Cyfoeth Naturiol Cymru
Natural Resources Wales

Guidance Note

At sea ornithological survey guidance

Reference number: GN055

Document Owner: Marine Programme Planning and Delivery Group

What is this document about?

This is guidance on designing and undertaking statistically robust ornithology surveys to inform assessments for marine licensing and other consenting regimes with respect to bird species recorded at sea.

Who is this document for?

This is guidance for developers and consultants designing and undertaking ornithology surveys to inform assessments for marine licensing and other consenting regimes.

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Version History

Document Version	Date Published	Summary of Changes
1.0	01-2022	Document published

Review Date: 01-2023

To report issues or problems with this guidance contact Guidance Development

Executive Summary

This guidance document is one of a series of marine and coastal guidance notes developed by Natural Resources Wales (NRW). The initial document was prepared under contract by ABP Marine Environmental Research Ltd (ABPmer) on behalf of NRW.

The guidance aims to assist in designing and undertaking statistically robust ornithology surveys to inform assessments for marine licensing and other consenting regimes with respect to bird species recorded at sea, thereby aiming to help streamline the regulatory review and consultation processes. These surveys will need to be tailored to answer the specific questions posed and should be discussed in the early stages of the consenting process.

The requirement for at sea ornithology surveys

The nature, scale and location of your proposed development will determine the requirements for baseline and post consent ornithology surveys. The requirement for surveys will generally need to be determined on a case by case basis. However, in order to assist with determining if project specific at sea surveys are likely to be required, guidance has been produced based on consideration of the following steps:

- Step 1: Identifying potential impact pathways for birds at sea.
- Step 2: Determining the marine licence band of an activity and understanding consenting risk with respect to birds at sea.
- Step 3: Identifying if the Zone of Influence (ZOI) of the proposed activity overlap with any areas which are protected or important for birds at sea.
- Step 4: Determining the suitability of existing data.

In summary, for activities with no impact pathways considered to affect birds at sea (or only negligible effects anticipated), project specific surveys will not be required. In addition, activities categorised within marine licensing Band 1 which are small scale activities with a low consenting risk will also not require project specific at sea ornithology surveys.

Band 2 licences are those not covered under Band 1 or Band 3 and encompass a wide range of activities and complexities. These activities are also generally considered to be of low consenting risk with respect to birds at sea and unlikely to require at sea ornithology surveys (with existing data likely to be sufficient for characterisation purposes). However, there is considered to be an increased potential for at sea ornithology surveys in some situations. For example, while most maintenance dredging projects are highly unlikely to require bird surveys (e.g. berth dredging in a marina or navigational dredging of a busy navigation channel), the potential for requiring project specific surveys is likely to increase in certain cases, such as larger scale navigational maintenance dredging in areas subject to limited dredging campaigns and overlaps with protected sites and/or areas with functional linkages.

Band 3 licences are any applications that require an Environmental Impact Assessment (EIA), determined through a screening process, or projects over £1 million and are typically larger scale developments. Activities that are considered to have a low to moderate consenting risk with respect to birds at sea (such as aquaculture, aggregates, cables and pipeline projects) are generally considered to have a low likelihood of project specific surveys being required. However, the likelihood of surveys increases if the ZOI of a project extends into protected sites and/or areas with functional linkages and where existing data for these areas is considered insufficient.

Band 3 activities that are considered to have a high consenting risk with respect to birds at sea and includes offshore renewable energy projects, large coastal developments (with extensive marine works) and nuclear energy developments (with marine works). These activities are generally considered to have a high likelihood of requiring project specific surveys. However, this likelihood is reduced if the ZOI of the proposed project does not extend into protected sites and/or areas with functional linkage and where existing data for these areas is considered sufficient.

Consultation is recommended on ornithology survey requirements with NRW as early in the planning process as possible to prevent delays in the overall project programme.

Survey design

The objectives of baseline surveys are to characterise conditions in an area prior to a development or activity taking place. Post consent surveys are undertaken once consent for a project has been granted and typically form part of the monitoring programme required in fulfilment of marine licence and/or planning conditions. Where applicable, the approach to surveys will need to be as consistent as possible for both baseline and post consent phases. The following key principles should be considered when designing surveys:

- Surveys should be designed based on the principle of proportionality.
- Where appropriate, opportunities to combine ornithology and marine mammal surveys should be considered.
- Surveys will be dependent on a range of project and site-specific considerations. The key aims and data requirements of a survey should be identified based on an initial desk-based review. With respect to baseline characterisation surveys, this review is important to ascertain the impact pathways of concern, the amount of existing survey data available, understand potential impacts and identify focus species for the surveys. Preliminary desk-based reviews for post consent surveys should draw on existing impact assessment documents, monitoring plans and relevant licensing and planning conditions.
- The focus of most baseline and post-consent monitoring surveys is to collect data on the abundance and spatial distribution of species in order to predict and detect potential changes (such as in population levels) as a result of potential effects resulting from a development. Additional or more comprehensive data might also need to be collected for certain types of developments or projects with respect to species/population characteristics, life history traits, behaviours or responses to anthropogenic activity in order to better understand potential impacts.
- The spatial extent of a survey area should include the development footprint as well as an appropriate buffer. This should be based on consideration of the ZOI of potential effects.
- Two years of data is often considered the minimum period suitable for baseline characterisation purposes. It is also generally common practice for surveys of birds at sea to undertake regularly spaced visits, typically at monthly intervals throughout the year to ensure that all the key seasons are captured (i.e. breeding, passage and

wintering periods). However, survey duration and frequency should be defined on a case by case basis considering factors including the risk of potential impacts, existing survey effort and the importance of the area for birds. Multiple years of monitoring could be required for post consent surveys (particularly those overlapping with both construction and operational phases).

- For certain larger scale projects (such as offshore wind farms), statistical techniques such as power analysis may be considered appropriate to help confirm if the spatial and temporal coverage of the surveys are robust for characterisation purposes and for detecting potential change (such as a result of displacement effects).
- Logistical constraints can influence survey design and the methods employed. This includes environmental conditions and access issues.

Survey methods and analysis

In order to derive distribution and abundance estimates for large scale survey areas, such as those associated with commercial scale offshore windfarms, aircraft based digital aerial survey methods are recommended. These techniques can effectively cover large areas in a relatively short time frame. Boat-based transect methods also collect abundance and distribution data and are generally considered the most appropriate technique for collecting data for smaller scale survey areas both inshore and offshore, such as those associated with demonstration scale tidal stream projects. Boat-based transect methods are also considered more effective at deriving densities and identifying to species level than aerial surveys for certain species (e.g. auks) and behavioural observations can also be recorded in these surveys. However, boat-based transect methods are not recommended for species sensitive to disturbance such as Common Scoter and Red-throated Diver. Coastal based Vantage Point (VP) surveys are generally not recommended in most circumstances due to a range of limitations including problems associated deriving accurate density estimates,

In addition, other survey methods are available for investigating in more detail fine scale movements and behaviour. This includes Unmanned Aerial Vehicles (UAVs) which have been applied to a range of distribution mapping and research applications on species behaviour in recent years. However, concerns about disturbance effects and limited operating distances currently limits the application of this technology. Tracking studies (such as boat-based following surveys and tagging based telemetry studies) can be used to understand the connectivity of a development area with functionally important areas for birds (such as breeding colonies, foraging areas). Other techniques include, radar and Light Detection and Ranging (LiDAR) which are capable of collecting accurate, high-resolution data on bird height and flight paths.

