidance.

Table of contents

1 Introduction

1.1 Background

The development and miniaturization of tracking devices and their ability of collecting ever more data, and less invasively, on a greater variety of animals (e.g., Kays *et al.*, 2015; Kays *et al*., 2020), enables researchers to investigate more closely the nature and range of the ways anthropogenic disturbances such as offshore windfarms may influence mobile marine animals such as seabirds and marine mammals (e.g., Warwick-Evans *et al.,* 2016; Warwick-Evans *et al.*, 2018). The potential impact of offshore wind farms (OWFs) on seabirds has been of particular interest. In the attempt to assess the possible effect of seabird displacement in response to OWFs, it is important to quantify both individual-level and population-level effects. Rijkswaterstaat and others formulated several research questions concerning seabird behaviour around offshore wind farms, with the most fundamental research questions being:

- Are seabirds displaced from offshore wind farms?
- What are the consequences of avoidance behaviour on various aspects of their life cycle (e.g., habitat loss, habituation, energy budget, reproductive capacity) on different time scales?

The advances made in technology during the last decades have enabled researchers to deploy a wide range of tracking devices in studies that address these and other related questions, such as behaviour inside OWFs, flight height, micro-avoidance, which could fill knowledge gaps concerning collision risks. In this project, we have sent out different questionnaires to researchers, policy makers and tag manufacturers in order to get an overview of the available tracking devices, and their applicability as a tool to answer these questions. These questionnaires can be found in Appendix I to III.

1.2 Overall project goal

The main goal of this project was to obtain a comprehensive overview of an as complete as possible array of available tracking devices suitable for studying the movement and behaviour of 13 different seabird species in relation to anthropogenic use of the marine environment that often attracts specific species of seabirds (buoys, platforms, fishery, ship traffic, sand extraction and OWFs). The species that are evaluated are: razorbill, common guillemot, northern gannet, great skua, Arctic skua, black-legged kittiwake, herring gull, lesser black-backed gull, great black-backed gull, Sandwich tern, common tern, red-throated diver and black tern. For the purpose of this study, we excluded geolocator and VHF-tags as possible tracking devices, as their spatial resolution is insufficient for studying offshore behaviour and movements in relation to anthropogenic disturbances such as offshore windfarms.

1.3 Reading guide

As described in the plan of action, this project consisted of three Work Packages:

- WP1. Technologies and methodology
- WP2. Research and knowledge gaps
- WP3. Strategy

In order to maximize readability, the results of these three Work Packages are restructured as follows:

- In Chapter 3, we present species-specific overviews of the results from WP1 as well as WP2. For each species, we start with an overview of tracking devices used by researchers (WP1) and tracking devices that have not (yet) been used but that might be suitable. With this overview, the manufacturer details and user-experiences of these tracking devices are scored using a multi-criteria analysis (MCA)*. For the potential devices, only manufacturer details are presented, as scores for user experience are not available. We also present a species-specific description of the international ongoing initiatives of tagging and tracking studies. Within this species-specific overview, we also highlight the existing knowledge gaps (WP2).

- Chapter 4 presents an overview of study-specific considerations, including a summary of used biologging devices and an overview of legal requirements for different countries around the North Sea, followed by a discussion of the results in Chapter 5 and a follow-up strategy, which can be supplemented with the outcomes and suggestions from a workshop, to be organized by RWS on April 15th 2021 (WP3).

*Note that the scores are based on a general scoring table, as presented in Table 2.1, but this does not automatically suggest using the device with the highest score. Depending on the specific research question, location, funding and legal regulations, different aspects may be more important. For that reason, in addition to the overall scores, the scores of the individual aspects are shown in the overview as well. Therefore, the device with the highest score is not necessarily the best choice in all situations. For example, a device with a low weight gets a high score, as this is generally less invasive to the study species, but this generally means a shorter life span of the battery. Depending on the research question, a somewhat heavier device may be more suitable (of course within the acceptable range). In addition, the tags mentioned in this report represent general commercially available tags, while manufactures also indicate they can customize the device to specific needs. Therefore, it should serve as an inventory guide on what is currently available.

2 Methods

2.1 General description of questionnaires

The online questionnaires were sent out to three groups: researchers, tag manufacturers and policy makers. Each group received a different questionnaire, which can be found in Appendices I-III. In this chapter, we give a description of the questions asked for each type of respondent.

2.1.1 Researchers

Researchers are the main users of tags and therefore the main aim of this questionnaire was to gain insight in their experiences with the different types of tags that are available for the species involved, as well as an inventory of the different tagging devices that are being used. Researchers were asked to indicate the level of malfunctioning, satisfaction with battery life and tag quality, price/quality ratio, impact on animals' welfare and recommendations to other researchers. In addition, the researchers were asked which tags were used per species to create a species-specific overview.

2.1.2 Tag manufacturers

Tag manufacturers developing tracking devices received a questionnaire containing questions about the specifications of their tracking devices. They were asked to indicate the power supply (battery only, solar only or a combination), data transfer, battery life, price per unit, delivery time within Europe, biologging options, and whether these devices are ready to use or still under development. Tag manufacturers were also asked which species are tagged with the different tags. This information will be used for the overview of the tags used per species.

2.1.3 Policy makers

Policy makers implement results from tagging studies into policy, hence the approach was to illuminate the extent to which these results are actually being used for different species. In addition, we aimed to gain insight in the types of questions policy makers would like to get answered in relation to offshore windfarms and birds.

2.2 Evaluation of questionnaire responses

Different types of data can be extracted from the questionnaire responses. Here we present our approach to the interpretation of the results of the questionnaire for all 13 species involved.

2.2.1 Scoring of characteristics / performance

In addition to the general overview of tracking devices (that can be) used for that particular species, each tracking device is scored for performance characteristics, such as:

- Price per unit
- Weight
- Life expectancy
- Data transfer (e.g., via base station, recapture or GSM-UMTS)
- Availability of biologging options
- Spatial and temporal resolution of resulting data

For each of these characteristics we used a Multi Criteria Analysis (MCA) approach and scored the different components according to the overall aim, i.e., studying offshore behaviour of seabirds in relation to anthropogenic pressures. As a result, the spatial and temporal resolutions of tracking data is an important characteristic. Specifications of the six predefined tag characteristics listed above were specifically requested in the questionnaires. The results presented in this report are based on responses from both researchers and tag manufacturers. In the MCA, each parameter is given a score between -5 and 5, where -5 indicates a major drawback of the tracking device, whereas 5 is the best score (Table 2.1). Some of these devices have already been used on a particular species and a review score is added based on the responses of the questionnaire (Table 2.2). In addition, some devices have not been used on the species and/or no reviews were available from the questionnaire but were deployed on a similar seabird species and are therefore included. In the latter case, a review is included, but receives a lower review score. The benefit of this approach is that it becomes clear which tags receive a high overall score due to the specifications and for which reviews and experiences from world leading scientists are available. Note that we do not automatically encourage or support the use of specific tracking devices based on the ranking of devices, but merely attempt to evaluate the available tracking devices suitable for the selected species and questions related to offshore behaviour in relation to anthropogenic disturbances, such as offshore windfarms. In the end, the researchers are always responsible for the choices that are to be made in selecting the appropriate devices that suit their questions best.

In addition to these scorings per type of tracking device, we generated a factsheet per species and indicate which institutes or individual researchers are some of the key players studying the particular species, and where most of the field work has been done (breeding grounds versus during migration, including country). In addition, we will incorporate species-specific responses from other questions into the text, such as knowledge gaps, limiting factors, and general issues.

Table 2.1 Multi Criteria Analysis score for the different parameters.

Parameter	Levels or criteria	Score (-5 to 5)
% Body mass score (tag mass / body mass * 100%)	< 1	5
	> 1 & < 2	3
	> 2 & < 3	0
	> 3 & < 4	-2
	> 4	-5
Power source	Battery	0
	Solar and Battery	3
	Solar	5
Price per tag	Lower than expected	-5
	As expected	0
	Higher than expected	5
Spatial resolution	Argos	0
	GPS (~ 5 m accuracy)	5
Data transfer	Recatching necessary	-5
	Data transfer via base station	0
	Data transfer via mobile network	5
Internal antenna	Yes	5
	No	0
Biologging options	1 point per biologging option	1

Table 2.2 Review score for the different parameters.

Parameter	Levels or criteria	Score (-5 to 5)
% Malfunctioning	< 1	5
	1 – 10	3
	11 – 25	0
	26 – 50	-4
	51 – 75	-5
	> 75	-5
Usability of the technique	Interpretation of questionniare response	-5 to 5
Satisfaction battery life	As expected	0
	Better than expected	5
	Worse than expected	-5
Satisfaction quality	As expected	0
	Better than expected	5
	Worse than expected	-5
Price / Quality ratio	< 2	-5
	3	-4
	4	-3
	5	-1
	6	1
	7	3
	8	4
	> 8	5
Recommendation of the tag	Never	-5
	No, unless you don't have other options	-2
	Yes, but with a few warnings	2
	Absolutely	5
Representativeness*	Very good (solid sample size, normal behaviour)	5
	Good (sample size could be increased, but normal behaviour)	4
	Reasonable (sample size could be increased, possibly slight influence on behaviour)	2
	Bad (sample size should be increased, behaviour was strongly influenced)	-5
Species	Review based on target species -Yes	5
	Review based on target species -No	0

* accounting for sample size and possible negative effects on the animal's welfare

3 Results

3.1 General results: Level of response from questionnaires

The three questionnaires have been sent out to researchers, tag manufacturers and policy makers. Table 3.1 gives an overview of the number of questionnaires that have been sent and the level of response.

Table 3.1 Number of sent out questionnaires per category.

	Requests sent	Filled in	No response or no interest	Percentage response
Researchers	97	48	49	49%
Tag manufacturers	21	15	6*	71%
Policy makers	7	3	4	43%

* 2 of these could not open the questionnaire in China, since all of Google's products are banned in China.

We sent a total of 97 invitations for our questionnaire to researchers that were identified to work on the 13 focal species. From these, 48 researchers filled in the questionnaire (49%). The reason for not participating in the survey was diverse. Some indicated that they were too busy, some mentioned that they did not work on offshore windfarms and some indicated that they shifted their work to other fields. After the first invitation, we sent a reminder 2 weeks later and when no response came in, we sent another reminder 2 weeks later again. As researchers move around much, have fieldwork in remote locations, or start new jobs with new contact details, we anticipated some delays in responding.

The questionnaire was sent to 21 tag manufacturers, of which 15 have filled in the questionnaire (71%). Of the 21 tag manufacturers, 15 filled in the questionnaire (71%), and 2 mentioned that they could not open our survey, since they are based in China and all of Google's products are banned in China. As in the other questionnaires, after the first invitation, we sent a reminder 2 weeks later and when no response came in, we sent another reminder 2 weeks later.

The questionnaire was sent out to seven policy makers, of which three have filled in the questionnaire (43%). These include the Royal Belgian Institute for Natural Sciences (RBINS), JNCC and Marine Scotland. One policy maker indicated to have no interest, without a clear reason, and three others did not respond. After the first invitation, we sent a reminder 2 weeks later and when no response came in, we sent another reminder 2 weeks later.

Below, we present for each study species a scoring overview for the potential tracking devices, and a map showing all the capture sites of researchers that responded to our online questionnaire. In addition, we give a general description of the ecology.

3.2 Black-legged kittiwake

General ecology

The black-legged kittiwake *Rissa tridactyla* is a common gull on the Dutch continental shelf during winter, mainly using areas further offshore. Large breeding colonies around the North Sea are located in Northeast-England, East-Scotland, and on the Orkneys and Shetland Isles. Colonies in Southern Norway, Denmark and Germany are smaller, totalling less than 10,000 pairs (Mitchell *et al.,* 2004). Some small numbers of kittiwakes breed on the oil platforms on the Dutch Continental Shelf (Camphuysen & Leopold, 2007; Geelhoed *et al*., 2011).

Kittiwakes spend the winter at sea in the Northwest Atlantic (Frederiksen *et al*., 2012), but also in the North Sea and Norwegian Sea. Individuals from the entire North-Atlantic breeding range are present in the Dutch North Sea (Frederiksen *et al*., 2012). Immature birds stay at sea until maturation (Coulson & Nève de Mévergnies, 1992). In summer, kittiwakes stay much closer to the colonies (mean feeding range of 25 km; Thaxter *et al.,* 2012). However, this range is dependent on colony and habitat characteristics (Soanes *et al.,* 2013). For example, adults from a colony in Northeast England have a feeding range of approximately 50 km during the breeding season (Robertson *et al.*, 2014) and even larger foraging ranges have been found for various colonies.

The European population has been declining since the 1980s, mainly due to decreased food availability (Frederiksen *et al.*, 2012). The current decline is estimated at >40% over three generations (39 years) leading to a 'vulnerable' status on the global 'IUCN Red List of Threatened Species' (BirdLife International 2021), in addition to a similar status on the European, British and Norwegian Red Lists ('Endangered').

Kittiwakes are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019), and tagging studies of kittiwakes which focus on the impact of wind turbines in the North Sea should take place on breeding birds within this area as tagging elsewhere would incur a high risk of individuals not using the North Sea. However, the vast majority of the kittiwakes that reside in the North Sea region are either non-breeders or wintering/migrating birds either from North Sea breeding colonies or from outside this region, hence focussing on breeding birds will lead to a bias. In order to estimate the effects of OWFs on this species, it would be favourable to study birds outside the breeding season as well as juvenile birds, despite practical and logistical issues. All researchers studying kittiwakes that responded to our questionnaire indicated they caught and attached tracking devices to birds in breeding colonies.

Scoring tracking devices

Based on the responses from researchers to our questionnaire, we rated their experiences for 21 types of tagging devices. To calculate the % of body mass, we assumed an average mass of 360g (Kotzerka *et al*., 2010). In addition, we rated 7 additional types of tagging devices based on specifications given by the manufacturer or similarly sized species. This resulted in the scoring of 28 tagging devices presented in Table 3.2.

Main research initiatives

Around the North Sea, tracking studies on black-legged kittiwakes are taking place in Denmark (Aarhus University), UK (University of Liverpool, RSPB, CEH, Queen's University of Belfast, University of Glasgow, University of Roehampton London), Germany (Kiel University), Norway (NINA, CRS, Norwegian University of Science and Technology NTNU) and France (CNRS and CEFE). In addition, the WWT does research on this species in Iceland, and Acadia University from Canada does research on kittiwakes in Arctic Canada.

Catching sites and catchability
All researchers that responded (n = 7) indicated they caught the species at the breeding sites (Figure 3.1), and 5 respondents indicated the sample size of their study also was limited due to catchability of this species.

Interested in Tagging and Tracking platform: 57%.

Table 3.2 Overview of the scores for tagging devices suitable for black-legged kittiwake. In this table, the tagging devices of Ornitela received the highest score.

Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna
					Characteristics					
Ornitela	Ornitrack-10		10	2.8	0	3	5	5	5	5
Ornitela	Ornitrack-15		15	4.2	-5	3	5	5	5	5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	1.1	3	3	-	5	5	5
Milsar	GSMRadioTag-M9		16	4.4	-5	3	0	5	5	5
North Star	Saker L		17	4.7	-5	3	0	5	5	5
TechnoSMart	Gipsy GSM/3G		10	2.8	0	3	0	5	5	0
Ecotone	KITE-L GPS		17	4.7	-5	3	0	5	5	5
Ecotone	ALLE-60 GPS-UHF	6.7	4.5	1.3	3	0	5	5	0	0
TechnoSMart	Axy-Trek Marine	1	14	3.9	-2	3	0	5	0	5
Milsar	GsmRadioTag-S9		12	3.3	-2	3	0	5	5	0
Milsar	Radio tag 14	5	10	2.8	0	3	0	5	0	0
UvaBITS	Uva-Bits 2DCSe	4	7.5	2.1	0	3	0	5	0	5
TechnoSMart	Axy-Trek Mini	3	9	2.5	0	3	0	5	0	0
PathTrack	Nanofix Geo+RF		14	3.9	-2	3	5	5	0	0
UvaBITS	Uva-Bits 5DCLeGSM		13.5	3.8	-2	3	0	5	0	5
CellTrack	ES-150		15	4.2	-5	3	0	0	5	5
Lotek	PP GPS Argos Solar		16.5	4.6	-5	3	0	5	0	5
Ecotone	URIA-300 GPS-UHF	6.7	13.5	3.8	-2	0	0	5	5	0

Manufacturer	Type (incl. link)	Barometric pressure	Speed	Direction	Acceleration	Temperature	Immersion sensor	Geofence	Dive depth	**Summary score**
		Biologging options								
Ornitela	Ornitrack-10	-	1	1	1	1	-	1	-	28
Ornitela	Ornitrack-15	-	1	1	1	1	1	1	-	24
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304	-	-	-	-	-	-	-	-	21
Milsar	GSMRadioTag-M9	1	1	-	1	1	-	1	1	19
North Star	Saker L	1	1	-	1	1	-	1	1	19
TechnoSMart	Gipsy GSM/3G	1	-	1	1	1	-	-	1	18
Ecotone	KITE-L GPS	1	-	-	1	1	-	-	1	17
Ecotone	ALLE-60 GPS-UHF	1	-	-	-	1	-	-	1	16
TechnoSMart	Axy-Trek Marine	1	-	-	1	1	1	-	1	16
Milsar	GsmRadioTag-S9	-	1	-	1	1	-	1	-	15
Milsar	Radio tag 14	1	1	-	1	1	-	1	1	14
UvaBITS	Uva-Bits 2DCSe	-	-	-	1	-	-	-	-	14
TechnoSMart	Axy-Trek Mini	1	-	-	1	1	1	-	1	13
PathTrack	Nanofix Geo+RF	-	-	-	-	-	-	-	1	12
UvaBITS	Uva-Bits 5DCLeGSM	-	-	-	1	-	-	-	-	12
CellTrack	ES-150	-	1	-	1	1	-	1	-	12
Lotek	PP GPS Argos Solar	-	-	-	1	1	-	1	-	11
Ecotone	URIA-300 GPS-UHF	1	-	-	-	-	-	-	1	10

Manufacturer	Type (incl. link)	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Kittiwake	**Average review score**
		Review								
Ornitela	Ornitrack-10	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-15	3	1	5	5	5	5	4	0	3.5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304	-	-	-	-	-	-	-	-	
Milsar	GSMRadioTag-M9	-	-	-	-	-	-	-	-	
North Star	Saker L	-	-	-	-	-	-	-	-	
TechnoSMart	Gipsy GSM/3G	0	1	-5	-5	-1	2	3	0	-0.6
Ecotone	KITE-L GPS	3	1	0	0	4	5	4	0	2.1
Ecotone	ALLE-60 GPS-UHF	3	1	0	5	5	5	4	5	3.5
TechnoSMart	Axy-Trek Marine	0	1	0	0	5	5	4	5	2.5
Milsar	GsmRadioTag-S9	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14	0	1	5	5	4	5	4	5	3.6
UvaBITS	Uva-Bits 2DCSe	3	1	-5	0	4	2	4	5	1.8
TechnoSMart	Axy-Trek Mini	0	1	0	0	5	5	4	5	2.5
PathTrack	Nanofix Geo+RF	0	1	0	0	4	2	4	0	1.4
UvaBITS	Uva-Bits 5DCLeGSM	0	2	0	0	-1	2	4	0	0.9
CellTrack	ES-150	-	-	-	-	-	-	-	-	
Lotek	PP GPS Argos Solar	-	-	-	-	-	-	-	-	
Ecotone	URIA-300 GPS-UHF	0	1	0	0	4	2	4	5	2.0

Biotrack	Mk3006	2	2.5	0.7	5	0	5	-	-	-	-	-	-	-	-	-	-	-	10	0	1	-5	-5	-1	2	3	5	0.0
PathTrack	Nanofix Geo+RF		4.2	1.2	3	0	0	5	0	0	-	-	-	-	-	1	-	-	9	5	1	0	5	4	2	4	0	2.6
Ecotone	Harrier H		16	4.4	-5	3	0	5	0	5	-	-	-	1	-	-	-	-	9	0	1	0	0	-1	2	3	0	0.6
IgotU	GT-120	2.8	20	5.6	-5	3	5	0	0	5	-	-	-	-	-	-	-	-	8	3	0	0	5	5	2	0	5	2.5
E-obs	Bird Solar 10	7	10.7	3.0	0	3	0	5	0	0	-	-	-	-	-	-	-	-	8	3	0	0	0	4	5	4	5	2.6
E-obs	Bird Solar Tags		15	4.2	-5	3	0	5	0	0	-	1	1	1	-	-	-	-	6	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		10	2.8	0	0	0	5	0	0	-	-	-	-	-	-	-	-	5	5	1	0	5	4	2	4	0	2.6
PathTrack	Nanofix Geo+RF		11	3.1	-2	0	0	5	0	0	-	-	-	-	-	1	-	1	5	5	1	0	5	4	2	4	0	2.6
GeoTrak	12G Solar Gps		12	3.3	-2	3	-5	0	5	0	-	1	1	1	1	-	-	-	5	-	-	-	-	-	-	-	-	
E-obs	Bird Solar 15	7	15	4.2	-5	3	0	5	0	0	-	-	-	-	-	-	-	-	3	3	0	0	0	4	5	4	5	2.6

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7 University of Kiel
8 University of Reykjavik

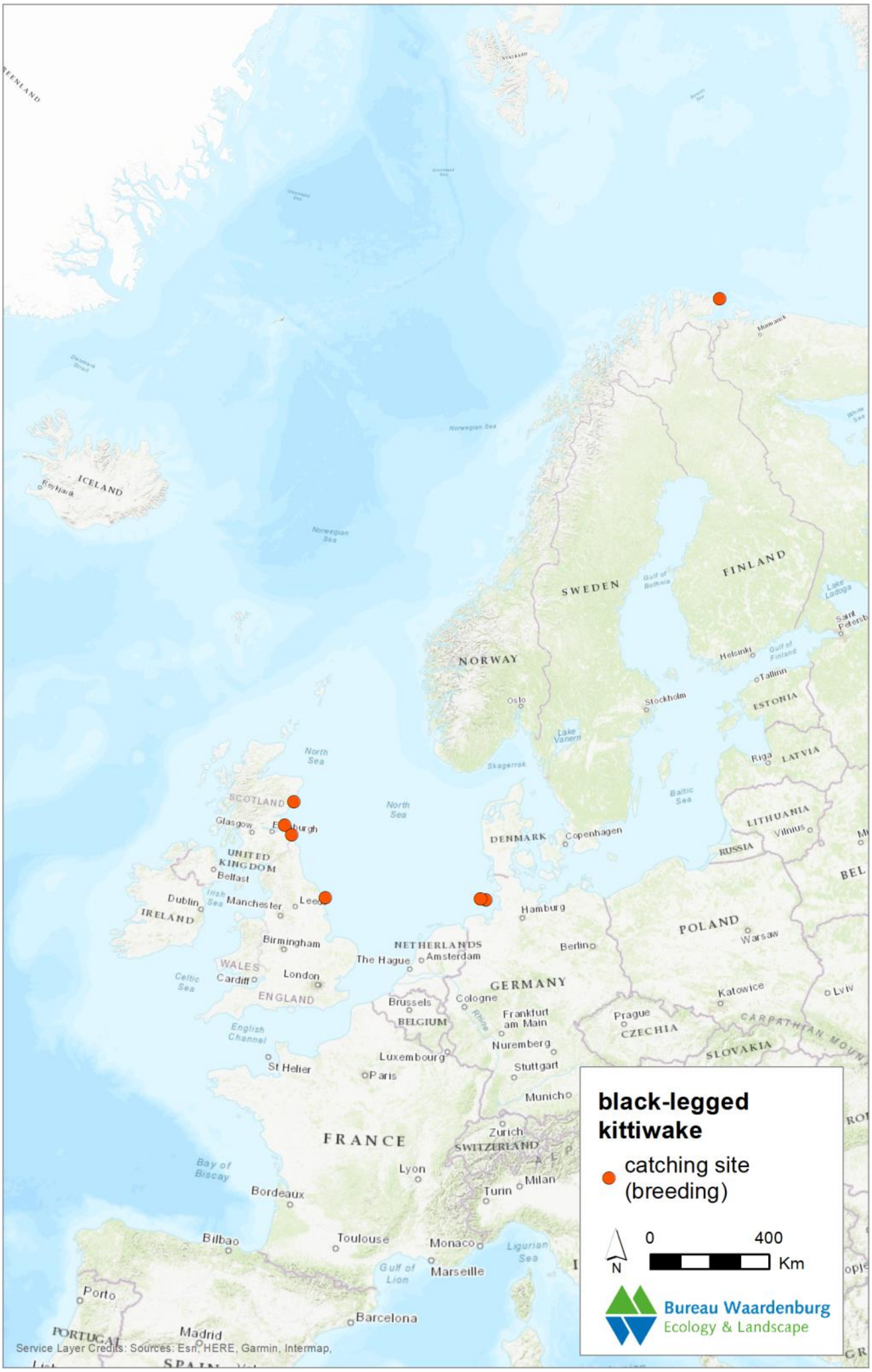

Figure 3.1 *Map with the catching sites of black-legged kittiwake of researchers that responded to our online survey.*

3.3 Great black-backed gull

General ecology

The breeding range of the great black-backed gull *Larus marinus* covers the north Atlantic and adjacent seas (Mitchell *et al.*, 2004). Of the ~100,000 breeding pairs in Europe, the majority breeds in Norway (40,000), followed by Britain (17,000), Sweden (15,000) and Iceland (15,000). Fewer individuals breed in the Netherlands and Germany, with an estimated 61-65 breeding pairs in the Netherlands (Boele *et al.,* 2017), and around 4,000 breeding pairs in France (Mitchell *et al.,* 2004).

Many great black-backed gulls breeding in the UK are residents and spend the winter close to their nesting grounds, where they mainly forage in the North Sea. Individuals breeding in Norway and Denmark move southwards outside the breeding season. Individuals breeding in France, Germany, the Netherlands, UK, Denmark, and the whole of Fennoscandinavia east to the Kola Peninsula use the North Sea in winter for foraging (Taylor, 2014, www.vogeltrekatlas.nl) and are therefore at risk of collisions with wind turbines located in this area and are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices

Based on the responses from researchers to our questionnaire, the experiences for 31 types of tagging devices were rated. Another 13 additional types of tagging devices were scored, based on specifications given by the manufacturer. This resulted in the scoring of 44 tagging devices presented in Table 3.3. To calculate the % of body mass, we assumed an average mass of 1600g (Maynard & Ronconi, 2018).

Main research initiatives

In countries around the southern North Sea, most research on great black-backed gulls with tracking devices is done by the University of Oslo, Lund University, Uni Kiel, Arhus University and in France (Bretagne Vivante and LPO). In addition, the Russian institute of geography is involved in research with tracking devices on great black-backed gulls.

Interested in Tagging and Tracking platform: 83%.

Catching sites and catchability

All researchers (n = 6) indicated they caught the species at the breeding sites (Figure 3.2), while 4 also indicated they caught them at foraging and roosting sites and 9 respondents indicated the sample size of their study also was limited due to catchability of this species.

Table 3.3 Overview of the scores for tagging devices suitable for great black-backed gull. In this table, the Ornitela devices received the highest score.

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	GBBG	**Average review score**
Ornitela	Ornitrack-10	-	10	0.6	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-15		15	0.9	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-30	3	30	1.9	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	5	4.1
Ornitela	Ornitrack-20	-	20	1.3	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-25	-	25	1.6	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	0	3.5
Movetech	Flyway 18s		18	1.1	3	3	5	5	5	5	-	-	-	1	1	-	-	-	28	5	3	0	0	1	2	3	0	1.8
Movetech	Flyway 25s		25	1.6	3	3	5	5	5	5	-	-	-	1	1	-	-	-	28	0	3	0	0	3	2	4	0	1.5
Ornitela	Ornitrack-50		50	3.1	-2	3	5	5	5	5	1	1	1	1	1	-	1	-	27	0	1	5	5	4	5	4	0	3.0
Milsar	GSMRadioTag-M9		16	1.0	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
North Star	Saker L		17	1.1	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+GSM		31	1.9	3	3	5	5	5	5	-	-	-	-	-	-	-	1	27	-	-	-	-	-	-	-	-	
Ecotone	KITE-L GPS	2	17	1.1	3	3	0	5	5	5	1	-	-	1	1	-	-	1	25	3	1	0	0	4	5	4	5	2.8
Ecotone	Griffon		38	2.4	0	3	0	5	5	5	1	1	-	1	1	1	-	1	24	3	1	0	0	4	2	4	0	1.8
TechnoSMart	Gipsy GSM/3G		10	0.6	5	3	0	5	5	0	1	-	1	1	1	-	-	1	23	0	1	-5	-5	-1	2	3	0	-0.6
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0.3	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Interrex	LEGO		18.7	1.2	3	3	0	5	5	5	-	-	-	1	-	-	1	-	23	-	-	-	-	-	-	-	-	
Milsar	GsmRadioTag-S9		12	0.8	5	3	0	5	5	0	-	1	-	1	1	-	1	-	22	-	-	-	-	-	-	-	-	
CellTrack	ES-150	-	15	0.9	5	3	0	0	5	5	-	1	-	1	1	-	1	-	22	-	-	-	-	-	-	-	-	
TechnoSMart	Axy-Trek Marine		14	0.9	3	3	0	5	0	5	1	-	-	1	1	1	-	1	21	0	1	0	0	5	5	4	0	1.9
Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	1.3	3	3	5	5	5	0	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	

Milsar	Radio tag 14		10	0.6	5	3	0	5	0	0	1	1	-	1	1	-	1	1	19	0	1	5	5	4	5	4	0	3.0
E-obs	Bird Solar UMTS	3	25	1.6	3	3	0	5	5	0	-	1	1	1	-	-	-	-	19	3	0	0	0	4	5	4	5	2.6
Ecotone	Gannet		40	2.5	0	3	0	5	5	0	1	1	-	1	1	1	-	1	19	3	1	0	0	4	5	4	0	2.1
PathTrack	Nanofix Geo+RF		14	0.9	5	3	5	5	0	0	-	-	-	-	-	-	-	1	19	0	1	0	0	4	2	4	0	1.4
UvaBITS	Uva-Bits 5DCLeGSM		13.5	0.8	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	2	0	0	-1	2	4	0	0.9
UvaBITS	Uva-Bits 2DCSe		7.5	0.5	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	-5	0	4	2	4	0	0.8
Lotek	PP GPS Argos Solar		16.5	1.0	3	3	0	5	0	5	-	-	-	1	1	-	1	-	19	-	-	-	-	-	-	-	-	
Ecotone	ALLE-60 GPS-UHF		4.5	0.3	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	0	2.9
UvaBITS	Uva-Bits 6CDLe		18.5	1.2	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	3	2	0	5	5	5	4	0	3.0
Ecotone	Harrier H		16	1.0	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	0	0	-1	2	3	0	0.6
Ecotone	URIA-300 GPS-UHF	1	13.5	0.8	5	0	0	5	5	0	1	-	-	-	-	-	-	1	17	-5	1	0	-5	-3	-5	0	5	-1.5
E-obs	Bird Solar Tags		15	0.9	5	3	0	5	0	0	-	1	1	1	-	-	-	-	16	3	0	0	0	4	5	4	0	2.0
IgotU	GT-120		20	1.3	3	3	5	0	0	5	-	-	-	-	-	-	-	-	16	3	0	0	5	5	2	0	0	1.9
Microwave Telemetry Inc.	Solar Argos PTT	-	22	1.4	3	3	-5	5	5	0	-	1	1	1	1	-	-	-	15	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G	-	25	1.6	3	3	-5	5	5	0	-	1	1	1	1	-	-	-	15	-	-	-	-	-	-	-	-	
Ecotone	Horse tail		71	4.4	-5	3	0	5	5	0	1	1	-	1	1	1	-	1	14	3	1	0	0	4	5	4	0	2.1
IgotU	GT-600		37	2.3	0	3	5	0	0	5	-	-	-	-	-	-	-	-	13	3	0	0	5	5	5	0	0	2.3
PathTrack	Nanofix Geo+RF		11	0.7	5	0	0	5	0	0	-	-	-	-	-	1	-	1	12	5	1	0	5	4	2	4	0	2.6
GeoTrak	12G Solar Gps	-	12	0.8	5	3	-5	0	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
E-obs	Bird Battery		39	2.4	0	3	0	5	0	0	-	1	1	1	-	-	-	-	11	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		10	0.6	5	0	0	5	0	0	-	-	-	-	-	-	-	-	10	5	1	0	5	4	2	4	0	2.6
GeoTrak	22G Solar Gps		22	1.4	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
Telonics	TAV-2618		18	1.1	3	0	-5	0	5	0	-	1	-	1	1	1	-	-	7	3	-5	-5	0	4	2	5	0	0.5
Telonics	TAV-2665		71	4.4	-5	0	-5	0	5	0	-	1	-	1	1	1	-	-	-1	3	-5	-5	0	4	2	5	0	0.5

1 LPO

2 University of the Highlands and islands

3 University of Kiel

Figure 3.2 *Map with the catching sites of great black-backed gull of researchers that responded to our online survey*

3.4 Herring gull

General ecology

Herring gulls *Larus argentatus* can be found year-round in and around the North Sea (Camphuysen, 2013). The highest concentrations are found within 12 miles from the coast, where breeding colonies are located (Fijn *et al*., 2015). Breeding occurs mostly along the coast of all countries around the North Sea. In winter, most individuals spend the winter inland or at coastal regions without moving through the North Sea (although some do use the intertidal areas for foraging). Only a small proportion uses the marine waters of the southern North Sea and the English Channel (unpublished results E. Stienen).