In summary, survey design and the choice of techniques used will need to be determined on a case by case basis based on a range of project and site-specific factors. Regular consultation should be undertaken with NRW to ensure that the surveys are robust, fit for purpose and consistent with best practice guidance and procedures.

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1 Introduction

1.1 Aim and scope of the guidance

This guidance document is one of a series of marine and coastal guidance notes developed by Natural Resources Wales (NRW). The initial document was prepared under contract by ABPmer on behalf of NRW.

The guidance aims to assist in designing and undertaking robust ornithology surveys to inform assessments for marine licensing and other consenting regimes with respect to bird species recorded at sea, thereby aiming to help streamline the regulatory review and consultation processes.

It is intended that the advice provided in this document is used directly by NRW staff as well as by developers and stakeholders to help inform both baseline data collection and post consent monitoring requirements. Any developers who may be planning surveys are advised to contact NRW prior to starting and if these are beyond 12 nautical miles offshore to seek additional advice from the Joint Nature Conservation Committee (JNCC) as the statutory adviser for offshore waters. The guidance has been developed not to be overly prescriptive since survey methods and approaches will need to be tailored on a case by case basis to consider the specific location, nature and scale of the proposed development or activity, and any associated requirements for ecological assessment.

The scope of the document primarily focuses on species that forage wholly or mainly in the marine environment (both offshore and coastal) through either diving or feeding on the water surface (including seabirds, sea ducks and divers)[1]. Within this guidance, these birds are collectively referred to as '*marine birds'*. In addition, other species of birds such as migratory coastal waterbirds that are recorded flying through a seaward area have also been considered. Bird survey methods focused on species utilising intertidal, coastal or terrestrial habitats have been excluded from the guidance.

1.2 Guidance structure

This guidance has been split into the following sections:

- **Section 2-Environmental assessment and licensing context**: Details on the role of NRW as an advisor, regulator and consultee as well as information on when an environmental assessment is required.
- **Section 3-Do you need to carry out project specific at sea ornithology surveys?** Guidance on when project specific surveys are required.
- **Section 4-Survey design:** This section has been broadly split into baseline and post consent surveys and details the key stages and main considerations when designing a survey.

[1] In the UK these species consist of seabird species within the families Procellariidae (fulmarine petrels and shearwaters), Hydrobatidae (storm-petrels), Phalacrocoracidae (cormorants/shags), Stercorariidae (skuas), Laridae (gulls /terns) Alcidae (auks); Sulidae (gannets) as well as Gaviidae (divers), grebes (Podicepididae) and seaducks/diving ducks from the family Anatidae.

- **Section 5-Survey methods and analysis:** A summary of existing survey approaches and analytical methods for aerial surveys, boat-based surveys, vantage surveys, remote sensing and telemetry tracking techniques.

2 Environmental assessment and licensing context

2.1 NRW's role as a regulator, advisor and consultee

NRW has two separate roles in this process.

NRW's permitting service determines marine licence applications according to Part 4 of The Marine and Coastal Access Act 2009. It also issues other environmental permits for activities such as water discharges to the marine environment and in relation to flood risk activities under The Environmental Permitting (England and Wales) Regulations 2016.

NRW's advisory service can provide advice to both applicants and to consenting authorities on the potential impact of development proposals on Wales' environment and natural resources. This includes pre-application advice and responding to consultation on applications for development. It is also a Statutory Nature Conservation Body (SNCB) under the Conservation of Habitats and Species Regulations 2017.

2.2 When is an environmental assessment required?

A requirement for some degree of environmental assessment applies to all regulated developments and activities in the marine environment. If you need a permit, licence or consent for your development or activity, you will need to provide sufficient information and evidence to the relevant regulator. The regulator will need this in order to assess your proposed project, its implications for the natural environment and its compliance with legislation before they can determine whether it can be consented.

All marine licence applications will be assessed by NRW's Marine Licensing Team to understand the likely impacts of the proposed activities. NRW needs to carry out relevant assessments of your application and ensure compliance with all relevant legislation (see the Marine Licensing pages on our website for further explanation of this). For example, if the proposed works have implications for features of a Special Protection Area (SPA), then a Habitats Regulations Assessment (HRA) will be required in accordance with the Conservation of Habitats and Species Regulations 2017.

The nature and scale of the information required will be proportionate to the proposed work. If the works fall under the Marine Works (Environmental Impact Assessment) Regulations 2017 (as amended) and a formal Environmental Impact Assessment (EIA) is required, you will be expected to submit an Environmental Statement (ES) with your application.

More information about environmental assessment is available on the NRW website. On the website there is also information about the EIA Regulations for marine works and NRW guidance (GN013) on scoping an Environmental Impact Assessment for marine developments. However, smaller developments and activities, which do not require a full EIA, may still require some form of ecological assessment (including potentially an HRA) and you will need to provide information to support this process. Advice on environmental assessment can also be sought from NRW, either as pre application advice or marine licensing advice.

With specific respect to marine birds and other species recorded at sea, the level of detail required for an EIA, HRA or other assessment of the impacts will be dependent on the nature of the project, the potential for impact and the significance or importance of the receptors that may be sensitive to the development.

Further practical advice for anyone involved with ecological evaluation and assessment for proposed developments in the marine, coastal, freshwater and terrestrial environments is provided in Guidelines for Ecological Impact Assessment in the UK and Ireland (2018) produced by the Chartered Institute of Ecology and Environmental Management (CIEEM). The CIEEM guidelines have been developed to promote good practice in Ecological Impact Assessment and are endorsed by NRW.

3 Do you need to carry out project specific at sea ornithology surveys?

For certain activities or developments, marine birds (and other species recorded at sea), might not be sensitive to environmental pressures that occur as a result of the activities (i.e. there are no impact pathways). However, if your project has the potential to affect marine birds, NRW need to understand what the effects could be, and so appropriate information must be submitted for consideration as part of impact assessments (such as EIAs and HRAs) and the licensing process more widely. In particular, baseline data is required to characterise conditions in an area prior to a development or activity taking place.

This section aims to assist developers in identifying the need to carry out at sea ornithology surveys based on the principle of proportionality i.e. survey and assessment requirements should be proportionate to the risk of significant impacts posed by the project (Sparling *et al*., 2015; ABPmer, 2019; CIEEM, 2018; IEMA, 2016). In this respect, projects considered to be lower risk should have less onerous survey requirements, potentially using existing data or involving lower survey effort (Sparling *et al.,* 2015).

The nature, scale and location of your proposed development and activity will determine the requirements for baseline and post consent ornithology surveys. The requirement for surveys will generally need to be determined on a case by case basis (with the exception of certain activities described in more detail below). However, in order to assist with determining if project specific at sea surveys are likely to be required, a decision tree has been produced (Figure). This is based on consideration of the following steps:

- Step 1: Identifying potential impact pathways for birds at sea (Section 3.1).
- Step 2: Determining the marine licence band of an activity and understanding consenting risk (Section 3.2).
- Step 3: Identifying if the Zone of Influence (ZOI) of the proposed activity overlap with any areas which are protected or important for birds at sea (Section 3.3).
- Step 4: Determining the suitability of existing data (Section 3.4).

Consultation is recommended on ornithology survey requirements with NRW as early in the planning process as possible to prevent delays in the overall project programme. It is important to note that not undertaking project specific ornithology surveys does not negate the requirement for considering ornithology within licencing and impact assessments (EIAs, HRAs etc). If surveys are required, design considerations are discussed in more detail in Section 4.