Herring gulls use both the sea and inland (for example agricultural areas, urban environments and rubbish dumps) for foraging. Feeding ranges of individuals from a Dutch colony were 35 km (Spaans, 1971). A more recent estimate is that 95% of the herring gulls breeding on Terschelling foraged within 54 km from the colony (Camphuysen *et al.*, 1995). In the last decades, at least the populations of herring gulls in the Netherlands and the United Kingdom declined (www.sovon.nl, JNCC Seabird Monitoring Programme Database: www.jncc.gov.uk/smp). Herring gulls are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices

Based on the responses from researchers to our questionnaire, we rated their experiences for 30 types of tagging devices. In addition, we rated 15 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 45 tagging devices presented in Table 3.4. To calculate the % of body mass, we assumed an average mass of 1100g (Camphuysen, 2013).

Main research initiatives

For herring gull, the most important research initiatives in Europe are in the UK (Univ. Bristol, Newcastle University, BTO), France (LPO), Belgium (INBO), the Netherlands (NIOZ, INBO, BuWa) and Germany (Uni Kiel, NABU). Outside of Europe, among others the Canadian Acadia University and the Russian Institute of Geography are involved.

Interested in Tagging and Tracking platform: 86%.

Catching sites and catchability

All researchers (n = 14) indicated they caught the species at the breeding sites (Figure 3.3), while 2 also indicated they caught them at foraging and roosting sites. Of these respondents, 8 respondents indicated the sample size of their study also was limited due to catchability of this species.

Table 3.4 *Overview of the scores for tagging devices suitable for herring gull. In this table, the Ornitela devices received the highest score.*

					Charactaristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	HG	**Average review score**
Ornitela	Ornitrack-10		10	0,9	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-15	1,3,4	15	1,4	3	3	5	5	5	5	-	1	1	1	1	1	1	-	32	3	1	5	5	5	5	4	5	4,1
Ornitela	Ornitrack-20	2-4	20	1,8	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	5	4,1
Ornitela	Ornitrack-25	4	25	2,3	0	3	5	5	5	5	1	1	1	1	1	1	1	-	30	3	1	5	5	5	5	4	5	4,1
Ornitela	Ornitrack-30	4	30	2,7	0	3	5	5	5	5	1	1	1	1	1	1	1	-	30	3	1	5	5	5	5	4	5	4,1
Movetech	Flyway 18s	7	18	1,6	3	3	5	5	5	5	-	-	-	1	1	-	-	-	28	5	3	0	0	1	2	3	5	2,4
Milsar	GSMRadioTag-M9		16	1,5	3	3	0	5	5	5	1	1		1	1	1	1	1	28	-	0	-	-	-	-	-		
North Star	Saker L		17	1,5	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-		
Movetech	Flyway 25s	8	25	2,3	0	3	5	5	5	5	-	-	-	1	1	-	-	-	25	0	3	0	0	3	2	4	5	2,1
Ecotone	KITE-L GPS		17	1,5	3	3	0	5	5	5	1	-	-	1	1	-	-	1	25	0	3	0	0	4	2	2	0	1,4
TechnoSMart	Gipsy GSM/3G		10	0,9	5	3	0	5	5	0	1		1	1	1	1		1	24	0	1	-5	-5	-1	2	3	0	- 0,6
PathTrack	Nanofix Geo+GSM		31	2,8	0	3	5	5	5	5	-	-	-	-	-	-	-	1	24	-	-	-	-	-	-	-	-	
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0,4	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0,4	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-		
Interrex	LEGO		18,7	1,7	3	3	0	5	5	5	-	-	-	1	-	-	1	-	23	-	-	-	-	-	-	-		
Ecotone	Griffon		38	3,5	-2	3	0	5	5	5	1	1	-	1	1	1	-	1	22	3	1	0	0	4	2	4	0	1,8
TechnoSMart	Axy-Trek Marine		14	1,3	3	3	0	5	0	5	1	-	-	1	1	1	-	1	21	0	1	0	0	5	5	4	0	1,9
Milsar	GsmRadioTag-S9		12	1,1	3	3	0	5	5	0		1		1	1	1	1		21	-	-	-	-	-	-	-		
Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	1,8	3	3	5	5	5	0	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-		

CellTrack	ES-150		15	1,4	3	3	0	0	5	5	-	1	-	1	1	-	1	-	20	-	-	-	-	-	-	-		
Milsar	Radio tag 14		10	0,9	5	3	0	5	0	0	1	1	-	1	1	-	1	1	19	0	1	5	5	4	5	4	0	3,0
UvaBITS	Uva-Bits 2DCSe		7,5	0,7	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	-5	0	4	2	4	0	0,8
Lotek	PP GPS Argos Solar		16,5	1,5	3	3	0	5	0	5	-	-	-	1	1	-	1	-	19	-	-	-	-	-	-	-		
Ecotone	ALLE-60 GPS-UHF		4,5	0,4	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	0	2,9
UvaBITS	Uva-Bits 6CDLe	2,3,9,11	18,5	1,7	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	3	2	0	5	5	5	4	5	3,6
Ecotone	Gannet		40	3,6	-2	3	0	5	5	0	1	1	-	1	1	1	-	1	17	3	1	0	0	4	5	4	0	2,1
PathTrack	Nanofix Geo+RF	3,8	14	1,3	3	3	5	5	0	0	-	-	-	-	-	-	-	1	17	0	1	0	0	4	2	4	5	2,0
UvaBITS	Uva-Bits 5DCLeGSM		13,5	1,2	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	2	0	0	-1	2	4	0	0,9
Ecotone	Harrier H		16	1,5	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	0	0	-1	2	3	0	0,6
E-obs	Bird Solar UMTS	4	25	2,3	0	3	0	5	5	0	-	1	1	1	-	-	-	-	16	3	0	0	0	4	5	4	5	2,6
IgotU	GT-120	5	20	1,8	3	3	5	0	0	5	-	-	-	-	-	-	-	-	16	3	0	0	5	5	2	0	5	2,5
Ecotone	URIA-300 GPS-UHF	3,5,10	13,5	1,2	3	0	0	5	5	0	1							1	15	-3	0	0	-5	-3	-2	3	5	- 0,6
E-obs	Bird Solar Tags		15	1,4	3	3	0	5	0	0	-	1	1	1	-	-	-	-	14	3	0	0	0	4	5	4	0	2,0
Microwave Telemetry Inc.	Solar Argos PTT		22	2,0	0	3	-5	5	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-		
Microwave Telemetry Inc.	GPS/GSM 25G		25	2,3	0	3	-5	5	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-		
IgotU	GT-600		37	3,4	-2	3	5	0	0	5	-	-	-	-	-	-	-	-	11	3	0	0	5	5	5	0	0	2,3
PathTrack	Nanofix Geo+RF		10	0,9	5	0	0	5	0	0	-	-	-	-	-	-	-	-	10	5	1	0	5	4	2	4	0	2,6
PathTrack	Nanofix Geo+RF		11	1,0	3	0	0	5	0	0	-	-	-	-	-	1	-	1	10	5	1	0	5	4	2	4	0	2,6
Biotrack	Mk3006	6	2,5	0,2	5	0	5	-	-	-	-	-	-	-	-	-	-	-	10	0	-	0	0	4	2	4	5	2,1
GeoTrak	12G Solar Gps		12	1,1	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-		
E-obs	Bird Battery		39	3,5	-2	3	0	5	0	0	-	1	1	1	-	-	-	-	9	3	0	0	0	4	5	4	0	2,0
Telonics	TAV-2618		18	1,6	3	0	-5	0	5	0	-	1	-	1	1	1	-	-	7	3	-5	-5	0	4	2	5	0	0,5
GeoTrak	22G Solar Gps		22	2,0	0	3	-5	0	5	0	-	1	1	1	1	-	-	-	7	-	-	-	-	-	-	-	-	
GeoTrak	22G Solar Gps		22	2,0	0	3	-5	0	5	0	-	1	1	1	1	-	-	-	7	-	-	-	-	-	-	-		
Uni Konstanz	Self made		40	3,6	-2	3	-	5	0	-	-	-	-	-	-	-	-	-	6	-4	0	-5	-	-	-	-		- 3,0

1 BuWa
2 INBO
3 University of the Highlands and islands
4 University of Kiel
5 Arcadia University,Canada
6 Russian Academy of Sciences
7 University of Newcastle
8 BTO
9 UvA
10 La Rochelle Université
11 University of Bristol

Figure 3.3 *Map with the catching sites of herring gull of researchers that responded to our online survey*

3.5 Lesser black-backed gull

General ecology

Lesser black-backed *Larus fuscus* gulls breed in all countries bordering the North Sea, the Baltic Sea and the North Atlantic (Camphuysen, 2011). Individuals breeding along the North Sea coasts forage at sea as well as inland. When foraging at sea, they often make foraging trips of more than 200 km. The distribution of lesser black-backed gulls in the southern North Sea during the breeding season is concentrated around the breeding colonies, with higher numbers also towards the Frisian Front area (Camphuysen, 2013). The breeding colonies are located along the coast, but with increasing frequency birds are also observed breeding as well as feeding more inland. After the breeding season, in August, large concentrations are observed in the southern North Sea and the southern part of the central North Sea. In autumn, lesser black-backed gulls migrate in southwestern direction towards the Iberian Peninsula and the west coast of Africa (Camphuysen, 2013, www.vogeltrekatlas.nl). Increasingly more individuals stay in Northwest Europe during winter (Ross-Smith *et al*., 2014), which is likely related to milder winters in recent decades. Lesser black-backed gulls are vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices

Based on the responses from researchers to our questionnaire, 29 types of tagging devices were evaluated. In addition, we rated 14 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 43 tagging devices presented in Table 3.5. To calculate the % of body mass, we assumed an average mass of 900g (Camphuysen, 2013).

Main research initiatives

Lesser black-backed gulls are well-studied. Some key tagging studies in the Netherlands and Belgium are being carried out by Bureau Waardenburg and INBO (e.g., Stienen et al., 2016; Vanermen *et al.*, 2020), University of Amsterdam (http://www.uva-bits.nl/project/multi-scale-movements-of-gulls-from-texel/) and NIOZ (e.g., Bouten *et al.,* 2013; Camphuysen *et al.*, 2015; van Donk *et al.*, 2017). In Germany, tagging studies on lesser black-backed gulls are taking place at the University of Kiel (e.g., Corman, 2015; Garthe *et al.,* 2016). In the UK several studies are being done by universities (https://www.bristol.ac.uk/aerodynamics-research/research-projects/bif/research/urban_gull/) and other institutes such as the British Trust for Ornithology (BTO; https://www.bto.org/our-science/topics/tracking/tracking-studies/tracking-lesser-black-backed-gulls).

Interested in Tagging and Tracking platform: 88%.

Catching sites and catchability

All researchers (n = 16) indicated they caught the species at the breeding sites (Figure 3.4), while 4 researchers also indicated they caught them at foraging and roosting sites and 9 respondents indicated the sample size of their study also was limited due to catchability of this species.

Table 3.5 *Overview of the scores for tagging devices suitable for lesser black backed gulls. In this table, the Ornitela Ornitrack -15 and -10 received the highest score.*

					Charactaristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	LBBG	**Average review score**
Ornitela	Ornitrack-15	1-4	15	1,7	3	3	5	5	5	5	-	1	1	1	1	1	1	-	32	3	1	5	5	5	5	4	5	4,1
Ornitela	Ornitrack-10	-	10	1,1	3	3	5	5	5	5	-	1	1	1	1	1	1	-	32	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-20	3	20	2,2	0	3	5	5	5	5	1	1	1	1	1	1	1	-	30	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-25	-	25	2,8	0	3	5	5	5	5	1	1	1	1	1	1	1	-	30	3	1	5	5	5	5	4	0	3,5
Milsar	GSMRadioTag-M9	-	16	1,8	3	3	0	5	5	5	1	1		1	1	1	1	1	28	-	0	-	-	-	-	-	-	
Ornitela	Ornitrack-30	-	30	3,3	-2	3	5	5	5	5	-	1	1	1	1	1	1	-	27	3	1	5	5	5	5	4	0	3,5
North Star	Saker L	-	17	1,9	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
Ecotone	KITE-L GPS	3,5	17	1,9	3	3	0	5	5	5	1	-	-	1	1	-	-	1	25	0	3	0	0	4	2	2	5	2,0
Movetech	Flyway 25s		25	2,8	0	3	5	5	5	5	-	-	-	1	1	-	-	-	25	0	3	0	0	3	2	4	0	1,5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0,4	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
TechnoSMart	Gipsy GSM/3G	12	10	1,1	3	3	0	5	5	0	1	-	1	1	1	1	-	1	22	0	1	-5	-5	-1	2	3	5	
PathTrack	Nanofix Geo+GSM		31	3,4	-2	3	5	5	5	5	-	-	-	-	-	-	-	1	22	-	-	-	-	-	-	-	-	
TechnoSMart	Axy-Trek Marine		14	1,6	3	3	0	5	0	5	1	-	-	1	1	1	-	1	21	0	1	0	0	5	5	4	0	1,9
Milsar	GsmRadioTag-S9	-	12	1,3	3	3	0	5	5	0	-	1	-	1	1	1	1	-	21	-	-	-	-	-	-	-	-	
Movetech	Flyway 18s	7,8	18	2,0	0	3	0	5	5	5	-	-	-	1	1	-	-	-	20	0	0	0	-	-	-	-	5	0,0
CellTrack	ES-150	-	15	1,7	3	3	0	0	5	5	-	1	-	1	1	-	1	-	20	-	-	-	-	-	-	-	-	
Interrex	LEGO		18,7	2,1	0	3	0	5	5	5	-	-	-	1	-	-	1	-	20	-	-	-	-	-	-	-	-	
Ecotone	Griffon		38	4,2	-5	3	0	5	5	5	1	1	-	1	1	1	-	1	19	3	1	0	0	4	2	4	0	1,8
UvaBITS	Uva-Bits 2DCSe		7,5	0,8	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	-5	0	4	2	4	0	0,8
Lotek	PP GPS Argos Solar	-	16,5	1,8	3	3	0	5	0	5	-	-	-	1	1	-	1	-	19	-	-	-	-	-	-	-	-	

Ecotone	ALLE-60 GPS-UHF		4,5	0,5	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	0	2,9
Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	2,2	0	3	5	5	5	0	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	1,1	3	3	0	5	0	0	1	1	-	1	1	-	1	1	17	0	1	5	5	4	5	4	0	3,0
PathTrack	Nanofix Geo+RF		14	1,6	3	3	5	5	0	0	-	-	-	-	-	-	-	1	17	0	1	0	0	4	2	4	0	1,4
UvaBITS	Uva-Bits 5DCLeGSM	2,8,9,13	13,5	1,5	3	3	0	5	0	5	0	-	-	1	-	-	-	-	17	-4	2	0	0	-1	2	4	5	1,0
Ecotone	Harrier H		16	1,8	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	0	0	-1	2	3	0	0,6
E-obs	Bird Solar UMTS		25	2,8	0	3	0	5	5	0	-	1	1	1	-	-	-	-	16	3	0	0	0	4	5	4	0	2,0
Ecotone	URIA-300 GPS-UHF	10,11	13,5	1,5	3	0	0	5	5	0	1							1	15	-5	0	0	-5	-3	-2	3	5	-0,9
UvaBITS	Uva-Bits 6CDLe		18,5	2,1	0	3	0	5	0	5	-	-	-	1	-	-	-	-	14	3	2	0	5	5	5	4	0	3,0
E-obs	Bird Solar Tags	4	15	1,7	3	3	0	5	0	0	-	1	1	1	-	-	-	-	14	3	0	0	0	4	5	4	5	2,6
Ecotone	Gannet		40	4,4	-5	3	0	5	5	0	1	1	-	1	1	1	-	1	14	3	1	0	0	4	5	4	0	2,1
IgotU	GT-120	5	20	2,2	0	3	5	0	0	5	-	-	-	-	-	-	-	-	13	3	0	0	5	5	2	0	5	2,5
Microwave Telemetry Inc.	Solar Argos PTT	-	22	2,4	0	3	-5	5	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G	-	25	2,8	0	3	-5	5	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF		11	1,2	3	0	0	5	0	0	-	-	-	-	-	1	-	1	10	5	1	0	5	4	2	4	0	2,6
Biotrack	Mk3006	6	2,5	0,3	5	0	5	-	-	-	-	-	-	-	-	-	-	-	10	0	-	0	0	4	2	4	5	2,1
GeoTrak	12G Solar Gps	-	12	1,3	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF		10	1,1	3	0	0	5	0	0	-	-	-	-	-	-	-	-	8	5	1	0	5	4	2	4	0	2,6
IgotU	GT-600		37	4,1	-5	3	5	0	0	5	-	-	-	-	-	-	-	-	8	3	0	0	5	5	5	0	0	2,3
GeoTrak	22G Solar Gps	-	22	2,4	0	3	-5	0	5	0	-	1	1	1	1	-	-	-	7	-	-	-	-	-	-	-	-	
E-obs	Bird Battery		39	4,3	-5	3	0	5	0	0	-	1	1	1	-	-	-	-	6	3	0	0	0	4	5	4	0	2,0
Telonics	TAV-2618	7	18	2,0	0	0	-5	0	5	0	-	1	-	1	1	1	-	-	4	3	-5	-5	0	4	2	5	5	1,1
Uni Konstanz	Self made		40	4,4	-5	3	-	5	0	-	-	-	-	-	-	-	-	-	3	-4	0	-5	-	-	-	-	-	-3,0

1 BuWa
2 INBO
3 University of the Highlands and islands
4 University of Kiel
5 Swedish Ornithological Society
6 Russian Academy of Sciences
7 University of Newcastle
8 BTO
9 NIOZ
10 LPO
11 La Rochelle Université
12 University of Oxford
13 University of Bristol

Figure 3.4 *Map with the catching sites of lesser black-backed gulls of researchers that responded to our online survey.*

3.6 Sandwich tern

General ecology

Sandwich terns *Thalasseus sandvicensis* breed along the coast of the North Sea in the UK, France, Netherlands, Germany, Denmark and southern Sweden, and also along the Baltic Sea. Presence in Dutch waters is largely limited to mainly April-September (Sovon Vogelonderzoek Nederland, 2018), and most birds winter along the west coast of Africa. Among the European tern species, Sandwich terns have the most specialized food choice and are ranked among the five most vulnerable seabirds with respect to reductions in food supply in the North Sea (Furness and Tasker, 2000). They feed on fish in the upper water layers, are single-prey loaders and feed up to 60 km from the colony (Fijn *et al*., 2017). Sandwich terns are considered to be vulnerable from displacement and habitat loss (Dierschke *et al*., 2016).