3.1 Stage 1: Identifying potential impact pathways for birds at sea

The first step in determining if surveys are required for birds at sea is to identify the potential impact pathways that could be of relevance to such birds. Key impact pathways for birds at sea are summarised below:

- disturbance and displacement effects due to noise (both airborne and underwater) and/or visual stimuli as a result of human activity (e.g. during construction or maintenance works)

- displacement as a direct result of anthropogenic structures
- collision with moving structures both above and below the water
- habitat loss and change (including changes in prey resources)
- changes in turbidity as a result of increased suspended sediment concentrations

Project specific surveys will not be required for activities where no impact pathways exist for birds at sea. In practice this initial evaluation should also take into account site specific considerations. For example, the location of the activity will influence if an impact pathway specifically affects birds at sea. Information to assist with identifying impact pathways and the sensitivity of birds to different pressures include, but are not limited to:

- NRW Conservation Advice for European Marine Sites: Information on operations that might cause damage to a feature or features of the site is contained within the conservation advice package for each site (Reg 37 document).
- Joint Nature Conservation Committee (JNCC) Pressures-Activities Database: For inshore and offshore waters UK-wide (within and outside of Marine Protected Areas (MPAs), JNCC have developed a pressures-activities database (PAD) which has compiled the evidence base for the relationships between 112 marine-based human activities and their associated pressures (based on the OSPAR pressure list). The JNCC PAD is a starting point to identify which pressures may be caused by which activities and gives an indication of the general risk the pressures pose to the environment under normal conditions (Robson *et al.* 2018).

Information on the sensitivity of seabirds and other bird species at sea to different anthropogenic pressures can be found in Pérez-Domínguez *et al., (*2016). In addition, guidance on the sensitivity of species is also available with specific respect to offshore windfarms (MacArthur Green Ltd, 2012; Furness *et al*., 2013) and tidal stream/wave energy devices (Furness *et al*., 2012).

The next step for determining the requirement for project specific at sea ornithology surveys for those activities for which impact pathways have been identified is to determine which licensing band the activity falls within, and the consenting risk associated with an activity (Section 3.2).

3.2 Stage 2: Determining the licencing banding of an activity and understanding consenting risk with respect to birds at sea

Marine licence applications in Wales are subject to three different bands which are based on the scale and nature of the proposed works. For activities for which impact pathways exist for birds at sea, the next step in understanding if project specific surveys are likely to be required is to determine which band the activity falls within and the consenting risk associated with an activity type.

3.2.1 Band 1 activities

Activities categorised as Band 1 are small scale activities with a low consenting risk (due to low potential impacts). Project specific at sea ornithology surveys are not required for these activities.

3.2.2 Band 2 activities

Band 2 licences are those not covered under Band 1 or Band 3 and encompass a wide range of activities and complexities. This includes:

- small to medium scale construction, alteration or improvement of works, for example coastal defence works, bridge repairs
- some removal activities using a vehicle or vessel e.g. removals from the seabed, pier demolition
- maintenance dredging activities (unless part of a wider construction scheme), for example navigational maintenance dredging

These activities are also generally considered to be of low consenting risk with respect to birds at sea with a low likelihood of requiring at sea ornithology surveys (with existing data likely to be sufficient for characterisation purposes-see Section 3.4). However, there is considered to be an increased potential for at sea ornithology surveys in some situations. For example, while most maintenance dredging projects are highly unlikely to require bird surveys (e.g. berth dredging in a marina or navigational dredging of a busy navigation channel), the potential for requiring project specific surveys is likely to increase in certain cases, such as larger scale navigational maintenance dredging in areas subject to limited dredging campaigns and which overlap with protected sites and/or areas with functional linkages (Section 3.3).

3.2.3 Band 3 activities

Band 3 licences are any applications that require an EIA (determined through a screening process) or projects over £1 million and are therefore typically larger scale developments. For this guidance, activities that are typically within this band have been split into the following broad categories based on consideration of the consenting risk associated with each activity:

- **Low to moderate consenting risk with respect to birds at sea:** This is either due to impacts that are generally considered to be of low potential magnitude or where impacts do exist there is considered to be a good understanding of the level of potential effects and/or the application of standard industry measures exist to reduce effects. Due to these factors, data requirements for characterisation purposes are considered to be less onerous. On this basis and as summarised in Figure , these activities typically have a low likelihood of project specific surveys being required. However, the likelihood of surveys increases if the ZOI of a project extends into protected sites and/or areas with functional linkages (Section 3.3) and where existing data for these areas is considered insufficient for characterisation purposes (Section 3.4).
- **High consenting risk with respect to birds at sea:** This is either due to impacts which are of a nature and scale which could potentially cause significant impacts to birds at sea and/or there is a degree of uncertainty with one of more of the impact pathways. Projects that are considered to be a higher consenting risk typically require more detailed data requirements for impact assessment purposes (such as EIAs or HRAs). On this basis, high consenting risk activities generally have a high likelihood of project specific surveys being required (as shown in Figure). However, this likelihood is reduced for proposed projects that do not extend into protected sites

and/or areas with functional linkages (Section 3.3) and existing data for these areas is considered sufficient (Section 3.4).

Table 1. Consenting risk for birds at sea for activities typically categorised as Band 3

Low to moderate	High
• Cables • Pipelines • Aquaculture • Capital dredging • Large coastal developments with limited marine works • Aggregates	• Offshore renewable energy projects (including wind, wave, tidal stream and tidal range)[1] • Large coastal developments with extensive marine works • Nuclear energy developments with marine works

3.3 Stage 3: Identifying if the ZOI of the proposed activity overlap with any areas which are protected or important for birds at sea?

The ZOI is the area over which ecological features may be vulnerable to biophysical changes as a result of the proposed project and associated activities. This is likely to extend beyond the project site, for example where there are ecological or hydrological links beyond the site boundaries. In the marine environment, ZOI can be extensive, for example as a result of underwater noise or pollution (CIEEM, 2018).

The potential requirement for at sea ornithology surveys is considered to increase for Band 3 activities, and more rarely for larger scale navigational maintenance dredging (a Band 2 activity) as a result of the following:

- if the ZOI directly overlaps with a designated site for marine birds (SPA, Ramsar, Site of Special Scientific Interest (SSSI))
- if the ZOI overlaps with a recognised important area which has functional relationship/connectivity with the designated site (such as a foraging ground for anSPA or SSSI designated for breeding seabirds)

Further information on SPAs and other protected sites for marine birds in Wales is provided in Appendix A.

3.4 Stage 4: Determining the suitability of existing data

[1] Offshore renewables vary in scale from demonstration projects (consisting of one or two devices installed in a location over short-term duration for pre-commercial testing and demonstration of emerging technologies) to large scale commercial projects. Whilst all offshore renewables projects have a high likelihood of requiring project specific surveys, large scale commercial projects are considered to almost always require project specific surveys. This is due to a large ZOI and/or the requirement for project specific data to input into predictive assessments such as offshore windfarm Collision Risk Modelling (CRM) or displacement studies (Band, 2012; Masden, 2015a; Trinder, 2017; Marine Industry Group for Ornithology, 2017).

Depending on the nature of the activity and the quality of existing survey data, project specific surveys might not be required. This would require existing survey data to be of a sufficient standard to meet the requirements of impact assessments and licensing. As discussed in Section 3.2, activities which are considered to be of higher consenting risk typically require more detailed data for input into impact assessments than lower consenting risk activities and will need to be agreed with the regulator/SNCBs/consultees on a case-by-case basis. The requirements for using existing data rather than project specific data for different activities is summarised below:

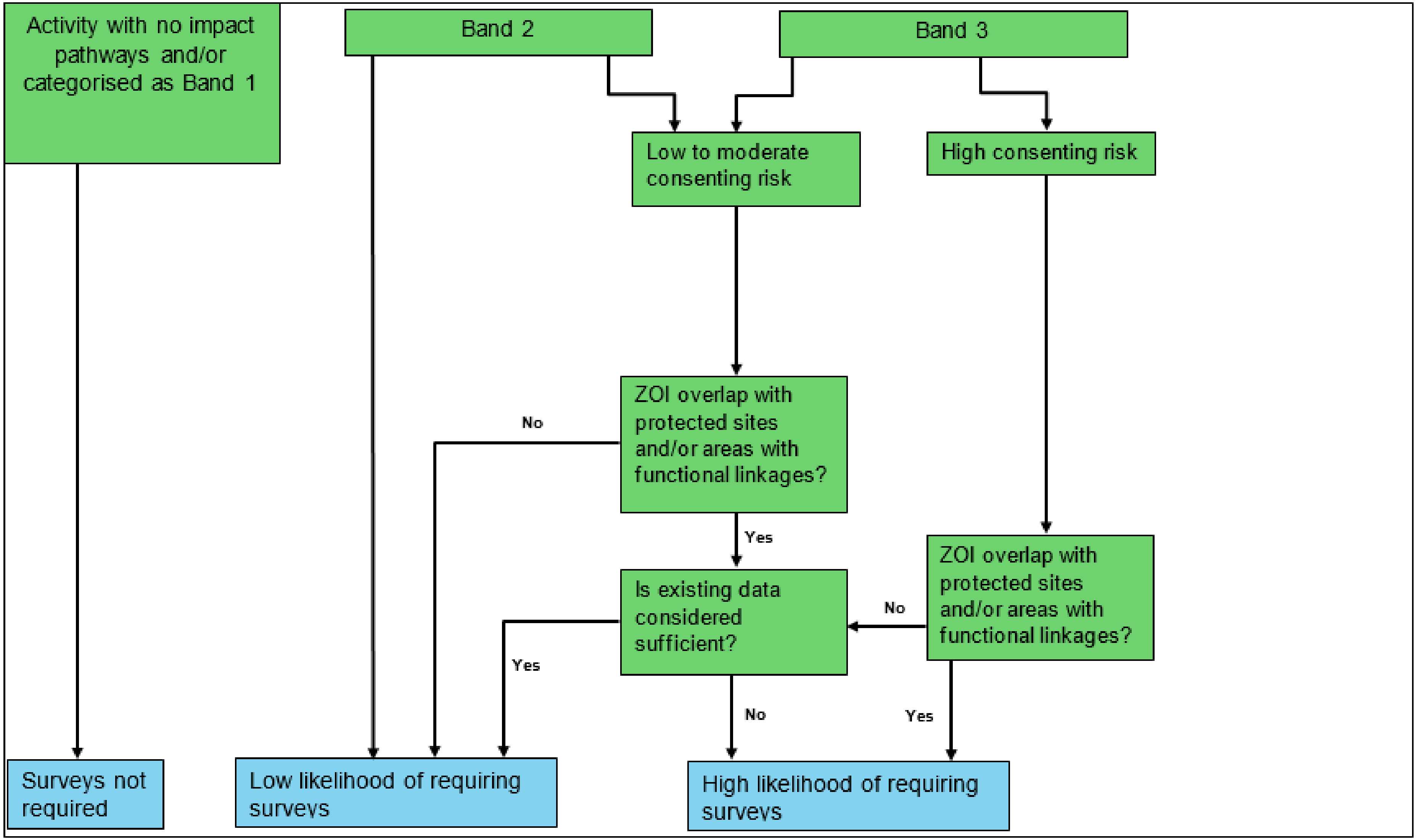
- **Band 3 activities (considered higher consenting risk):** Existing survey data will typically need to provide robust distribution and abundance estimates within the project specific ZOI (based on using appropriate surveying techniques) suitable for use within complex models. The data will also need to be of a contemporary nature. In this respect, while data older than 5-years could provide useful contextual information, more recent data is typically required to provide accurate distribution and density estimates for characterisation purposes.
- **Band 2 activities and Band 3 activities (lower consenting risk):** Survey data collected at a project level is less likely to be required with existing data collected over a broader scale (such as the datasets described below) being potentially suitable for characterisation purposes.

NRW Guidance Note (GN006) highlights marine ecology datasets and information sources (including marine ornithology) owned or recommended by NRW. This includes the NRW Seabirds at Sea Evidence Base which presents data on the abundance and distribution of seabirds in Welsh waters based on data held in the European Seabirds at Sea Partnership (ESAS) database (managed by JNCC) and the Wildfowl and Wetlands (Consulting) Ltd marine aerial surveys database. JNCC have also published aerial survey data from around the UK, collected as part of their SPA identification programme. Other relevant sources of data include seabird hotspot maps based on bird tracking data collected as part of the Future of the Atlantic Marine Environment (FAME) project and STAR (Seabird and Tracking Research) project. Data from these projects have been used to develop predictive species distribution models and high-density usage maps for a variety of species (Wakefield *et al.,* 2017; Cleasby *et al*., 2018). In addition, data on the foraging ranges of seabirds based on tracking data are summarised in Woodward *et al*., (2019)[1]. Mapping exercises have used various available data (including ESAS, aerial survey datasets and SeaMaST (held by Natural England but covering some Welsh areas such as Liverpool Bay)), with the most comprehensive that we are aware of published in Waggit et al. (2019) as part of MERP.

These data sources are summarised in more detail in Appendix A. However, it should be noted that some of these datasets (such as ESAS data) are relatively out of date (data collection continues to be collected but at a low effort, with the bulk of the data contained within the database being collected between 1979 and 2002) and might not be considered appropriate for characterisation purposes (particularly with respect to higher consenting risk activities). In addition, data from surveys undertaken at a more site-specific scale (such as to inform project assessments or as part scientific research) should also be reviewed where applicable.

[1] This study updates a previous review of foraging ranges undertaken by Thaxter *et al.,* (2012).

Figure 1. Decision tree to assist with determining project specific at sea ornithology survey requirements



Infographic explanation

Activity with no impact pathways and/or categorised as Band 1 - Surveys not required

Band 2 - Low likelihood of requiring surveys

Band 2 & 3 - Low to moderate consenting risk

ZOI overlap with protected sites and/or areas with functional linkages? No - Low likelihood of requiring surveys. Yes - Is existing data considered sufficient? No - High likelihood of requiring surveys

Band 3 - High consenting risk - ZOI overlap with protected sites and/or areas with functional linkages? No - Is existing data considered sufficient? No - High likelihood of requiring survey

Band 3 - High consenting risk - ZOI overlap with protected sites and/or areas with functional linkages? Yes - High likelihood of requiring survey

4 Survey design

4.1 Introduction and overarching principles

This chapter discusses in more detail survey design considerations, once it has been determined that project specific surveys are required (Chapter 3).

This chapter has been broadly split into the following sub sections:

- Section 4.1: Baseline surveys (i.e. surveys required to inform the consenting process such as for an EIA and Habitats Regulations Appraisal (HRA).
- Section 4.2: Post consent surveys and monitoring (i.e. for impact monitoring purposes).