Scoring tracking devices

Based on the responses from researchers to our questionnaire, we rated their experiences for 8 types of tagging devices. In addition, we rated 1 additional type of tagging device based on specifications given by the manufacturer. This resulted in the scoring of 9 tagging devices presented in Table 3.6. To calculate the % of body mass, we assumed an average mass of 230g (Fijn *et al*., 2017).

Main research initiatives

Research on Sandwich terns using tagging devices is taking place at Bureau Waardenburg (Netherlands and UK) and Wageningen Marine Research in cooperation with the University of Amsterdam.

Interested in Tagging and Tracking platform: 100%.

Catching sites and catchability

Both researchers that responded (n = 2) indicated they caught the species at the breeding sites (Figure 3.5), both indicated the sample size of their study was also limited due to catchability of this species.

Table 3.6 Overview of the scores for tagging devices suitable for sandwich tern. In this table, the Ornitela Ornitrack-10 received the highest score.

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Sandwich tern	**Average review score**
Ornitela	Ornitrack-10	-	10	4,3	-5	3	5	5	5	5	-	1	1	1	1	1	1	-	24	3	1	5	5	5	5	4	0	3,5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	1,7	3	3	-	5	5	5	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	
Ornitela	Ornitrack-9	-	9,5	4,1	-5	3	5	5	5	0	-	1	1	1	1	1	1	-	19	-	-	-	-	-	-	-	-	
Ecotone	ALLE-60 GPS-UHF	1	4,5	2,0	0	0	5	5	0	0	1	-	-	-	1	-	-	1	13	3	1	0	5	5	5	4	5	3,5
Ecotone	Pica	1	5,6	2,4	0	3	5	5	0	0	-	-	-	-	-	-	-	-	13	3	1	0	5	4	2	4	5	3,0
TechnoSMart	Gipsy GSM/3G		10	4,3	-5	3	0	5	5	0	1	-	1	1	1	-	-	1	13	0	1	-5	-5	-1	2	3	0	-0,6
UvaBITS	Uva-Bits 2DCSe	2	7,5	3,3	-2	3	0	5	0	5	-	-	-	1	-	-	-	-	12	5	1	0	0	5	5	4	5	3,1
Milsar	Radio tag 14		10	4,3	-5	3	0	5	0	0	1	1	-	1	1	-	1	1	9	0	1	5	5	4	5	4	0	3,0
PathTrack	Nanofix Geo+RF		11	4,8	-5	0	0	5	0	0	-	-	-	-	-	1	-	1	2	5	1	0	5	4	2	4	0	2,6
PathTrack	Nanofix Geo+RF		10	4,3	-5	0	0	5	0	0	-	-	-	-	-	-	-	-	0	5	1	0	5	4	2	4	0	2,6

1 BuWa
2 WMR

Figure 3.5 *Map with the catching sites of sandwich terns of researchers that responded to our online survey*

3.7 Common tern

General ecology

Common terns *Sterna hirundo* breed throughout Europe, including countries surrounding the North Sea. Birds are present in the Netherlands between March and August (Sovon Vogelonderzoek Nederland, 2018). The majority of first-year birds remain off the west coast of Africa (between Senegal and Nigeria) with most second-year birds returning north, albeit later than breeding birds (Wernham *et al*., 2002). Feeding trips in Germany last on average almost 2h and cover about 30 km per foraging flight, with a mean radius of ~ 6 km (Becker *et al*., 1993). Common terns are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices

Based on the responses from researchers to our questionnaire, we rated their experiences for 4 types of tagging devices. In addition, we rated 1 additional type of tagging device based on specifications given by the manufacturer. This resulted in the scoring of 5 tagging devices presented in Table 3.7. To calculate the % of body mass, we assumed an average mass of 130g (Becker *et al.,* 2016).

Main research initiatives

The most important research initiatives on common tern using tracking devices are carried out by the German Institute of Avian Research. In addition, the University of Washington Bothell use tracking devices on common terns.

Interested in Tagging and Tracking platform: 100%.

Catching sites and catchability

All researchers that responded (n = 2) indicated they caught the species at the breeding sites (Figure 3.6), and all three indicated the sample size of their study was also limited due to catchability of this species.

Table 3.7 Overview of the scores for tagging devices suitable for common tern. In this table, the Hangzhou Yuehai satellite tag received the highest score.

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Common tern	**Average review score**
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	3.1	-2	3	-	5	5	5	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF	3	1.5	1.2	3	0	5	5	0	0	-	-	-	-	-	-	-	-	13	3	1	0	-5	-3	2	4	5	0.9
Ecotone	ALLE-60 GPS-UHF		4.5	3.5	-2	0	5	5	0	0	1	-	-	-	1	-	-	1	11	3	1	0	5	5	5	4	0	2.9
PathTrack	Nanofix Geo+RF	1	2.6	2.0	0	0	5	5	0	0	-	-	-	-	-	-	-	-	10	3	3	0	3	4	2	4	5	3.0
Ecotone	Pica	2	5.6	4.3	-5	3	5	5	0	0	-	-	-	-	-	-	-	-	8	3	1	0	5	4	2	4	5	3.0

1 Institute of Avian Research
2 BuWa
3 University of Washington Bothell

Figure 3.6 *Map with the catching site of the common tern researchers that responded to our online survey*

3.8 Black tern

General ecology

Although the black tern *Chlidonias niger* has a wide range, the Dutch and adjacent German black tern breeding populations are relatively isolated within Europe and are of major importance for the West European population (van der Winden and Viksne, 1997). The number of breeding pairs in the Netherlands and Germany strongly declined in the last century, most likely due to poor breeding success, and stabilized since 1990 (van der Winden and van Horssen, 2008).

Black terns are present in the Netherlands from the second half of April until October (sovon.nl) and spend the winter in West Africa (van der Winden *et al*., 2014). Individuals in their first year stay in West Africa, and only come back to the breeding grounds at the age of two or three years, when first breeding takes place (Servello, 2000; van der Winden and van Horssen, 2008). Migration occurs both over land and over sea (del Hoyo *et al*., 1992; van der Winden *et al*., 2014). In winter, black terns are predominantly coastal and use inland waters in the vicinity of the coast, as well as marine waters up to 400-600 km offshore (BirdLife International, 2021). Migration largely takes place over marine waters, hence black terns are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices

Unfortunately, we received no responses from researchers to our questionnaire, thus we rated 4 comparable types of tagging devices. This resulted in the scoring of 4 tagging devices presented in Table 3.8. To calculate the % of body mass, we assumed an average mass of 65g (van der Winden, 2002).

Main research initiatives

In the Netherlands, Lowland Ecology uses tracking devices on black terns. To our knowledge, no other research initiatives perform tracking studies on this species.

Interested in Tagging and Tracking platform: unknown.

Catching sites and catchability

Based on literature (e.g., van der Winden *et al*., 2014; van der Winden & van Horssen, 2008), this species is caught at breeding sites, and the sample size of their study was also limited due to catchability of this species.

Table 3.8 Overview of the scores for tagging devices suitable for black tern. In this table, the nanoFix® GEO – MINI received the highest score.

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	Immersion sensor	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Black tern	**Average review score**
PathTrack	Nanofix Geo+RF		0.95	1.5	3	0	5	5	0	0	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF		1.5	2.3	0	0	5	5	0	0	-	-	-	-	-	-	-	-	10	3	1	0	-5	-3	2	4	0	0.3
PathTrack	Nanofix Geo		2	3.1	-2	0	5	5	0	0	-	-	-	-	-	1	-	-	9	3	1	0	-5	-3	2	4	0	0.3
PathTrack	Nanofix Geo+RF		2.6	4.0	-5	3	5	5	0	0	-	-	-	-	-	-	-	-	8	3	3	0	3	4	2	4	0	2.4

3.9 Great skua

General ecology
The main breeding areas of great skua *Stercorarius skua* are located in Great Britain and Iceland, with resp. 9,600 and 5,400 breeding pairs (Mitchell *et al.*, 2004). Smaller numbers breed in Svalbard (600-1500 bp), Faroes (500) and along the Norwegian and N-Russian coasts (200-250; BirdLife International, 2021), where the breeding range has recently expanded along the Barents Sea shores.

Wintering grounds of great skuas are located off northwest Africa, off southern Europe and off Newfoundland (Magnusdottir *et al*., 2012). Although most individuals winter further south, small numbers of great skuas are present in the Dutch North Sea from July to February, with a peak during migration in September and October (trektellen.nl; Camphuysen & Leopold, 1994; Furness, 2015), when birds perform part of the primary moult in this area (van Bemmelen *et al.*, 2018). Most of these individuals are located relatively far offshore, for example at the Brown Ridge area (Fijn *et al.*, 2017). Great skuas are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices
Unfortunately, we received no responses from researchers to our questionnaire, and therefore we rated 44 possible types of tagging devices, as presented in Table 3.9. To calculate the % of body mass, we assumed an average mass of 1600g (Phillips and Furness, 1997).

Main research initiatives
In this study, we received no information about active users of GPS units to study their movements. It is unclear why this is, because the species is large enough to attach some tracking devices. It is however not unlikely that this is a difficult species for attaching devices, as they are very strong and might tear them apart. A colleague from Iceland provided some information about using geolocators from the British Antarctic Survey (BAS) on this species, namely the Mk5/7. This provided insightful information about their temporal occurrence and large-scale distribution, but the resolution is insufficient to study their behaviour in relation to offshore windfarms. In a published study from the UK (Figure 3.7), it is mentioned they used UvA bits tags to study their movements (Thaxter *et al*., 2016; Wade *et al*., 2014), but they recommend not to use a full body harness, because there is strong evidence of reduced overwinter return rates. Consequently, a device attached using a wing harness was considered unsuitable for long-term deployment on great skuas.

Interested in Tagging and Tracking platform: unknown.

Catching sites and catchability
The known catching sites based on literature are in the breeding areas (Phillips & Furness, 1997; Thaxter *et al*., 2016).

Table 3.9 Overview of the scores for tagging devices suitable for great skua. In this table, the Ornitela Ornitrack devices received the highest score.

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Great Skua	**Average review score**
Ornitela	Ornitrack-10	-	10	0.6	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-15		15	0.9	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-20	-	20	1.3	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-25	-	25	1.6	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-30	-	30	1.9	3	3	5	5	5	5	1	1	1	1	1	1	1	-	33	3	1	5	5	5	5	4	0	3.5
Movetech	Flyway 18s		18	1.1	3	3	5	5	5	5	-	-	-	1	1	-	-	-	28	5	3	0	0	1	2	3	0	1.8
Movetech	Flyway 25s		25	1.6	3	3	5	5	5	5	-	-	-	1	1	-	-	-	28	0	3	0	0	3	2	4	0	1.5
Ornitela	Ornitrack-50		50	3.1	-2	3	5	5	5	5	1	1	1	1	1	-	1	-	27	0	1	5	5	4	5	4	0	3.0
Milsar	GSMRadioTag-M9		16	1.0	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
North Star	Saker L		17	1.1	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+GSM		31	1.9	3	3	5	5	5	5	-	-	-	-	-	-	-	1	27	-	-	-	-	-	-	-	-	
Ecotone	KITE-L GPS		17	1.1	3	3	0	5	5	5	1	-	-	1	1	-	-	1	25	3	1	0	0	4	5	4	0	2.1
Ecotone	Griffon		38	2.4	0	3	0	5	5	5	1	1	-	1	1	1	-	1	24	3	1	0	0	4	2	4	0	1.8
TechnoSMart	Gipsy GSM/3G		10	0.6	5	3	0	5	5	0	1	-	1	1	1	-	-	1	23	0	1	-5	-5	-1	2	3	0	-0.6
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0.3	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Interrex	LEGO		18.7	1.2	3	3	0	5	5	5	-	-	-	1	-	-	1	-	23	-	-	-	-	-	-	-	-	
Milsar	GsmRadioTag-S9		12	0.8	5	3	0	5	5	0	-	1	-	1	1	-	1	-	22	-	-	-	-	-	-	-	-	
CellTrack	ES-150	-	15	0.9	5	3	0	0	5	5	-	1	-	1	1	-	1	-	22	-	-	-	-	-	-	-	-	
TechnoSMart	Axy-Trek Marine		14	0.9	3	3	0	5	0	5	1	-	-	1	1	1	-	1	21	0	1	0	0	5	5	4	0	1.9

Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	1.3	3	3	5	5	5	0	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	0.6	5	3	0	5	0	0	1	1	-	1	1	-	1	1	19	0	1	5	5	4	5	4	0	3.0
Ecotone	Gannet		40	2.5	0	3	0	5	5	0	1	1	-	1	1	1	-	1	19	3	1	0	0	4	5	4	0	2.1
E-obs	Bird Solar UMTS		25	1.6	3	3	0	5	5	0	-	1	1	1	-	-	-	-	19	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		14	0.9	5	3	5	5	0	0	-	-	-	-	-	-	-	1	19	0	1	0	0	4	2	4	0	1.4
UvaBITS	Uva-Bits 5DCLeGSM		13.5	0.8	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	2	0	0	-1	2	4	0	0.9
UvaBITS	Uva-Bits 2DCSe		7.5	0.5	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	-5	0	4	2	4	0	0.8
Lotek	PP GPS Argos Solar		16.5	1.0	3	3	0	5	0	5	-	-	-	1	1	-	1	-	19	-	-	-	-	-	-	-	-	
Ecotone	ALLE-60 GPS-UHF		4.5	0.3	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	0	2.9
UvaBITS	Uva-Bits 6CDLe		18.5	1.2	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	3	2	0	5	5	5	4	0	3.0
Ecotone	URIA-300 GPS-UHF		13.5	0.8	5	0	0	5	5	0	1	-	-	-	-	-	-	1	17	0	1	0	0	4	2	4	0	1.4
Ecotone	Harrier H		16	1.0	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	0	0	-1	2	3	0	0.6
E-obs	Bird Solar Tags		15	0.9	5	3	0	5	0	0	-	1	1	1	-	-	-	-	16	3	0	0	0	4	5	4	0	2.0
IgotU	GT-120		20	1.3	3	3	5	0	0	5	-	-	-	-	-	-	-	-	16	3	0	0	5	5	2	0	0	1.9
Microwave Telemetry Inc.	Solar Argos PTT		22	1.4	3	3	-5	5	5	0	-	1	1	1	1	-	-	-	15	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G		25	1.6	3	3	-5	5	5	0	-	1	1	1	1	-	-	-	15	-	-	-	-	-	-	-	-	
Ecotone	Horse tail		71	4.4	-5	3	0	5	5	0	1	1	-	1	1	1	-	1	14	3	1	0	0	4	5	4	0	2.1
IgotU	GT-600		37	2.3	0	3	5	0	0	5	-	-	-	-	-	-	-	-	13	3	0	0	5	5	5	0	0	2.3
PathTrack	Nanofix Geo+RF		11	0.7	5	0	0	5	0	0	-	-	-	-	-	1	-	1	12	5	1	0	5	4	2	4	0	2.6
GeoTrak	12G Solar Gps		12	0.8	5	3	-5	0	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
E-obs	Bird Battery		39	2.4	0	3	0	5	0	0	-	1	1	1	-	-	-	-	11	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		10	0.6	5	0	0	5	0	0	-	-	-	-	-	-	-	-	10	5	1	0	5	4	2	4	0	2.6
GeoTrak	22G Solar Gps		22	1.4	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
Telonics	TAV-2618		18	1.1	3	0	-5	0	5	0	-	1	-	1	1	1	-	-	7	3	-5	-5	0	4	2	5	0	0.5
Telonics	TAV-2665		71	4.4	-5	0	-5	0	5	0	-	1	-	1	1	1	-	-	-1	3	-5	-5	0	4	2	5	0	0.5

Figure 3.7 *Map with the catching sites of great skua of researchers (sites derived from Wade et al. 2014)*

3.10 Arctic skua

General ecology

Arctic skuas *Stercorarius parasiticus* breed in coastal (mostly the islands of) Scotland, Iceland, Norway and Sweden. During migration, the species is widespread throughout the North Sea with highest numbers in autumn (Furness, 2015). During autumn, most birds in the North Sea originate from breeding populations in the High-Arctic, Fennoscandia and Iceland with the remainder from Scottish populations (Furness, 2015). Their main wintering areas are in the southern hemisphere off Australia, South Africa and South America (Wernham *et al*., 2002). Birds usually breed annually, although may fail to lay in years with poor food availability (Mitchell *et al.*, 2004). In the United Kingdom, the species shows the steepest decline of any seabird (Perkins *et al*., 2018), and also Norwegian and Icelandic populations are in strong decline. Consequently, the species is on the EU27 Red List (Birdlife International, 2021). Arctic skuas are considered to be vulnerable to impact from turbine collisions (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices

In this study, we received no information about active users of GPS units to study their movements. However, we could include 6 types of tagging devices that have been used by researchers. In addition, we rated 7 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 24 tagging devices presented in Table 3.10. To calculate the % of body mass, we assumed an average mass of 450g (Phillips & Furness, 1997).