Each sub section considers the following key tasks which should to be considered when designing a survey:

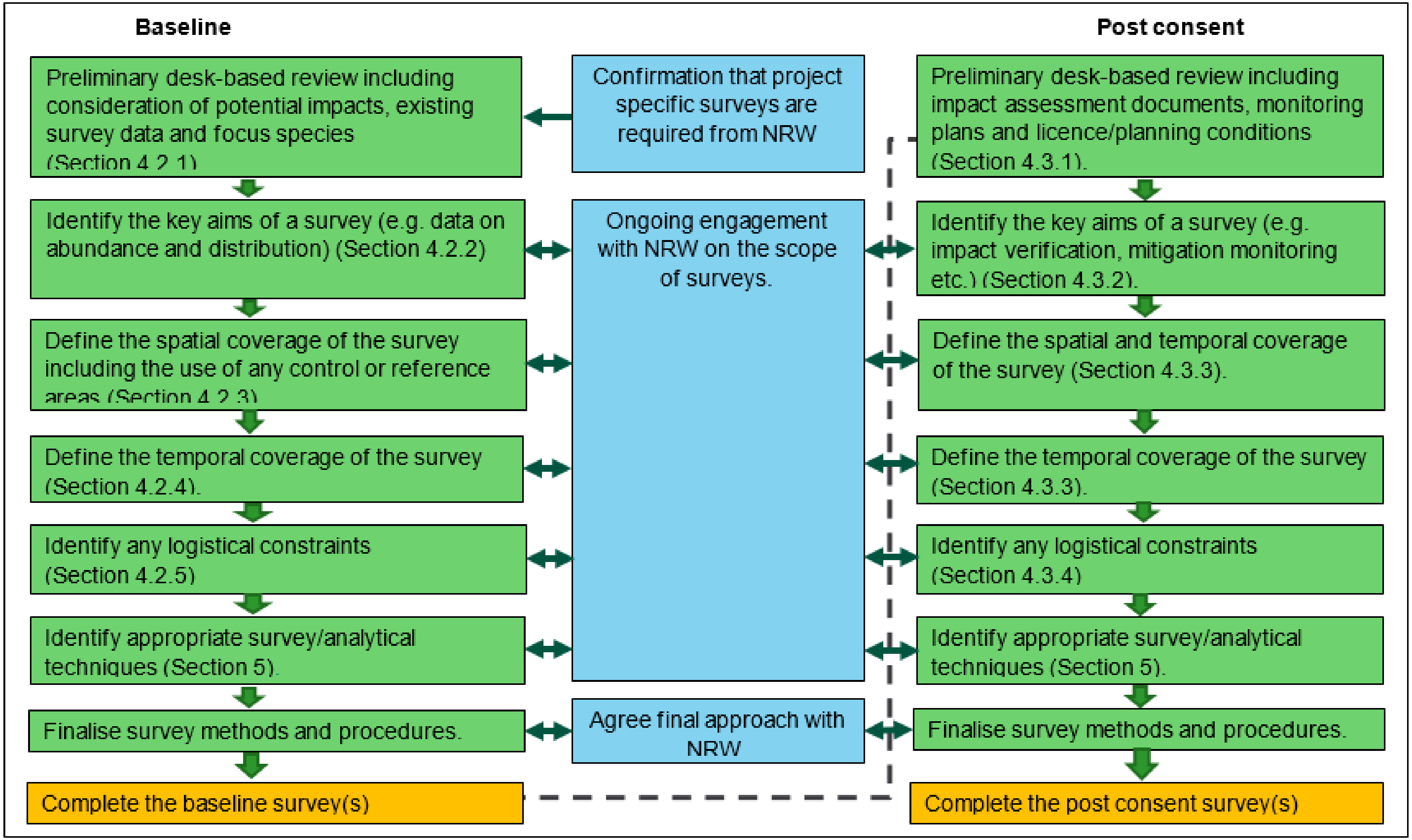
- undertaking a preliminary desk-based review
- identifying the key aims and data requirements of a survey
- defining the spatial extent and coverage of the surveys
- defining the temporal coverage of the surveys
- identifying any logistical constraints

Consideration of these factors will help identify the most appropriate survey techniques to be used for a survey. Different survey and analytical techniques are discussed in greater detail in Section 5. It may be beneficial for applicants to consult NRW on ornithology survey requirements as early in the planning process as possible (as shown in Figure). Agreeing survey requirements at an early stage in a project can help avoid delays to the overall programme (BSI, 2015). The main steps which need to be undertaken when designing both baseline and post consent surveys are summarised in the conceptual diagram shown in Figure .

It is important to note that where required, for both baseline and post consent phases, the approach to surveys will need to be statistically robust and as consistent as possible, recognising that each will need to be tailored to answer the specific questions posed (MMO, 2014; BSI, 2015; Jackson and Whitfield; 2011: Webb and Nehls, 2019). This should be discussed in the early stages of the consenting process. For example, Before After Control Impact (BACI) and Before After Gradient (BAG) designs require surveys during both baseline and post consent phases (Section 4.3.3.1). When designing any survey, it is important that the principle of proportionality is considered, for example projects considered to be lower risk should involve lower survey effort (Sparling et al., 2015; ABPmer, 2019; CIEEM, 2018; IEMA, 2016).).

It is also important to consider the scope for combining ornithology and marine mammal surveys when designing both baseline and post consent surveys. For example, digital aerial surveys methods collect data which can be analysed for both birds and marine mammals (Section 5.2). Information on different marine mammal survey techniques are described in more detail in Sparling *et al*., (2015).

Figure 2. Suggested approach for designing a project specific marine ornithological survey


Baseline
Post consent
Preliminary desk-based review including consideration of potential impacts, existing survey data and focus species (Section 4.2.1)
Confirmation that project specific surveys are required from NRW
Preliminary desk-based review including impact assessment documents, monitoring plans and licence/planning conditions (Section 4.3.1).
Identify the key aims of a survey (e.g. data on abundance and distribution) (Section 4.2.2)
Ongoing engagement with NRW on the scope of surveys.
Identify the key aims of a survey (e.g. impact verification, mitigation monitoring etc.) (Section 4.3.2).
Define the spatial coverage of the survey including the use of any control or reference areas (Section 4.2.3)
Define the spatial and temporal coverage of the survey (Section 4.3.3).
Define the temporal coverage of the survey (Section 4.2.4).
Define the temporal coverage of the survey (Section 4.3.3).
Identify any logistical constraints (Section 4.2.5)
Identify any logistical constraints (Section 4.3.4)
Identify appropriate survey/analytical techniques (Section 5).
Identify appropriate survey/analytical techniques (Section 5).
Finalise survey methods and procedures.
Agree final approach with NRW
Finalise survey methods and procedures.
Complete the baseline survey(s)
Complete the post consent survey(s)

There is a range of existing guidance relevant to surveying birds at sea which are recommended to be used alongside the information provided in this section to assist with survey design. This includes, but is not limited to:

- Scoping an Environmental Impact Assessment for Marine Developments: Guidance for developers and NRW staff (Guidance note: GN13).
- Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2018).
- Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland: Volume 4 Birds (Jackson and Whitfield (2011).
- Environmental Impact Assessment for Offshore Renewable Energy Projects – Guide (BSI, 2015).
- Surveying Seabirds (Webb and Nehls, 2019). In Perrow, M. ed., (2019). Wildlife and Wind Farms-Conflicts and Solutions: Offshore: Monitoring and Mitigation.
- Natural England Advice: Offshore Ornithology Baseline Surveys (Natural England, 2019).
- Review of Post-consent Offshore Wind Farm Monitoring Data Associated with Licence Conditions (MMO, 2014).
- Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Wind Farm Developers (King *et al*., 2009).
- Joint Statutory Nature Conservation Body (SNCB) Interim Displacement Advice Note (Marine Industry Group for Ornithology, 2017).