Main research initiatives

GPS-tagging of breeding birds has been carried out in the Shetlands (BTO, UK), Faroe Islands (University of Copenhagen, Denmark), North-east Greenland (University of Bourgogne, France) and Arctic Canada (Smithsonian Conservation Biology Institute, USA). The European studies were exclusively targeted at movements during the breeding period, using temporary tag deployments. In addition, a collaborative network using geolocators to map large-scale migration patterns is led by Rob van Bemmelen (employee of Bureau Waardenburg). This network covers breeding sites between East Greenland and West Siberia.

Interested in Tagging and Tracking platform: unknown.

Catching sites and catchability

Arctic skuas have only been captured while breeding. The catchability of the species strongly depends on the local food situation during breeding.

Table 3.10 *Overview of the scores for tagging devices suitable for arctic skua. In this table, the Ornitela Ornitrack-10 received the highest score.*

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Arctic Skua	**Average review score**
Ornitela	Ornitrack-10		10	2.2	0	3	5	5	5	5	-	1	1	1	1	1	1	-	29	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-15		15	3.3	-2	3	5	5	5	5	-	1	1	1	1	1	1	-	27	3	1	5	5	5	5	4	0	3.5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0.9	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Milsar	GSMRadioTag-M9	1	16	3.6	-2	3	0	5	5	5	1	1	-	1	1	-	1	1	22	-	-	-	-	-	-	-	-	
North Star	Saker L		17	3.8	-2	3	0	5	5	5	1	1	-	1	1	-	1	1	22	-	-	-	-	-	-	-	-	
Movetech	Flyway 18s	1	18	4.0	-5	3	5	5	5	5	-	-	-	1	1	-	-	-	20	5	3	0	0	1	2	3	0	1.8
Ecotone	KITE-L GPS		17	3.8	-2	3	0	5	5	5	1	-	-	1	1	-	-	1	20	3	1	0	0	4	5	4	0	2.1
TechnoSMart	Gipsy GSM/3G		10	2.2	0	3	0	5	5	0	1	-	1	1	1	-	-	1	18	0	1	-5	-5	-1	2	3	0	-0.6
UvaBITS	Uva-Bits 2DCSe		7.5	1.7	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	-5	0	4	2	4	0	0.8
Milsar	GsmRadioTag-S9		12	2.7	0	3	0	5	5	0	-	1	-	1	1	-	1	-	17	-	-	-	-	-	-	-	-	
TechnoSMart	Axy-Trek Marine		14	3.1	-2	3	0	5	0	5	1	-	-	1	1	1	-	1	16	0	1	0	0	5	5	4	0	1.9
Ecotone	ALLE-60 GPS-UHF		4.5	1.0	3	0	5	5	0	0	1	-	-	-	1	-	-	1	16	3	1	0	5	5	5	4	0	2.9
CellTrack	ES-150		15	3.3	-2	3	0	0	5	5	-	1	-	1	1	-	1	-	15	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	2.2	0	3	0	5	0	0	1	1	-	1	1	-	1	1	14	0	1	5	5	4	5	4	0	3.0
Lotek	PP GPS Argos Solar		16.5	3.7	-2	3	0	5	0	5	-	-	-	1	1	-	1	-	14	-	-	-	-	-	-	-	-	
Ecotone	Harrier H		16	3.6	-2	3	0	5	0	5	-	-	-	1	-	-	-	-	12	0	1	0	0	-1	2	3	0	0.6
UvaBITS	Uva-Bits 5DCLeGSM		13.5	3.0	-2	3	0	5	0	5	-	-	-	1	-	-	-	-	12	0	2	0	0	-1	2	4	0	0.9
PathTrack	Nanofix Geo+RF		14	3.1	-2	3	5	5	0	0	-	-	-	-	-	-	-	1	12	0	1	0	0	4	2	4	0	1.4
Ecotone	URIA-300 GPS-UHF		13.5	3.0	-2	0	0	5	5	0	1	-	-	-	-	-	-	1	10	0	1	0	0	4	2	4	0	1.4

E-obs	Bird Solar Tags		15	3.3	-2	3	0	5	0	0	-	1	1	1	-	-	-	-	9	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		11	2.4	0	0	0	5	0	0	-	-	-	-	-	1	-	1	7	5	1	0	5	4	2	4	0	2.6
GeoTrak	12G Solar Gps		12	2.7	0	3	-5	0	5	0	-	1	1	1	1	-	-	-	7	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF		10	2.2	0	0	0	5	0	0	-	-	-	-	-	-	-	-	5	5	1	0	5	4	2	4	0	2.6
Telonics	TAV-2618		18	4.0	-5	0	-5	0	5	0	-	1	-	1	1	1	-	-	-1	3	-5	-5	0	4	2	5	0	0.5

3.11 Common guillemot

General ecology

Common guillemots *Uria aalge* breed along the coasts of the UK, Iceland, Faroes, Helgoland, Scandinavia and north-west France (BirdLife International, 2021). They spend most of their lives at sea. In the non-breeding season, they disperse into the surrounding oceans, vacating higher latitudes. Regarding impacts from offshore wind farms, guillemots are considered to be vulnerable to impact from habitat loss, but face very low collision risks (Rijkswaterstaat, 2015; 2019). Tagging studies focussing on the impact assessment of offshore wind farms in the North Sea should take place on breeding and non-breeding birds. During the non-breeding period guillemots might be exposed to other offshore windfarms located further away from their breeding colony, and thus may become vulnerable to habitat loss.

Scoring tracking devices

Based on the responses from researchers to our questionnaire, we rated their experiences for 29 types of tagging devices. In addition, we rated 13 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 42 tagging devices presented in Table 3.11. To calculate the % of body mass, we assumed an average mass of 900g (Peschko *et al*., 2020).

Main research initiatives

Large research initiatives using tracking devices on common guillemot are carried out in the UK (BTO, RSPB, CEH), Norway (NINA) and Sweden (Lund University). In addition, tracking studies on this species are carried out in Canada (McGill University) and Greenland (Aarhus University).

Interested in Tagging and Tracking platform: 72%

Catching sites and catchability

All researchers (*n* = 11) indicated they caught the species at the breeding sites (Figure 3.8), and 6 respondents indicated the sample size of their study also was limited due to catchability of this species.

Table 3.11 Overview of the scores for tagging devices suitable for common guillemot. In this table, the Ornitela Ornitrack-10 and -15 received the highest score.

					Charactaristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	Immersion sensor	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Guilemot	**Average review score**
Ornitela	Ornitrack-10		10	1,1	3	3	5	5	5	5	-	1	1	1	1	-	1	-	31	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-15	2,8	15	1,7	3	3	5	5	5	5	-	1	1	1	1	-	1	-	31	3	1	0	5	5	5	4	5	3,5
Ornitela	Ornitrack-25	-	25	2,8	0	3	5	5	5	5	-	1	1	1	1	1	1	-	29	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-20	1,8	20	2,2	0	3	5	5	5	5	-	1	1	1	1	-	1	-	28	0	1	0	5	4	2	4	5	2,6
Ornitela	Ornitrack-30	-	30	3,3	-2	3	5	5	5	5	-	1	1	1	1	1	1	-	27	3	1	5	5	5	5	4	0	3,5
Milsar	GSMRadioTag-M9		16	1,8	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
North Star	Saker L		17	1,9	3	3	0	5	5	5	1	1	-	1	1	-	1	1	27	-	-	-	-	-	-	-	-	
Ecotone	KITE-L GPS	1,2,5	17	1,9	3	3	0	5	5	5	1	-	-	1	1	-	-	1	25	3	1	0	5	4	5	4	5	3,4
Movetech	Flyway 25s		25	2,8	0	3	5	5	5	5	-	-	-	1	1	-	-	-	25	0	3	0	0	3	2	4	0	1,5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0,4	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Ecotone	Griffon		38	4,2	-2	3	0	5	5	5	1	1	-	1	1	1	-	1	22	3	1	0	0	4	2	4	0	1,8
PathTrack	Nanofix Geo+GSM		31	3,4	-2	3	5	5	5	5	-	-	-	-	-	-	-	1	22	-	-	-	-	-	-	-	-	
TechnoSMart	Axy-Trek Marine	4	14	1,6	3	3	0	5	0	5	1	-	-	1	1	1	-	1	21	0	1	0	0	-1	2	3	5	1,3
TechnoSMart	Gipsy GSM/3G	3	10	1,1	3	3	0	5	5	0	1	-	1	1	1	-	-	1	21	0	1	-5	-5	-1	2	3	5	0,0
Movetech	Flyway 18s		18	2,0	0	3	0	5	5	5	-	-	-	1	1	-	-	-	20	0	0	0	-	-	-	-	0	0,0
Milsar	GsmRadioTag-S9		12	1,3	3	3	0	5	5	0	-	1	-	1	1	-	1	-	20	-	-	-	-	-	-	-	-	
CellTrack	ES-150		15	1,7	3	3	0	0	5	5	-	1	-	1	1	-	1	-	20	-	-	-	-	-	-	-	-	
Interrex	LEGO		18,7	2,1	0	3	0	5	5	5	-	-	-	1	-	-	1	-	20	-	-	-	-	-	-	-	-	
UvaBITS	Uva-Bits 2DCSe		7,5	0,8	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	-5	0	4	2	4	0	0,8
Lotek	PP GPS Argos Solar		16,5	1,8	3	3	0	5	0	5	-	-	-	1	1	-	1	-	19	-	-	-	-	-	-	-	-	
Ecotone	ALLE-60 GPS-UHF	1,2	4,5	0,5	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	5	3,5

Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	2,2	0	3	5	5	5	0	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	1,1	3	3	0	5	0	0	1	1	-	1	1	-	1	1	17	0	1	5	5	4	5	4	0	3,0
Ecotone	Gannet		40	4,4	-2	3	0	5	5	0	1	1	-	1	1	1	-	1	17	3	1	0	0	4	5	4	0	2,1
UvaBITS	Uva-Bits 5DCLeGSM	1	13,5	1,5	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	0	0	4	2	4	5	2,0
PathTrack	Nanofix Geo+RF		14	1,6	3	3	5	5	0	0	-	-	-	-	-	-	-	1	17	0	1	0	0	4	2	4	0	1,4
Ecotone	Harrier H	5	16	1,8	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	0	0	-1	2	3	5	1,3
E-obs	Bird Solar UMTS		25	2,8	0	3	0	5	5	0	-	1	1	1	-	-	-	-	16	3	0	0	0	4	5	4	0	2,0
Ecotone	URIA-300 GPS-UHF	1,2,6	13,5	1,5	3	0	0	5	5	0	1	-	-	-	-	-	-	1	15	0	1	0	0	4	2	4	5	2,0
UvaBITS	Uva-Bits 6CDLe		18,5	2,1	0	3	0	5	0	5	-	-	-	1	-	-	-	-	14	3	2	0	5	5	5	4	0	3,0
E-obs	Bird Solar Tags	8	15	1,7	3	3	0	5	0	0	-	1	1	1	-	-	-	-	14	3	0	0	0	4	5	4	5	2,6
IgotU	GT-120	2,4,6	20	2,2	0	3	5	0	0	5	-	-	-	-	-	-	-	-	13	3	0	0	5	5	2	0	5	2,5
Microwave Telemetry Inc.	Solar Argos PTT		22	2,4	0	3	-5	5	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G	-	25	2,8	0	3	-5	5	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
IgotU	GT-600		37	4,1	-2	3	5	0	0	5	-	-	-	-	-	-	-	-	11	3	0	0	5	5	5	0	0	2,3
PathTrack	Nanofix Geo+RF	1	11	1,2	3	0	0	5	0	0	-	-	-	-	-	1	-	1	10	5	1	0	5	4	2	4	5	3,3
Biotrack	Mk3006	3	2,5	0,3	5	0	5	-	-	-	-	-	-	-	-	-	-	-	10	0	1	-5	-5	-1	2	3	5	0,0
GeoTrak	12G Solar Gps		12	1,3	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
E-obs	Bird Battery		39	4,3	-2	3	0	5	0	0	-	1	1	1	-	-	-	-	9	3	0	0	0	4	5	4	0	2,0
PathTrack	Nanofix Geo+RF		10	1,1	3	0	0	5	0	0	-	-	-	-	-	-	-	-	8	5	1	0	5	4	2	4	0	2,6
GeoTrak	22G Solar Gps		22	2,4	0	3	-5	0	5	0	-	1	1	1	1	-	-	-	7	-	-	-	-	-	-	-	-	
Telonics	TAV-2618	7	18	2,0	0	0	-5	0	5	0	-	1	-	1	1	1	-	-	4	3	-5	-5	0	4	2	5	5	1,1

1 University of the Highlands and islands
2 Swedish Ornithological Society
3 University of Oxford
4 Okinawa Institute of Science and Technology
5 National Institute of Polar Research, Japan
6 Arcadia University, Canada
7 Brittish Antarctic Survey
8 University of Kiel
9 University of Reykjavik

Figure 3.8 *Map with the catching sites of common guillemot of researchers that responded to our online survey*

3.12 Razorbill

General ecology
Razorbills *Alca torda* breed along the coast of the UK, Iceland, Faroes, Scandinavia, Helgoland and north-west France (BirdLife International, 2021). They spend most of their lives at sea and after a short breeding season, they migrate on sea away from their breeding sites with their young. The European population winters at sea, with some individuals moving south as far as the western Mediterranean. Approximately 60 to 70% of the entire razorbill population breeds in Iceland (Lavers *et al.,* 2009). Regarding impacts from offshore wind farms, razorbills are considered to be vulnerable to impact from habitat loss, but not from collision (Rijkswaterstaat, 2015; 2019).

Scoring tracking devices
Based on the responses from researchers to our questionnaire, we rated their experiences for 27 types of tagging devices. In addition, we rated 13 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 40 tagging devices presented in Table 3.12. To calculate the % of body mass, we assumed an average mass of 730g (Shoji *et al.*, 2015).

Main research initiatives
Large tracking studies on razorbill are carried out in the UK (BTO, CEH) and Sweden (Lund University).

Interested in Tagging and Tracking platform: 100%.

Catching sites and catchability
Contacted researchers indicated they are all caught at the breeding sites (Figure 3.9), and 2 (out of 4) researchers indicated the sample size of their study was limited due to catchability of this species.