As mentioned in Section 3, the requirement for surveys as well as the type and amount of survey and monitoring that need to be undertaken will depend on the nature, scale and location of the proposed development or activity. When NRW Advisory is consulted in relation to applications for proposed developments and activities, the sort of information and level of detail that we expect to be provided in terms of ornithology surveys at sea is outlined below.

Whether we are consulted as part of a pre-application enquiry or during formal consultation by the regulator, we need to be able to understand the rationale behind your survey and monitoring and why you have proposed your stated approach and scope of work. We also need to see specific detail relating to the proposed methods and approaches and sufficient information about project design. Having this level of detail helps us assess the suitability of the proposed survey and monitoring work.

4.2 Baseline design considerations

The purpose of a baseline survey is to characterise conditions in an area prior to a development or activity taking place and can also be used for pre-construction / post consent monitoring if adequate to do so. Assessing and monitoring the environmental impacts of any project and associated activities requires an understanding of the baseline conditions prior to and at the time of the project proceeding or specific activities taking place (CIEEM, 2018). It is recommended that the principles of a dynamic baseline which take into account trends are also considered. This is especially important for species which are showing substantial ongoing temporal population changes and for longer-term developments (Milieu Ltd, 2017).

Information on baseline ecological conditions can be established through using existing data sources and through undertaking project specific surveys. It should be noted that for some projects, depending on the quality of existing data and the scale of potential impacts, it might not be considered necessary to undertake project specific surveys (Section 3) although we would encourage dialogue with the regulator and consultees to establish this.

If you are submitting proposals for baseline characterisation surveys, the sort of information that NRW Advisory would expect to receive is set out in Table 2. This is not a definitive list but provides a series of prompt questions to help you understand the information and level of detail that we are looking for.

Table 2. Information checklist for baseline characterisation surveys

Information needed	Details
Joined-up approach to baseline and post consent surveys (Section 4.1)	• Have you considered the potential need for a joined-up approach between baseline and post consent surveys (if required) in terms of consistency and compatibility of the design, methods and analysis used?
The Zone of Influence for your development (Section 3.3 and Section 4.2.1)	• Have you defined the ZOI? • Have you considered all aspects of the proposed works and the implications of these for the likely area that will be affected? • Have you considered any likely far-field effects that may arise from your development during both construction and operation? For example, the influence of your proposal on coastal processes or terrestrial habitats and the implications of this for potential impacts on marine birds? • Are there current areas of uncertainty about potential effects and the ZOI that may subsequently require further work?
Use of existing data (Section 4.2.1)	• Have you looked at and used existing data to inform the design of your survey? • If you have used existing data, what data have you used and how have you used it?

Information needed	Details
Protected sites and species (Section 4.2.1)	• Does the ZOI directly overlap with SPAs or SSSIs that support relevant qualifying bird species **or** provide supporting functional habitat for species of these designated sites? • Are species listed as Birds of Conservation Concern (BoCC)/Birds of Conservation Concern Wales (BoCC W) known to occur in the area?
Focus species (Section 4.2.1)	• What are key species which the surveys need to target?
Survey aims and data requirements (Section 4.2.2)	• What are the key aims of your survey and how will this data be used to inform the impact assessment process and/or post-consent monitoring requirements?
Spatial survey coverage (Section 4.2.3)	• Has the spatial coverage of the survey area been based on consideration of the ZOI? • Within the survey area, what is the extent of spatial coverage? • Are survey control/reference areas required to understand impacts (such as a Before–After Control Impact (BACI) design or Before-After-Gradient (BAG) design?
Temporal survey coverage (Section 4.2.4)	• What is the proposed duration of the survey programme? • What intervals are being proposed between surveys (e.g. monthly)? • Has the potential requirement for additional survey effort during important periods for focus species been considered?
Statistical power to detect change (Section 4.2.3 and Section 4.2.4)	• Is the spatial and temporal coverage of the surveys of a suitable scale to robustly detect change?
Logistical constraints (Section 4.2.5)	• Have logistical constraints been considered in the survey design such as potential weather downtime risks and access issues?
Survey methods and analysis (Section 5)	• Based on the considerations above, have you clearly explained the survey method(s) you intend to use? • Have you explained why you have chosen the methods?

Information needed	Details
	• Have you used NRW's or the appropriate SNCB guidance for the chosen survey method(s)? • Will you be complying with recommended guidelines and standards where applicable? • Have you provided details of your quality control procedures? • Have you identified how you intend to analyse the survey data? • Are the chosen survey methods compatible with the intended analysis so they provide, for example, statistical robustness?
Combining ornithology and marine mammal surveys (Section 4.1).	• Is there any potential for combining ornithology and marine mammal surveys? If so, are there any consequential limitations with respect to the quality of data that will be collected.

4.2.1 Preliminary desk-based study

An initial desk-based study should be undertaken to help identify survey aims (Section 4.2.2) and assist with survey design, including defining the spatial and temporal extent of survey coverage (Sections 4.2.3 and Section 4.2.4 respectively). This should include consideration of the following:

- **The key potential impacts:** As part of the survey design process, it is important to understand the likely impacts associated with the proposed development or activity as well as the potential significance of these impacts and potential spatial and temporal extent of effects on protected sites such as SSSIs and SPAs as well as the populations. For example, the ZOI is an important consideration with respect to defining the spatial coverage of the surveys (Section 4.2.3).
- **Existing survey data effort and intensity**: The amount of existing survey data available for a survey area could influence the key aims and scope of project specific surveys. For example, the scope of project specific ornithology surveys could be reduced if comprehensive and contemporary survey data is already available which is considered robust in terms of surveying techniques and analysis as well as sufficient for the assessment process. However, the applicant should seek advice from NRW about the suitability of the existing information before adopting this approach. This would need to be agreed with NRW.
- **The identification of focus species:** As part of the desk-based review the key species which are known to occur within the area of interest should be identified. This is important to understand so that the surveys are designed in an appropriate manner to adequately target the main species of interest and capture the data required.

This information will also help ensure that the most suitable survey techniques are employed. For example, Red-throated Divers *Gavia stellate* and Common Scoter *Malanitta nigra* are considered sensitive to vessel related disturbance and so in areas of importance for these species, methods avoiding boat-based techniques will be required (such as using aerial techniques) (Section 5.2).

4.2.2 Identifying the key aims and data requirements of a baseline characterisation survey

As discussed above, the purpose of a baseline survey is to characterise conditions in an area prior to a development or activity taking place. The data from the surveys will be used to inform impact assessments (such as EIAs and HRAs) and the consenting process more widely. With specific respect to ornithology surveys at sea, the key aim of most baseline surveys is the following:

- To collect data on the abundance and spatial distribution of species to understand better the usage of the survey area by birds. Accurate information on these parameters is important in order to detect potential changes (such as in population levels) as a result of potential effects resulting from a development. Distinction needs to be made between species likely to be utilising an area for foraging and species passing through (such as on migration). This information is typically used to provide density estimates, population estimates and for distribution mapping purposes.
- Where a proposed development is near or functionally linked to a designated site (such as a SPA), it will be important to understand the usage of the area of interest by the population and functional relationship/connectivity with the designated site (such as a foraging ground for an SPA or SSSI designated for breeding seabirds).