Table 3.12 *Overview of the scores for tagging devices suitable for razorbill. In this table, the Ornitela Ornitrack-10 received the highest score and could be considered when studying offshore behaviour of this species.*

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Razorbill	**Average review score**
Ornitela	Ornitrack-10		10	1.4	3	3	5	5	5	5	-	1	1	1	1	1	1	-	32	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-15	2	15	2.1	0	3	5	5	5	5	-	1	1	1	1	1	1	-	29	3	1	0	5	5	5	4	5	3.5
Ornitela	Ornitrack-20	1	20	2.7	0	3	5	5	5	5	-	1	1	1	1	1	1	-	29	0	1	0	5	4	2	4	5	2.6
Ornitela	Ornitrack-25	-	25	3.4	-2	3	5	5	5	5	-	1	1	1	1	1	1	-	27	3	1	5	5	5	5	4	0	3.5
Milsar	GSMRadioTag-M9		16	2.2	0	3	0	5	5	5	1	1		1	1	1	1	1	25	-	-	-	-	-	-	-	-	
Ornitela	Ornitrack-30	-	30	4.1	-5	3	5	5	5	5	-	1	1	1	1	1	1	-	24	3	1	5	5	5	5	4	0	3.5
North Star	Saker L		17	2.3	0	3	0	5	5	5	1	1	-	1	1	-	1	1	24	-	-	-	-	-	-	-	-	
Movetech	Flyway 25s		25	3.4	-2	3	5	5	5	5	-	-	-	1	1	-	-	-	23	0	3	0	0	3	2	4	0	1.5
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0.5	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Ecotone	KITE-L GPS	1.2	17	2.3	0	3	0	5	5	5	1	-	-	1	1	-	-	1	22	3	1	0	5	4	5	4	5	3.4
TechnoSMart	Gipsy GSM/3G	3	10	1.4	3	3	0	5	5	0	1	-	1	1	1	1		1	22	0	1	-5	-5	-1	2	3	5	0.0
TechnoSMart	Axy-Trek Marine		14	1.9	3	3	0	5	0	5	1	-	-	1	1	1	-	1	21	0	1	0	0	5	5	4	0	1.9
Milsar	GsmRadioTag-S9		12	1.6	3	3	0	5	5	0	-	1	-	1	1	1	1	-	21	-	-	-	-	-	-	-	-	
Movetech	Flyway 18s		18	2.5	0	3	0	5	5	5	-	-	-	1	1	-	-	-	20	0	0	0	-	-	-	-	0	0.0
Interrex	LEGO		18.7	2.6	0	3	0	5	5	5	-	-	-	1	-	-	1	-	20	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF	1	2.6	0.4	5	3	5	5	0	0	-	-	-	-	-	-	-	1	19	0	1	0	0	4	2	4	5	2.0
PathTrack	Nanofix Geo+GSM		31	4.2	-5	3	5	5	5	5	-	-	-	-	-	-	-	1	19	-	-	-	-	-	-	-	-	
Ecotone	ALLE-60 GPS-UHF	1.2	4.5	0.6	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	5	3.5

Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	2.7	0	3	5	5	5	0	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	1.4	3	3	0	5	0	0	1	1	-	1	1	-	1	1	17	0	1	5	5	4	5	4	0	3.0
UvaBITS	Uva-Bits 5DCLeGSM	1	13.5	1.8	3	3	0	5	0	5	0	-	-	1	-	-	-	-	17	0	1	0	0	4	2	4	5	2.0
PathTrack	Nanofix Geo+RF		14	1.9	3	3	5	5	0	0	-	-	-	-	-	-	-	1	17	0	1	0	0	4	2	4	0	1.4
UvaBITS	Uva-Bits 2DCSe		7.5	1.0	3	3	0	5	0	5	-	-	-	1	-	-	-	-	17	0	1	-5	0	4	2	4	0	0.8
CellTrack	ES-150		15	2.1	0	3	0	0	5	5	-	1	-	1	1	-	1	-	17	-	-	-	-	-	-	-	-	
Lotek	PP GPS Argos Solar		16.5	2.3	0	3	0	5	0	5	-	-	-	1	1	-	1	-	16	-	-	-	-	-	-	-	-	
Ecotone	URIA-300 GPS-UHF	1.2	13.5	1.8	3	0	0	5	5	0	1	-	-	-	-	-	-	1	15	0	1	0	0	4	2	4	5	2.0
UvaBITS	Uva-Bits 6CDLe		18.5	2.5	0	3	0	5	0	5	-	-	-	1	-	-	-	-	14	3	2	0	5	5	5	4	0	3.0
E-obs	Bird Solar UMTS		25	3.4	-2	3	0	5	5	0	-	1	1	1	-	-	-	-	14	3	0	0	0	4	5	4	0	2.0
Ecotone	Harrier H		16	2.2	0	3	0	5	0	5	-	-	-	1	-	-	-	-	14	0	1	0	0	-1	2	3	0	0.6
IgotU	GT-120	2	20	2.7	0	3	5	0	0	5	-	-	-	-	-	-	-	-	13	3	0	0	5	5	2	0	5	2.5
IgotU	GT-120		20	2.7	0	3	5	0	0	5	-	-	-	-	-	-	-	-	13	3	0	0	5	5	2	0	0	1.9
E-obs	Bird Solar Tags		15	2.1	0	3	0	5	0	0	-	1	1	1	-	-	-	-	11	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		11	1.5	3	0	0	5	0	0	-	-	-	-	-	1	-	1	10	5	1	0	5	4	2	4	0	2.6
Biotrack	Mk3006	3	2.5	0.3	5	0	5	-	-	-	-	-	-	-	-	-	-	-	10	0	1	-5	-5	-1	2	3	5	0.0
GeoTrak	12G Solar Gps		12	1.6	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	Solar Argos PTT		22	3.0	-2	3	-5	5	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G	-	25	3.4	-2	3	-5	5	5	0	-	1	1	1	1	-	-	-	10	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF		10	1.4	3	0	0	5	0	0	-	-	-	-	-	-	-	-	8	5	1	0	5	4	2	4	0	2.6
GeoTrak	22G Solar Gps		22	3.0	-2	3	-5	0	5	0	-	1	1	1	1	-	-	-	5	-	-	-	-	-	-	-	-	
Telonics	TAV-2618	7	18	2.5	0	0	-5	0	5	0	-	1	-	1	1	1	-	-	4	3	-5	-5	0	4	2	5	5	1.1

1 University of the Highlands and islands

2 Swedish Ornithological Society

3 University of Oxford

Figure 3.9 *Map with the catching sites of razorbill of researchers that responded to our online survey*

3.13 Red-throated diver

General ecology
Red-throated divers *Gavia stellata* breed in Spitsbergen, Russia, Scandinavia, Iceland, Faroes and UK (EBCC). This species winters along the European coasts of the North Sea and Atlantic Ocean, and along the coasts of southern France and northern Italy. In winter, large groups of red-throated divers can be found in for example the German Bight, but also in other parts of the North Sea (Burger *et al.*, 2019). Furthermore, the southern North Sea is an important migration route for birds wintering in more southern regions.

Regarding impacts from offshore wind farms, red-throated divers are considered to be vulnerable to impact from habitat loss (Rijkswaterstaat, 2015; 2019). Tagging studies focussing on the impact assessment of offshore wind farms in the North Sea can take place in breeding sites or in wintering areas.

Scoring tracking devices
Based on the responses from researchers to our questionnaire, we rated their experiences for 31 types of tagging devices. In addition, we rated 13 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 44 tagging devices presented in Table 3.13. To calculate the % of body mass, we assumed an average mass of 1800g (Heinänen *et al.*, 2020).

Main research initiatives
Large tagging studies on red-throated diver are carried out by JNCC, with tagging locations in breeding areas in Finland, Orkney (UK), Shetland (UK) and Iceland (O'Brien *et al.*, 2018). In addition, in a large German study (DIVER), tracking devices were implanted in the German Bight, i.e., in their wintering area (Heinänen *et al.*, 2020).

Interested in Tagging and Tracking platform: 100%.

Catching sites and catchability
Of the 3 researchers that responded (n = 2) indicated they caught the species at the breeding sites (Figure 3.10), while 1 study caught them at sea and 1 indicated the sample size of their study was also limited due to catchability of this species.

Implanting
For this species it is not uncommon to implant tracking devices (Heinänen *et a*l., 2020), however in the overview of tracking devices only 2 different devices were implanted and one other study used common tracking devices. When considering studying this species in relation to offshore wind farms, it is recommended to have a look at the following website and contact the researchers to discuss the possibilities of implanting or the use of ‘regular’ tracking devices (https://www.divertracking.com/project-partners/).

Table 3.13 Overview of the scores for tagging devices suitable for red-throated diver. In this table, the Ornitela Ornitrack-10 and -15 received the highest score

					Characteristics						Biologging options										Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	magnetic field strength	Geofence	implant	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Red throated diver	**Average review score**
Ornitela	Ornitrack-10	-	10	0.6	5	3	5	5	5	5	-	1	1	1	1	1	1	-	-	34	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-15		15	0.8	5	3	5	5	5	5	-	1	1	1	1	1	1	-	-	34	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-20	-	20	1.1	3	3	5	5	5	5	-	1	1	1	1	1	1	-	-	32	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-25	-	25	1.4	3	3	5	5	5	5	-	1	1	1	1	1	1	-	-	32	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-30		30	1.7	3	3	5	5	5	5	-	1	1	1	1	1	1	-	-	32	3	1	5	5	5	5	4	0	3.5
Ornitela	Ornitrack-50		50	2.8	0	3	5	5	5	5	1	1	1	1	1	-	1	-	-	29	0	1	5	5	4	5	4	0	3.0
Milsar	GSMRadioTag-M9		16	0.9	5	3	0	5	5	5	1	1	-	1	1	-	1	-	1	29	-	-	-	-	-	-	-	-	
North Star	Saker L		17	0.9	5	3	0	5	5	5	1	1	-	1	1	-	1	-	1	29	-	-	-	-	-	-	-	-	
Movetech	Flyway 18s		18	1.0	3	3	5	5	5	5	-	-	-	1	1	-	-	-	-	28	5	3	0	0	1	2	3	0	1.8
Movetech	Flyway 25s		25	1.4	3	3	5	5	5	5	-	-	-	1	1	-	-	-	-	28	0	3	0	0	3	2	4	0	1.5
Ecotone	KITE-L GPS	1	17	0.9	5	3	0	5	5	5	1	-	-	1	1	-	-	-	1	27	5	1	0	0	0	2	3	5	2.0
PathTrack	Nanofix Geo+GSM		31	1.7	3	3	5	5	5	5	-	-	-	-	-	-	-	-	1	27	-	-	-	-	-	-	-	-	
Ecotone	Griffon		38	2.1	0	3	0	5	5	5	1	1	-	1	1	1	-	-	1	24	3	1	0	0	4	2	4	0	1.8
TechnoSMart	Axy-Trek Marine		14	0.8	5	3	0	5	0	5	1	-	-	1	1	1	-	-	1	23	0	1	0	0	5	5	4	0	1.9
TechnoSMart	Gipsy GSM/3G		10	0.6	5	3	0	5	5	0	1	-	1	1	1	-	-	-	1	23	0	1	-5	-5	-1	2	3	0	-0.6
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0.2	5	3	-	5	5	5	-	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Interrex	LEGO		18.7	1.0	3	3	0	5	5	5	-	-	-	1	-	-	1	-	-	23	-	-	-	-	-	-	-	-	
Milsar	GsmRadioTag-S9		12	0.7	5	3	0	5	5	0	-	1	-	1	1	-	1	-	-	22	-	-	-	-	-	-	-	-	
CellTrack	ES-150	-	15	0.8	5	3	0	0	5	5	-	1	-	1	1	-	1	-	-	22	-	-	-	-	-	-	-	-	
Lotek	PP GPS Argos Solar		16.5	0.9	5	3	0	5	0	5	-	-	-	1	1	-	1	-	-	21	-	-	-	-	-	-	-	-	

Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	1.1	3	3	5	5	5	0	-	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	0.6	5	3	0	5	0	0	1	1	-	1	1	-	1	-	1	19	0	1	5	5	4	5	4	0	3.0
Ecotone	Gannet		40	2.2	0	3	0	5	5	0	1	1	-	1	1	1	-	-	1	19	3	1	0	0	4	5	4	0	2.1
E-obs	Bird Solar UMTS		25	1.4	3	3	0	5	5	0	-	1	1	1	-	-	-	-	-	19	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		14	0.8	5	3	5	5	0	0	-	-	-	-	-	-	-	-	1	19	0	1	0	0	4	2	4	0	1.4
UvaBITS	Uva-Bits 5DCLeGSM		13.5	0.8	5	3	0	5	0	5	-	-	-	1	-	-	-	-	-	19	0	2	0	0	-1	2	4	0	0.9
UvaBITS	Uva-Bits 2DCSe		7.5	0.4	5	3	0	5	0	5	-	-	-	1	-	-	-	-	-	19	0	1	-5	0	4	2	4	0	0.8
Ecotone	Harrier H		16	0.9	5	3	0	5	0	5	-	-	-	1	-	-	-	-	-	19	0	1	0	0	-1	2	3	0	0.6
Ecotone	ALLE-60 GPS-UHF		4.5	0.3	5	0	5	5	0	0	1	-	-	-	1	-	-	-	1	18	3	1	0	5	5	5	4	0	2.9
UvaBITS	Uva-Bits 6CDLe		18.5	1.0	3	3	0	5	0	5	-	-	-	1	-	-	-	-	-	17	3	2	0	5	5	5	4	0	3.0
Ecotone	Horse tail		71	3.9	-2	3	0	5	5	0	1	1	-	1	1	1	-	-	1	17	3	1	0	0	4	5	4	0	2.1
Ecotone	URIA-300 GPS-UHF		13.5	0.8	5	0	0	5	5	0	1	-	-	-	-	-	-	-	1	17	-5	1	0	-5	-3	-5	0	0	-2.1
E-obs	Bird Solar Tags		15	0.8	5	3	0	5	0	0	-	1	1	1	-	-	-	-	-	16	3	0	0	0	4	5	4	0	2.0
IgotU	GT-120		20	1.1	3	3	5	0	0	5	-	-	-	-	-	-	-	-	-	16	3	0	0	5	5	2	0	0	1.9
Microwave Telemetry Inc.	Solar Argos PTT	-	22	1.2	3	3	-5	5	5	0	-	1	1	1	1	-	-	-	-	15	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G	-	25	1.4	3	3	-5	5	5	0	-	1	1	1	1	-	-	-	-	15	-	-	-	-	-	-	-	-	
IgotU	GT-600		37	2.1	0	3	5	0	0	5	-	-	-	-	-	-	-	-	-	13	3	0	0	5	5	5	0	0	2.3
PathTrack	Nanofix Geo+RF		11	0.6	5	0	0	5	0	0	-	-	-	-	-	1	-	-	1	12	5	1	0	5	4	2	4	0	2.6
GeoTrak	12G Solar Gps	-	12	0.7	5	3	-5	0	5	0	-	1	1	1	1	-	-	-	-	12	-	-	-	-	-	-	-	-	
E-obs	Bird Battery		39	2.2	0	3	0	5	0	0	-	1	1	1	-	-	-	-	-	11	3	0	0	0	4	5	4	0	2.0
PathTrack	Nanofix Geo+RF		10	0.6	5	0	0	5	0	0	-	-	-	-	-	-	-	-	-	10	5	1	0	5	4	2	4	0	2.6
GeoTrak	22G Solar Gps		22	1.2	3	3	-5	0	5	0	-	1	1	1	1	-	-	-	-	10	-	-	-	-	-	-	-	-	
Telonics	TAV-2618		18	1.0	3	0	-5	0	5	0	-	1	-	1	1	1	-	-	-	7	3	-5	-5	0	4	2	5	0	0.5
Telonics	TAV-2640	2,3	45	2.5	3	0	-5	0	5	0	-	-	-	1	1	-	-	1	-	6	-5	-5	-5	0	-1	-2	0	5	-1.6

1 USGS Alaska Science Center

2 University of Kiel

3 Bioconsult

Figure 3.10 *Map with the catching sites of red-throated diver of researchers that responded to our online survey*

3.14 Northern gannet

General ecology

Northern gannets *Morus bassanus* breed along the coast of the UK, Iceland, Faroes, Scandinavia, Helgoland and north-west France (BirdLife International, 2021), and the northern limit of their breeding area depends on the presence of waters that are free of sea ice during the breeding season. They can make long foraging trips from their breeding colony, foraging up to 300-400 km from the colony (Lane et al., 2020; Langston et al., 2013). Adult northern gannets disperse after the breeding season over a wide area and migrate between 800 and 1600 km from the breeding colony. Many adults migrate to the west of the Mediterranean, passing over the Strait of Gibraltar and mostly stay above sea.

Northern gannets are considered to be vulnerable to impact from turbine collisions as well as habitat loss (Rijkswaterstaat, 2015; 2019). All respondents of our questionnaire who worked with Northern gannet attached tracking devices in breeding colonies.

Scoring tracking devices

Based on the responses from researchers to our questionnaire, we rated their experiences for 32 types of tagging devices. In addition, we scored 13 additional types of tagging devices based on specifications given by the manufacturer. This resulted in the scoring of 45 tagging devices presented in Table 3.14. To calculate the % of body mass, we assumed an average mass of 3300g (Warwick-Evans et al., 2016).

Main research initiatives

Many tracking studies on Northern gannet are carried out by UK institutes (University of Exeter, University of Leeds, University of St Andrews, RSPB, BTO, British Antarctic Survey, University of Glasgow, Plymouth University, University of Liverpool). In addition, several studies are taking place from Germany (Kiel University, Max Planck Institute of Animal Behaviour), Iceland (University of Iceland), Canada (Canadian Wildlife Service) and USA (USGS).

Interested in Tagging and Tracking platform: 78%.

Catching sites and catchability

All researchers that responded (*n* = 9) indicated they caught the species at the breeding sites (Figure 3.11), and 3 respondents indicated the sample size of their study also was limited due to catchability of this species.

Table 3.14 Overview of the scores for tagging devices suitable for northern gannet. In this table, the Ornitella Ornitrack 25 received the highest score.