This type of data is typically required for most development projects that require project specific surveys. Additional or more comprehensive data might also need to be collected for certain types of developments or projects in order to better understand potential impacts with respect to species/population characteristics, life history traits, behaviours or anthropogenic activity. For example, detailed data on birds in flight is required to understand potential aerial collision impacts. In particular, data on the number of birds flying through a site and their flight height is required to input into Collision Risk Modelling (CRM) and data on the densities of birds at sea is used to inform displacement assessments for offshore windfarms (Band, 2012; Masden, 2015a; Trinder, 2017; Marine Industry Group for Ornithology, 2017). With respect to tidal range and tidal stream projects, surveys might need to be tailored to ensure that the surveys focus in greater detail on diving behaviour as well as population density of diving birds within the development area to inform collision risk modelling.

While surveys might be focused to target specific species, all relevant species should be recorded as part of any commissioned surveys.

4.2.3 Defining the spatial extent and coverage of the surveys

The appropriate spatial scale for a survey will be dependent on a range of site and project specific considerations. The survey area should include the footprint of the proposed development. The survey area should also include a buffer to provide information on the birds using the area surrounding a development. The size of a buffer typically ranges from several kilometres for smaller scale developments to up to 10 kilometres or more for large infrastructure projects but this will depend on the species affected, e.g. Red-throated diver have recently been seen to be displaced at a greater distance than previously thought (Natural England, 2019; MMO, 2014, Jackson and Whitfield, 2011; Webb and Nehls, 2019). However, this buffer size should consider the wider ZOI to ensure it sufficiently captures all potential effects. Buffers are also important given the high degree of spatial heterogeneity which can occur as a result of the mobile nature of marine birds and the prey resources they depend on. Buffers can therefore provide useful wider contextual data. Buffer extent will also be affected by the approach adopted to reference and control areas as in some cases the buffer may serve a dual role (see Section 4.3.3.1)

Complete coverage of a survey area is unlikely to be cost effective or practical for larger scale developments, therefore, surveys need to collect a representative sample of data on bird density across the survey area. Independent 'samples' are typically considered to be individual transects or survey grids. For example, a minimum target coverage of 10 % of the survey area has been used for some offshore windfarm projects (Webb and Nehls, 2019). It should be noted that further work is currently being undertaken which is investigating in more detail sufficiency of coverage. Survey coverage over too small an area or with a limited number of independent samples can lead to inaccurate density estimates (Natural England, 2019). For example, for Distance Analysis (Section 5.3.1), a minimum of 10 - 20 survey transects is generally required to produce estimates of density (Jackson and Whitfield; 2011).

Furthermore, it is important that the survey area extent (and coverage) is of a suitable scale to robustly characterise an area and detect potential change (such as a result of displacement effects). For certain larger scale projects (such as offshore windfarms), statistical techniques such as power analysis may, therefore, be required. Power analysis is an analytical technique used to determine statistical power (the probability of detecting a specified change in numbers) [1] (Maclean *et al*., 2006; Maclean *et al.,* 2013; MMO, 2014). This will, therefore, help with informing the adequacy of the spatial scale. The power to detect change from survey data alone is also related to the frequency of surveys and their temporal extent (Section 4.2.4). However, the application of these techniques will need to be determined on a case by case basis.

4.2.4 Defining the temporal coverage of the surveys

Two years of data is often considered the minimum period suitable for baseline characterisation purposes (Marine Industry Group for Ornithology, 2017; Jackson and Whitefield, 2011; MMO, 2014; Natural England, 2019). It is also generally common practice to undertake regularly spaced surveys of birds at sea, typically at monthly intervals through the year to ensure that all the key seasons are captured (i.e. breeding, passage and wintering periods). However, survey duration and frequency should be

[1] Statistical power (also just known as 'power') is the probability of detecting a specified change in
numbers (Maclean *et al.,* 2006). The statistical power of detecting changes is sensitive to variations in abundance, but also improves with increased availability of data or with additional information that may account for or explain some of the variation in numbers (Maclean *et al.,* 2013).

defined on a case by case basis based on factors such as the scale of potential impacts, existing survey effort and the importance of the area for birds.

For some larger scale projects, it may be considered suitable to undertake statistical analysis (such as power analysis) to ensure that the survey period and frequency of surveys is sufficient for characterisation purposes and to robustly detect change (see Section 4.2.3). In addition, it is worth noting that additional survey effort might be required during important periods for certain focus species to ensure that these periods are adequately characterised (e.g. June is generally considered the busiest period for tern activity).

It is also important to consider the time of day surveys are undertaken and tidal conditions as part of survey design. Surveys are typically undertaken during daylight hours. However, if surveys are focused on species which show a high degree of nocturnal activity (such as shearwaters or storm petrels near breeding colonies), further consideration of the timing of the survey will be needed. With respect to tidal conditions, the extent that tidal state needs to be taken into consideration in the survey design will depend on strength of the tidal influence at the site. For example, proposed developments in areas with very strong tidal currents (such as tidal stream sites) will need to be designed to give coverage of all phases of a tidal cycle.

4.2.5 Logistical constraints on survey design

Environmental conditions associated with a site could influence survey design and the methods employed. Any design needs to take into consideration programme risks due to potential weather downtime. Areas with very strong hydrodynamic conditions (such as tidal rapids between a headland and a mainland) might be considered too dangerous to survey during certain phases of the tide.

Access to some areas might also be difficult as a result of imposed restrictions on land, water and in the air. For example, flight restrictions imposed by the Civil Aviation Authority (CAA) or Military of Defence (MOD) exclusion areas. These potential constraints should be factored into the design process. In addition, if baseline and post consent surveys require the same approach, it will be important to consider any access issues that might occur as a result of construction activity or built infrastructure once a project is operational when choosing the most appropriate design and survey techniques (Section 5).

4.3 Post consent surveys

Post consent surveys are undertaken once consent has been granted by the relevant licensing authority(ies). These surveys typically form part of the monitoring programme which is required in fulfilment of marine licence conditions and/or planning conditions.

If you are submitting proposals for post consent monitoring, the type of information that NRW Advisory would expect to receive is set out in Table 3. This is not a definitive list but provides a series of prompt questions to help you understand the sort of information and level of detail that we are looking for.

Table 3. Information checklist for post consent surveys

Information needed	Details
Joined-up approach to baseline and post consent surveys (Section 4.1)	• Where relevant, is the approach consistent and compatible with baseline surveys in terms of the design and methods used?
The purpose of the post consent ornithology monitoring programme (Section 4.3.1)	• Is the rationale for the monitoring activity clearly defined? • Are stated objectives or hypotheses clearly stated and where applicable are they cross referenced to consent conditions and/or the level of predicted impact for that receptor within corresponding assessment documents (such as the ES)?
Adaptive management (Section 4.3.1)	• Do the surveys form part of an adaptive management approach? • Are feedback mechanisms in place which will use data collected as part of post consent surveys to modify any existing mitigation or trigger additional mitigation? Are these detection thresholds clearly defined and are the mitigation measures specified?
Spatial and temporal coverage (Section 4.3.3)	• Are the temporal and spatial scale of the surveys consistent with surveys during the baseline phase? If not, what is the rationale for any discrepancies?
Statistical power (Section 4.2.3)	• Will data be collected over the appropriate spatial and temporal scales in order to successfully detect change?
Logistical constraints (Section 4.3.4)	• Have logistical constraints been considered such as the navigational access issues relating from construction activity or built infrastructure once a project is operational?
Survey methods and analysis (Section 5).	• Have you clearly explained the survey method(s) you intend to use? • Are the methods proposed consistent with those undertaken for baseline surveys? Are additional methods proposed? If so, what is the rationale for these additional surveys? • Have you identified how you intend to analyse the survey data? Will the chosen analytical approaches robustly show change between baseline and post consent periods?