					Characteristics						Biologging options									Review								
Manufacturer	Type (incl. link)	Users	Weight (grams)	% of body mass	% body mass score	Type of power	Price per tag	Resolution	Data transfer	Internal antenna	Barometric pressure	Speed	Direction	Acceleration	Temperature	Immersion sensor	Geofence	Dive depth	**Summary score**	Malfunctioning	Usability of the technique	Satisfaction with battery life	Satisfaction with tag quality	Price / Quality ratio	Recommendation	Representativeness	Gannet	**Average review score**
Ornitela	Ornitrack-25	-	25	0,8	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-30	-	30	0,9	5	3	5	5	5	5	-	1	1	1	1	1	1	-	34	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-10		10	0,3	5	3	5	5	5	5	-	1	1	1	1	-	1	-	33	3	1	5	5	5	5	4	0	3,5
Ornitela	Ornitrack-15		15	0,5	5	3	5	5	5	5	-	1	1	1	1	-	1	-	33	3	1	0	5	5	5	4	0	2,9
Ornitela	Ornitrack-20		20	0,6	5	3	5	5	5	5	-	1	1	1	1	-	1	-	33	0	1	0	5	4	2	4	0	2,0
Ornitela	Ornitrack-50	9	50	1,5	3	3	5	5	5	5		1	1	1	1	-	1	-	31	0	1	5	5	4	5	4	5	3,6
Movetech	Flyway 25s		25	0,8	5	3	5	5	5	5	-	-	-	1	1	-	-	-	30	0	3	0	0	3	2	4	0	1,5
Milsar	GSMRadioTag-M9		16	0,5	5	3	0	5	5	5	1	1	-	1	1	-	1	1	29	-	-	-	-	-	-	-	-	
North Star	Saker L		17	0,5	5	3	0	5	5	5	1	1	-	1	1	-	1	1	29	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+GSM		31	0,9	5	3	5	5	5	5	-	-	-	-	-	-	-	1	29	-	-	-	-	-	-	-	-	
Ecotone	Griffon	9	38	1,2	3	3	0	5	5	5	1	1	-	1	1	1	-	1	27	3	1	0	0	4	2	4	5	2,4
Ecotone	KITE-L GPS		17	0,5	5	3	0	5	5	5	1	-	-	1	1	-	-	1	27	3	1	0	0	4	5	4	0	2,1
Movetech	Flyway 18s		18	0,5	5	3	0	5	5	5	-	-	-	1	1	-	-	-	25	0	0	0	-	-	-	-	0	0,0
Interrex	LEGO		18,7	0,6	5	3	0	5	5	5	-	-	-	1	-	-	1	-	25	-	-	-	-	-	-	-	-	
TechnoSMart	Axy-Trek Marine	4	14	0,4	5	3	0	5	0	5	1	-	-	1	1	1	-	1	23	0	1	0	0	5	5	4	5	2,5
TechnoSMart	Gipsy GSM/3G		10	0,3	5	3	0	5	5	0	1	-	1	1	1	-	-	1	23	0	1	-5	-5	-1	2	3	0	-0,6
Hangzhou Yuehai Technology Co	GPS/GSM satellite tag YH-GTG0304		4	0,1	5	3	-	5	5	5	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	
Hunan Global Messenger Technology Co. Ltd	HQBG1815S		20	0,6	5	3	5	5	5	0	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-	

Ecotone	Gannet		40	1,2	3	3	0	5	5	0	1	1	-	1	1	1	-	1	22	3	1	0	0	4	5	4	0	2,1
Milsar	GsmRadioTag-S9		12	0,4	5	3	0	5	5	0	-	1	-	1	1	-	1	-	22	-	-	-	-	-	-	-	-	
CellTrack	ES-150		15	0,5	5	3	0	0	5	5	-	1	-	1	1	-	1	-	22	-	-	-	-	-	-	-	-	
E-obs	Bird Solar UMTS		25	0,8	5	3	0	5	5	0	-	1	1	1	-	-	-	-	21	3	0	0	0	4	5	4	0	2,0
Lotek	PP GPS Argos Solar		16,5	0,5	5	3	0	5	0	5	-	-	-	1	1	-	1	-	21	-	-	-	-	-	-	-	-	
Milsar	Radio tag 14		10	0,3	5	3	0	5	0	0	1	1	-	1	1	-	1	1	19	0	1	5	5	4	5	4	0	3,0
UvaBITS	Uva-Bits 6CDLe		18,5	0,6	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	3	2	0	5	5	5	4	0	3,0
Ecotone	Horse tail	9	71	2,2	0	3	0	5	5	0	1	1	-	1	1	1	-	1	19	3	1	0	0	4	5	4	5	2,8
UvaBITS	Uva-Bits 2DCSe	5	7,5	0,2	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	-5	0	4	2	4	5	1,4
PathTrack	Nanofix Geo+RF		14	0,4	5	3	5	5	0	0	-	-	-	-	-	-	-	1	19	0	1	0	0	4	2	4	0	1,4
UvaBITS	Uva-Bits 5DCLeGSM		13,5	0,4	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	2	0	0	-1	2	4	0	0,9
Ecotone	Harrier H		16	0,5	5	3	0	5	0	5	-	-	-	1	-	-	-	-	19	0	1	0	0	-1	2	3	0	0,6
Ecotone	ALLE-60 GPS-UHF		4,5	0,1	5	0	5	5	0	0	1	-	-	-	1	-	-	1	18	3	1	0	5	5	5	4	0	2,9
IgotU	GT-120	1,2,6,7	20	0,6	5	3	5	0	0	5	-	-	-	-	-	-	-	-	18	3	0	0	5	5	2	0	5	2,5
Ecotone	URIA-300 GPS-UHF		13,5	0,4	5	0	0	5	5	0	1	-	-	-	-	-	-	1	17	0	1	0	0	4	2	4	0	1,4
Microwave Telemetry Inc.	Solar Argos PTT		22	0,7	5	3	-5	5	5	0	-	1	1	1	1	-	-	-	17	-	-	-	-	-	-	-	-	
Microwave Telemetry Inc.	GPS/GSM 25G	-	25	0,8	5	3	-5	5	5	0	-	1	1	1	1	-	-	-	17	-	-	-	-	-	-	-	-	
IgotU	GT-600	2,3,6,7	37	1,1	3	3	5	0	0	5	-	-	-	-	-	-	-	-	16	3	0	0	5	5	5	0	5	2,9
E-obs	Bird Solar Tags		15	0,5	5	3	0	5	0	0	-	1	1	1	-	-	-	-	16	3	0	0	0	4	5	4	0	2,0
E-obs	Bird Battery	8,9	39	1,2	3	3	0	5	0	0	-	1	1	1	-	-	-	-	14	3	0	0	0	4	5	4	5	2,6
PathTrack	Nanofix Geo+RF		11	0,3	5	0	0	5	0	0	-	-	-	-	-	1	-	1	12	5	1	0	5	4	2	4	0	2,6
GeoTrak	12G Solar Gps		12	0,4	5	3	-5	0	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
GeoTrak	22G Solar Gps		22	0,7	5	3	-5	0	5	0	-	1	1	1	1	-	-	-	12	-	-	-	-	-	-	-	-	
PathTrack	Nanofix Geo+RF		10	0,3	5	0	0	5	0	0	-	-	-	-	-	-	-	-	10	5	1	0	5	4	2	4	0	2,6
Biotrack	Mk3006		2,5	0,1	5	0	5	-	-	-	-	-	-	-	-	-	-	-	10	0	1	-5	-5	-1	2	3	0	-0,6
Telonics	TAV-2618		18	0,5	5	0	-5	0	5	0	-	1	-	1	1	1	-	-	9	3	-5	-5	0	4	2	5	0	0,5
Telonics	TAV-2665	1	71	2,2	0	0	-5	0	5	0	-	1	-	1	1	1	-	-	4	3	-5	-5	0	4	2	5	5	1,1

1 British Antarctic Survey
2 University of Liverpool
3 University of St Andrews
4 CRNS
5 RSPB
6 University of Iceland
7 University of Exeter
8 Environment and Climate Change Canada
9 University of Kiel

Figure 3.11 Map with the catching sites of Northern gannets of researchers that responded to our online survey

4 Study-specific considerations

4.1 Biologging

Which biologging tools to use on wildlife is depending on the species, location, funding and the research question at hand: choosing the right tool and technique will further depend on the species' size and mass, the behaviour of the birds (some populations are extremely shy, others are more resilient to capture), hence the option to recapture the individuals or not, the accessibility to the site, the breeding stage. Therefore, to what degree a certain tag type and deployment method used successfully in one study will also work in other contexts is difficult to say. In addition, biologging tools are developing rapidly, with constant adjustments and improvements to existing models/brands constantly changing the landscape of options.

In addition to biologging devices that are integrated in the tag, many researchers also opt for separate biologging devices targeting specific measurements. Table 4.1 gives an overview of the biologging devices that were deployed on the 13 species covered in this report.

Table 4.1 Overview of biologging devices used by researcher respondents.

Biologging device	Users (n = 54)	%
Accelerometer*	32	59,3
Dive depth logger*	25	46,3
Temperature logger*	19	35,2
Pressure logger*	18	33,3
Heart-rate logger	4	7,4
Video logger	2	3,7
Immersion logger*	1	1,9
Magnetic field intensity*	1	1,9
Acoustic logger	1	1,9
Salinity logger	1	1,9
ECG logger	1	1,9
Near-infrared spectroscopy	1	1,9

* Often integrated in tag

4.2 Legal requirements and limitations

In general, a ringing permit, an ethical permit and permission for entering the study area are required. However, legal requirements for tagging birds differ between countries. In this chapter, we give a brief overview of legal requirements for countries in and close to Europe where most research on the study species takes place. Note that legal requirements should always be checked due to regular updates.

In the Netherlands, a permit under the Nature Protection Act is required to catch birds. In addition, anyone carrying out an animal experiment needs an agreement from the animal ethics committee, and a permit from the local nature management authority or landowner is needed to get access to study areas. An agreement from the animal ethics committee is necessary in Belgium as well.

In France, the CRBPO (Centre de Recherches sur la Biologie des Populations d'Oiseaux) is managing bird ringing at the Muséum National d'Histoire Naturelle (MNHN) under the authority of the ministry in charge of ecology. In addition, administrative authorization is needed for access to the catching and study area, and a permit from the ethical committee is required for up to 3 actions (for example for ringing, tagging and blood sampling).

In Germany, a permit from the city is required to allow entering the colony. In addition, in Germany as well as in Denmark, permits from animal welfare committees and bird ringing licenses are required. A permit from the animal welfare committees in Germany are necessary for each federal state in which fieldwork is carried out.

In Sweden, an ethical permit is required, which only universities can obtain. In addition, a permit is required for catching birds. If tagging is to take place in a breeding colony, a permit is necessary for accessing breeding colonies, which are in most cases situated in bird protection areas on islands with landing restrictions.

In Norway, permits are required for ethical approval (Norwegian Animal Welfare Committee), and for catching, handling and tagging birds (Mattilsynet and Miljødirektoratet).

In the UK, regulations are relatively strict. All fieldworkers attaching tags must be qualified experienced bird ringers (permits obtained from British Trust for Ornithology). It also requires local statutory agency approval (4 separate bodies in the 4 countries of the UK - Natural England for England, Natural Resources Wales for Wales, Northern Ireland Environment Agency for Northern Ireland, and Scottish Natural Heritage for Scotland). Landowner permission is required as well. When work is conducted in a Site of Special Scientific Interest or Natura 2000 site, a permit is required to work at that site from Natural England (SSSI Consent). In addition, a "special methods" permit for the project is required. This is an add-on to the standard bird ringing permit and is issued to the project leader (who must report on it annually) and also added to the ringing permits of the other named fieldworkers. In order to get this permit, a very specific description of the study aims, devices to be used, attachment methods and experience of personnel needs to be reported. This is then reviewed by an independent Special Methods Technical Panel made up of tracking experts (non-BTO) which decide whether to approve or not. All projects are legally required to submit annual reports with any data collected on effectiveness and impacts to birds, often comparing various measures of survival/productivity/behaviour with an unmarked control group. If there are any indications of adverse effects all fieldwork must be stopped immediately. If attachment methods are novel for a particular species, then extensive justification and trials are usually necessary before a license is issued.

In Iceland, a ringing permit from the Icelandic Natural History Institute is required. For a permit to use tagging devices, an additional license from the same institute is required. In order to get this permit for the use of tagging devices, researchers need to describe their aims and fieldwork in detail.

5 Discussion

5.1 General discussion

Tracking devices are adequate tools to study the interactions between wildlife and human activities, particularly in environments where direct observation is challenging (e.g., remote areas such as offshore marine areas). When studying the impacts of anthropogenic disturbances, such as impact assessment of windfarms on (sea)birds, the main application of tracking devices is studying spatial overlap with development and Special Protected Areas (SPAs). Many tracking devices can measure GPS altitude within those areas, though the best results are achieved with a barometric pressure device, and this information is crucial information for collision rate modelling. Tracking data can also be used to study how environmental disturbances or factors, such as distribution of fishing vessels, affect bird distribution, but also to predict where birds occur and how they select resources. Differences in age and sex can also be studied, as well as the degree of site fidelity. In addition, movement patterns can be compared between breeding and non-breeding individuals. All of these factors have implications on how populations may be impacted by anthropogenic disturbance.

Chapter 3 of this report presents an overview of suitable tagging devices and a scoring based on a multicriteria analysis. Note that the highest scoring device is not necessarily the most suitable for each research question. The scores on individual aspects should always be taken into account when choosing a suitable tagging device.

Some respondents of our online survey used tags which are not available anymore or are outdated. In addition, some newly developed tagging devices were so new that feedback on experiences using those devices were not yet available. For that reason, the overview presented in this report is not static, and should be updated regularly.

5.2 Malfunctions

Researchers indicated that when equipping birds with tags, in the long-term all tags fail in the end at least after a few years. Most common causes for failure are the end of the battery (even when using solar cells) and detachment of the device by the bird. In addition, in several cases tag failure seemed to be caused by water intrusion. Some issues with base stations and software were regularly mentioned by the respondents. In general, the percentage of malfunctions was relatively low; 43% of the respondents indicated less then 10% of the tags malfunctioned and 37% of the respondents indicated that the percentage of malfunctions was between 10 and 25%. Only a few studies (~ 5%), indicated they had some issues with the tags or base stations and reported a relatively high percentage of malfunction (> 50%).

5.3 Knowledge gaps

In the questionnaires, researchers were asked about the main knowledge gaps. Here, we summarize the main responses and comments.

- In general, movement and dispersal data is biased towards the breeding season. Behaviour and distribution outside of the breeding season are often relatively unknown for these species. Moreover, data on several years would provide additional insights in site faithfulness and individual consistency.
- Tracking data of immatures are often lacking. Insight into differences in behaviour and distribution are important for the assessment of stage-specific collision rates or stage-dependent consequences of OWF-induced habitat loss. If collision rates or the degree of habitat loss vary among life stages, this can strongly impact the results of the assessment at population level. For example, Camphuysen and Leopold (1994) found for lesser black-backed gull that adults use offshore areas more than other age classes. As a result, the percentage of adults among collision victims is expected to be higher than expected based on the stable stage structure (Potiek et al., 2019).
- For diving species, several researchers are interested in comparing diving depth between species. In addition, there is interest in the relation of diving depth with season and prey availability.
- Cost of different flight, foraging and migration strategies. The costs of avoiding offshore windfarms is largely unknown and it was suggested to study flight behaviour and energetics before and after construction of an offshore windfarm.
- Moreover, some species seem to habituate to offshore windfarms. Long-term tracking studies would provide more insight into this phenomenon.
- For several species, it is unclear how closing an area to fishing affects foraging effort within that area.
- The definition of location-specific behaviour based on tracking data is often challenging. For diving species, biologging tools can indicate foraging behaviour, but for other species this is often more challenging. More information on foraging success rate would improve insight in habitat use in and around wind farms.
- In many studies, data are only collected after impact. Before-and-after-impact studies (BACI) are crucial for the assessment of changes in behaviour and distribution.

5.4 General experience of researchers with tracking devices

Depending on the type of tracking device used, some researchers are satisfied with the accuracy, whereas others were disappointed and concluded that the devices could not be used to study fine-scale moment and/or behaviour in and around the wind farm. Hence, if the aim is to study fine-scale movement and/or behaviour, this should be taken into account for the choice of tracking device (higher accuracy), as well as for the settings of the device (sampling frequency). Note that a higher sampling frequency does take up more battery. Some tracking devices have the option to allocate a ‘geo-fence’, which is a spatial square that can be programmed to gather data at a very high temporal resolution within this geofence, such as around wind turbines, and at a lower temporal resolution elsewhere. The advantage of this option in this context is that it allows to collect fine-scale behavioural data at specific areas of interest and increases the battery life.

Several researchers indicated that the interpretation and analysis of accelerometer data is not straight forward. Even in cases where real time observations were made, the classification into behaviour is not always correct. In addition, GPS altitude measurements are often inaccurate and for reliable height measurements, a barometric pressure device is recommended.

The technique of tagging individuals provides valuable insight into individual variation in spatial behaviour; however, several researchers indicate that it is often insufficient to derive more general conclusions at population level, due to often small sample sizes. These sample sizes are often limited by funding limitations, but in some cases legal limitations and the catchability of some species (e.g., red-throated diver and great skuas).

Researchers studying migratory behaviour indicate that the resolution is insufficient to accurately assess or determine stopover behaviour. Moreover, especially for the smaller species where a base station needs to be located close to the breeding site to download the data, data can only be collected when the birds return to the colony. As a result, data tend to be biased to the individuals that survive and are site faithful. For the larger species and the newest tracking devices, it is more common to have the option the transfer the data via GSM-UTMS or SMS.

Species and individuals differ in the difficulty of capturing or recapturing. Some species or individuals are known for their negative trap-dependence (indicating trap-happiness), or the opposite (trap shyness), though the reason for this behaviour is still poorly understood. The difficulty of capture or recapture thus depends on the location and catching method, as well as the level of experience of field workers and the trap-dependence. Local knowledge of colonies and behaviour of birds within these colonies is often invaluable and cannot be generalised here.

Some (larger) species are suitable for long-term deployment using harnesses, allowing the investigation of individual variation in space use over time (day/night, within season and between years). These results have been used to investigate breeding season interactions with local wind farms (informing Environmental Impact Assessment and Post-consent Monitoring) and vulnerability to wind farms through the year (informing Spatial Planning).

Other aspects to consider before starting a tracking study are tag effects associated with weight/drag (and ethical considerations, disturbance at the colony for example), sample size, and longevity of device.

5.5 Issues with responses

Not the anticipated response

The questionnaires were not always entered as we anticipated, and the following issues arose in the evaluation:

- Some questions within the questionnaire were interpreted differently.
- Several respondents did not fill out all questions.
- Several respondents filled out the questions for several types of tags combined and as a result the experience with each specific type of tag is sometimes unclear.

In several of these cases, the answer on the question could be found in a different (similar) question, while in other cases, the respondents were contacted again for clarification.

Species coverage
For some species, the number of filled out questionnaires is limited or even zero (Table 5.1). For black tern and great skua, no questionnaires were filled in. For razorbill, common guillemot and Arctic skua, only 1 respondent filled in the questionnaire.

Table 5.1 Response per species, where the number represents to the number of respondents and the number between brackets indicate the total number of invitations send to the different researchers. Note that a single respondent may have worked on multiple species. As some researchers worked on different species than our study species, numbers do not coincide with Table 3.1.

Species	**Researchers**
Razorbill	1(3)
Common guillemot	1(4)
Northern gannet	3(16)
Great skua	0(5)
Arctic skua	1(4)
Black-legged kittiwake	5(14)
Herring gull	6(11)
Lesser black-backed gull	6(13)
Great black-backed gull	4(7)
Sandwich tern	3(3)
Common tern	2(2)
Red-throated diver	4(7)
Black tern	0(1)

5.6 Follow-up strategy

Based on the knowledge gaps, more research is required on individuals outside the breeding season, and on subadult individuals and differences between the sexes. An increase in sample size is needed to be able to generalise the results on the population level. In addition, research on habitat use for different types of behaviour (for example foraging versus transit flights), is crucial for understanding impacts of anthropogenic changes such as the presence of offshore wind farms. Moreover, there is an urgent need for comparing behaviour and movements from the situation before and after construction of a wind farm.

Within the questionnaires to researchers, the interest for a tagging and tracking platform was evaluated. In total 85% of the researchers showed interest. Rijkswaterstaat (RWS) will take the lead to set up this international tagging and tracking platform in the short term.

It should be noted that this report presents an inventory of the current state of tracking devices and can be used as a standard for the species of interest. Given the fast pace of development of those devices, the information in this report needs to be verified and updated regularly. The smaller species are underrepresented thus far for obvious reasons, but it is expected that more suitable tracking devices will become available for these species in the near future, though the manufactures could not provide us with a clear time window.

5.7 Workshop seabird and marine mammal telemetry

On April 15, a workshop was organized by RWS. During the workshop, presentations were held on options and perspectives of new, innovative tagging and tracing devices for seabirds as well as for marine mammals. The aim of the workshop was to create broader awareness of the existence, applicability, reliability, and likely costs of these techniques and technologies (including reviews by actual users). In addition, to create commitment among the governmental representatives of the North Sea countries for attempting to address joint research efforts in the near future. Here we address a few highlights of this workshop.

- To produce reliable predictions, reliable information is needed about individual seabirds/marine mammals on how they behave and react to their environment. Therefore, telemetry studies are necessary to collect this data to develop and create Individual Based Models (IBMs), which can help to make reliable assessments of relevant bird species in relation to of future offshore windfarm developments.
- Some studies show that the survival of birds is hampered when equipped with tagging devices (e.g. Cleasby *et al*., 2021). This is a big issue in the UK and it hampers the credibility of tagging data used in a case-work context.
- Cross-boundary collaboration is very worthwhile and necessary. Each country bordering the North Sea needs to make decisions on similar bird species and birds are not bound by boundaries. Cross-boundary collaboration will improve our ecological understanding when methodologies are streamlined, and duplication of work is avoided.
- Academia should be included as well to get them interested in the ‘applied’ side of things. At times they are reluctant to share data, unsure of what might happen to their datasets.
- Funding is limited and usually, funding by specific parties is only interested in what happens for example in local waters and not necessarily across the border.
- Collaboration needs to be stimulated on the governmental level.

Almost all participants of the workshop are committed to working together in a cross-boundary set-up for the development of international research initiatives. To follow up on this commitment the next actions/steps will be taken:

- Define some key research questions – these will help guide the collaboration partners;
- Ask the right research questions, also from a spatial planning point of view;
- Define possible methods to approach the research questions;
- Rase governmental awareness;
- Explore international funding;
- Inform CEAF working group;
- Work towards open data requirements;
- Communicate more and see if we can line up projects that already exist;
- Establish a "pack" (2-3 slides PPT/1 A4 Word) on a joint agreed methodology/species to monitor;
- Explore more funding options and continue to work together;
- Make concrete research proposals involving all or almost all countries.

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Appendix I – Questionnaire for researchers

Inventory of tagging devices on seabirds

We would be so grateful if you took 3 – 5 minutes of your time and completed our questionnaire. Your feedback is of the utmost importance to us, and it will greatly help to improve our knowledge of tagging devices used by our peers and manufactures working on offshore seabird behaviour.

While using a third party for data collection, we keep all your responses anonymous: we do not collect nor record your IP address, geolocation, or any other identifying information.

*Vereist

What is your name?

Jouw antwoord

Are you (or have you been) using tags to study the distribution and/or behaviour of seabirds at sea?

- ◯ Yes
- ◯ No
- ◯ No, but I am planning this in the future

Are you (or have you been) using tags to study offshore behaviour in relation to anthropogenic factors (e.g. offshore windfarms)?

- ○ Yes
- ○ No
- ○ Not yet, but perhaps in the future

Which species are you studying? (Multiple answers allowed) *

- ☐ Lesser black-backed gull
- ☐ Great black-backed gull
- ☐ Herring gull
- ☐ Kittiwake
- ☐ Great skua
- ☐ Arctic skua
- ☐ Common tern
- ☐ Black tern
- ☐ Red-throated diver
- ☐ Northern gannet
- ☐ Razorbill
- ☐ Common guillemot
- ☐ Sandwich tern
- ☐ Anders:

In which country are you studying the species selected above? (Multiple answers allowed)

- [ ] UK
- [ ] Germany
- [ ] Denmark
- [ ] Belgium
- [ ] the Netherlands
- [ ] Sweden
- [ ] Norway
- [ ] Iceland
- [ ] France
- [ ] Poland
- [ ] Canada
- [ ] USA
- [ ] Anders:

We would like to gain insight in the licencing requirements for tagging studies; i.e. legal requirements for each country. Can you briefly give these requirements?

Jouw antwoord

We would like to gain insight in the spatial distribution of tagging studies of seabirds. Can you please provide the name(s), country(ies) and/or coordinates of you study site(s)?

Jouw antwoord

To identify opportunities and pitfalls for catching individuals of different seabird species, we aim to identify appropriate catching sites. Could you indicate where you've been succesfull in catching your focal species?

- [ ] Breeding site
- [ ] Roosting site
- [ ] Catch at sea
- [ ] Other, please specify below

If you've answered other in the above question, please elaborate.

Jouw antwoord

Which type of tags are you (or have you been) using in relation to offhore behaviour and antropogenic factors such as windfarms? (Multiple answers allowed)

- [ ] GPS logger
- [ ] GPS Argos
- [ ] GPS
- [ ] Icarus
- [ ] VHF (e.g. Motus)
- [ ] Geolocator
- [ ] Anders:

Can you provide the tag specifics? (brand, type, weight, attachment, size, external antenna etc)

e.g. TechnoSMart, Gipsy GSM/3G, antenna, 10 g, 35x19x13mm, or you can provide a weblink, e.g.: https://www.technosmart.eu/gipsy-gsm-3g/

Jouw antwoord

What sample size did you obtain (number of individuals)?

- ◯ 1 - 10
- ◯ 11 - 20
- ◯ 21 - 30
- ◯ 31 - 50
- ◯ 51 - 100
- ◯ 101 - 200
- ◯ >200

Which factor limited your sample size? (Multiple answers allowed)

- ☐ Price per tag
- ☐ Catchability of the study species
- ☐ Sufficient for our research question
- ☐ Limited by the licencing requirements

What percentage of tags malfuntioned in the course of your study?

- < 1
- 1 - 10
- 11 - 25
- 26 - 50
- 51 - 75
- > 75

Can you explain this percentage? (e.g. battery failure, death of study species). What was/were the most important reasons for tag failure?

Jouw antwoord

Are you (or have you been) satisfied with the battery life?

- Better than expected
- As expected
- Worse than expected

How is (or was) the tag powered?

- Solar panel
- Solar and battery
- Anders:

Are you (or have you been) satisfied with the quality of the tag? (in terms of resolution, robustness, user-friendliness)

- Better than expected
- As expected
- Worse than expected

What is (or was) the price per unit? (price in EUR)

- 0 - 150
- 151 - 500
- 501 - 1000
- 1001 - 1250
- 1251 - 1750
- 1751 - 2000
- 2001 - 2500
- > 2500

How would you rate the price quality of your tag? Price/quality ratio

	1	2	3	4	5	6	7	8	9	10	
Poor	○	○	○	○	○	○	○	○	○	○	Exellent

Would you recommend this tagging device to fellow researchers?

- Absolutely
- Yes, but with a few warnings
- No, unless you don't have other options
- Never

How would you classify the representativeness of the data, accounting for sample size and possible negative effects on the animal’s welfare?

- Very good, a solid sample size and the animals behaved normal
- Good, the sample size could be increased, but animals behaved normal
- Reasonable, the sample size could be increased, and the animals possibly influenced their behaviour slightly
- Bad, the sample size should be increased, and the animals behaviour was strongly influenced

What is/was duration of your study?

- 1 year
- 2 years
- 3 years
- > 3 years

Are you (or have you been) using biologging devices?

- Yes
- No
- Not yet, I am exploring the different options

Which biologging tools have you been using? If you haven't used them, you can skip this question.

- [ ] Accelerometer
- [ ] Heart-rate loggers
- [ ] Dive depth loggers
- [ ] Temperature loggers
- [ ] Pressure logger
- [ ] Anders:

Are you planning to do more tracking studies in the (near) future?

- ○ Yes
- ○ Maybe
- ○ Not likely

Can you give us your impression of the usability of the technique? More specifically, what kind of questions can be answered and what kind of questions remain unanswered?

Jouw antwoord

Would you like us to keep you updated on the outcomes of this survey?

- ○ Yes
- ○ No

Would you be interested in participating in a future (new) joint research effort and interested to take part in a 'Tagging and Tracking platform' for studying offshore seabird behaviour?

- ◯ Yes
- ◯ No

If you answered one of the last 2 question with yes, please provide your email adress below. Note that we will only use this email adress to keep you informed about the outcomes of this survey and any future developments regarding a tagging and tracking platform, not for any other purposes.

Please provide email

Jouw antwoord

Do you have any other relevant information that you want to share?

Jouw antwoord

Verzenden Pagina 1 van 1

Appendix II – Questionnaire for manufacturers

Inventory of tagging devices on seabirds

We would be so grateful if you took 3 – 5 minutes of your time and completed our questionnaire. Your feedback is of the utmost importance to us, and it will greatly help to improve our knowledge of tagging devices used by our peers working on offshore seabird behaviour. If you have any additional questions or remarks, please do not hesitate to contact us directly (i.e., reply to the email with this request)

While using a third party for data collection, we keep all your responses anonymous: we do not collect nor record your IP address, geolocation, or any other identifying information.

*Vereist

What is the name of your company?

Jouw antwoord

Where are you located?

Please provide country and place

Jouw antwoord

Are your tags being used to study the distribution and behaviour of seabirds at sea?

- ◯ Yes
- ◯ No
- ◯ Not that we are aware
- ◯ No, but we're planning to develop this in the future

Are your tags being used on one of the species mentioned below? (Multiple answers possible; if you can provide tags for multiple species, we would appreciate filling out the survey per species or contact us directly) *

- ☐ Lesser black-backed gull
- ☐ Great black-backed gull
- ☐ Herring gull
- ☐ Kittiwake
- ☐ Great skua
- ☐ Arctic skua
- ☐ Common tern
- ☐ Black tern
- ☐ Red-throated diver
- ☐ Northern gannet
- ☐ Razorbill
- ☐ Common guillemot
- ☐ Sandwich tern

Which type(s) of tags do you offer that can be used on the species listed above and are suitable to identify offshore seabird behaviour? (bird weight range 60 - 3000 g) (Multiple answers possible)

- [ ] GPS logger
- [ ] GPS
- [ ] GPS Argos
- [ ] Icarus
- [ ] VHF (e.g. Motus)
- [ ] Geolocator
- [ ] Anders:

Tag details per species

Please give the type specification(s) per species or provide a weblink

Jouw antwoord

Tag details per species

Please provide the dimensions (cm) per species or provide a weblink

Jouw antwoord

Tag details per species

Please give the weight (g) of the tag per species or provide a weblink

Jouw antwoord

Tag details per species

Please indicate how the tag should be attached to the study species

Jouw antwoord

Can you provide the tag details per species?

Does the tag have an external antenna?

- ◯ Yes
- ◯ No

Please provide any other relevant info, such as geofence option, interval settings, data handling etc.

Jouw antwoord

How is the tag powered?

- ◯ Solar panel
- ◯ Solar and battery
- ◯ Anders:

How is retrieval and elaboration of the data generated,? Do the animals need to be recaptured in order to retrieve the data or can they be transferred by e.g. radar systems installed on or near windfarms, satellite or GSM?

- ◯ Recapture
- ◯ Remote download (e.g. systems installed on breeding site, roosting site or on offshore windfarm)
- ◯ Satelite
- ◯ GSM network
- ◯ Anders:

What is the average battery life expectancy?

Jouw antwoord

What is the price per unit? (price in EUR)

Jouw antwoord

What is the expected delivery time within Europe?

- ◯ < 2 weeks
- ◯ 1 - 2 months
- ◯ 3 - 6 months
- ◯ > 6 months

What is the state of the 'technology readiness' of the tag(s) to study offshore seabird behaviour?

- ○ Off the shelf available
- ○ Under development, likely available within 6 months
- ○ Under development, likely available within 1 year
- ○ Under development, likely available within 2 years
- ○ Unknown

Are you able to include biologging options or devices?

- ○ Yes
- ○ No
- ○ Not yet, but we're exploring the different options

What kind of biologging tools would you be able to provide?

- ☐ Accelerometer
- ☐ Heart-rate loggers
- ☐ Dive depth loggers
- ☐ Temperature loggers
- ☐ Pressure logger
- ☐ Anders:

Do you have any other relevant information that you want to share?

Jouw antwoord

Verzenden

Pagina 1 van 1

Appendix III – Questionnaire for policy makers

Inventory of tagging initiatives on seabirds in relation to offshore human activities

We would be so grateful if you took 2 – 4 minutes of your time and completed our questionnaire. Your feedback is of the utmost importance to us, and it will greatly help to generate an overview of ongoing research projects or initiatives using tagging and tracking techniques aimed at determining the impact of offshore human activities, such as Offshore Wind Farm development.

While using a third party for data collection, we keep all your responses anonymous: we do not collect nor record your IP address, geolocation, or any other identifying information.

*Vereist

What is the name of your organisation? *

Jouw antwoord

Where are you located?

Please provide country and place

Jouw antwoord

Are your aware of studies in your country that are being conducted or proposed to study the distribution and behaviour of seabirds at sea in relation to human activities?

- ○ Yes
- ○ No

If you mentioned yes, please select the species that is being studied.

- ☐ Lesser black-backed gull
- ☐ Great black-backed gull
- ☐ Herring gull
- ☐ Kittiwake
- ☐ Great skua
- ☐ Arctic skua
- ☐ Common tern
- ☐ Black tern
- ☐ Red-throated diver
- ☐ Northern gannet
- ☐ Razorbill
- ☐ Common guillemot
- ☐ Sandwich tern
- ☐ Anders:

Are you using these studies for policy goals?

For example to assign new areas of interest to develop offshore windfarms

- Yes
- No
- Not yet, but I intend to include them in the future

What questions would you like to see answered in relation to offshore windfarms and birds?

Jouw antwoord

Do you have any other relevant information that you want to share?

Jouw antwoord

Verzenden Pagina 1 van 1

Bureau Waardenburg
Ecology & Landscape

Varkensmarkt 9, 4101 CK Culemborg, The Netherlands
Tel. +31 345 51 27 10
www.buwa.nl, info@buwa.nl