4.3.1 Preliminary desk-based review for post consent monitoring

A desk-based review should be initially undertaken to help identify the purpose and objectives of post consent monitoring. This should include consideration of the following:

- Impact Assessment Documents: A review of relevant information included within assessment documents such as the ES and HRA. This includes marine ornithological technical chapters, baseline survey appendices and chapters outlining cumulative/in-combination effects and mitigation.
- Monitoring Plans: Ornithology survey requirements outlined within documents which set out provisions for the management, mitigation and monitoring of environmental effects for a proposed development. Relevant documents could include Construction Environmental Monitoring Plans (CEMPs), Operational Environmental Monitoring Plans (OEMPs), Adaptive Environmental Monitoring Plan (AEMPs) and Ecological Monitoring Strategies (CIEEM, 2017).
- Licence and Planning Conditions: Conditions which are stipulated in marine licence or planning conditions that state the requirement for marine ornithological surveys.
- Survey Results: The latest results from any ongoing surveys or monitoring.

4.3.2 Identifying the key aims and data requirements of a post consent survey

Post consent ornithology surveys are typically undertaken for several key purposes:

- Impact prediction verification: To detect potential changes in bird populations as a result of environmental effects. This is important to validate predictions on potential impacts stated within respective environmental assessments.
- Mitigation monitoring: Ensure compliance and provide evidence of the effectiveness of measures which have been implemented to mitigate potentially significant environmental effects.

While not specifically a requirement of consent conditions, post consent surveys can also provide important information which can add to the evidence base on the understanding of impacts and to validate predictions. This can help ensure that future surveys are proportionate to the scale of impacts and targeted most effectively. It may sometimes be useful to consider impacts as spatially disjunct from a project, for example, by monitoring comparative survival rates at functionally linked colonies rather than only within a project footprint. This understanding can also influence future licensing conditions.

Post consent surveys might be required during the construction phase of a development (e.g. to monitor potential construction disturbance) and/or during the operational phase (e.g. to monitor potential displacement or collision risk with turbines).

Post consent surveys should be hypothesis focused and driven by specific questions and objectives targeted at significant environmental effects (BSI, 2015). If required, the monitoring could also provide a feedback mechanism for adaptive management.

Adaptive management is a tool that can allow developments to potentially be consented when the environmental effects are not well understood. In this context, survey data can be used to inform decisions on the suitability of agreed mitigation or compensation and the potential requirement to trigger additional mitigation or compensation measures (CIEEM, 2018). For these types of monitoring programmes, it is important that detection thresholds[1] and response measures are identified.

4.3.3 Defining the spatial and temporal coverage of the surveys

The spatial extent of post consent survey areas is typically the same as for baseline surveys although if the aim is to verify impacts then monitoring at a different spatial scale and/or location may be useful in some cases. It is always advisable to contact NRW to discuss such plans. In addition, the frequency of post consent monitoring could be consistent with baseline surveys, however there is often a pre-construction baseline survey which can be different from characterisation surveys. This consistency in approach is to ensure direct comparability and that change can be effectively detected between the two monitoring periods (Webb and Nehls, 2019). However, for other post consent monitoring programmes, (particularly those that span both the construction and operational phases), multiple years of monitoring can be required. Relevant monitoring plans and licensing conditions should be consulted (Section 4.3.2) to identify any modifications required to the spatial coverage and temporal extent (such as duration and survey frequency).

4.3.3.1 Using control areas

In order to understand the effects of certain impacts (such as displacement or disturbance), it is important to consider the requirement for reference or controls areas. This allows for data to be collected away from the development area for comparative purposes. Control areas are only typically required for projects in which post-consent surveys are required. However, for such monitoring projects, control areas will need to be defined and surveyed during the baseline survey phase (Section 4.2).

BACI design has been applied widely to ecological survey design. This design was advocated in the Collaborative Offshore Wind Research into the Environment (COWRIE) guidance for offshore wind farm bird surveys (Camphuysen *et al.* 2004) and has subsequently been used extensively in survey design (MMO, 2014). The basic principle underlying this survey design is that the study site and multiple control sites are surveyed at repeated points in time before and after the development is constructed (to provide adequate spatial and temporal variation to reach reliable conclusions).

Control areas should have similar baseline conditions to, but be independent from, a development site, both in terms of environmental conditions (e.g. oceanography, hydrography) and the ornithology populations which characterise them. For example, if both the development site and control sites fall within the foraging range of seabirds from a single colony then, although they may be comparable to one another, they will not be independent because birds feeding on the development site can potentially move to the control site, and *vice versa*. Due to the wide-ranging nature of seabirds, and because seabirds are often concentrated at a small number of breeding colonies, finding multiple control sites which are both comparable to and independent from the development site can, therefore, be challenging. It has also been identified that where the BACI approach has been adopted for some offshore windfarm surveys, control sites have been chosen

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[1] A detection threshold is defined as “a target level or state based on the avoidance of unacceptable outcomes, or an ecologically defined shift in system status” (Polasky, 2011).

immediately adjacent to the development which disregards the assumed independence of the study and control sites (Webb and Nehls, 2019).

An alternative approach to survey design has evolved known as the BAG method. In many cases, this is now considered a more appropriate approach to monitoring the effects of larger scale developments such as renewable energy projects (Harding et al., 2010; Jackson and Whitfield; 2011; Webb and Nehls, 2019). A BAG design assumes that impacts decline with increasing distance from the source of the impact (i.e. the development) and involves all areas within a given radius of the development being monitored before and after the development. BAG designs can provide a scientifically powerful approach for establishing the magnitude and spatial extent of anthrophonic effects (such as habitat loss and displacement), providing data is collected along a long enough gradient. It is recommended that professional statistical advice is sought with respect to the length of gradient (distance from development) that should be surveyed in order to robustly detect changes.

4.3.4 Logistical constraints on survey design

Construction activity or built infrastructure once a project is operational can result in navigational access restrictions (such as around windfarm turbines). This can reduce survey coverage and limit the comparability of baseline and post consent survey data. For surveys that require baseline and post consent surveys to be undertaken in a consistent manner it will be important to consider a design and survey techniques that limit this risk. Alternatively, appropriate analytical techniques should be applied which take this into account. For example, aircraft conducting digital aerial surveys fly at an altitude which means that they can pass directly over constructed windfarms and collect survey data within them which is considered more difficult using vessel-based approaches. In this situation aerial methods are likely to be the preferred method for both baseline and post consent surveys (Natural England, 2019).

5 Survey methods and analysis

5.1 Introduction

This section provides an overview of the following key survey techniques:

- Aerial surveys (Section 5.2): The collection of high definition digital imagery using fixed-winged aircraft and Unmanned Aerial Vehicles (UAVs).
- Vessel based surveys (Section 5.3): This includes both standardised techniques for boat based transect surveys and also tracking surveys (involving following individual birds in flight such as tern species).
- Shore based vantage point surveys (Section 5.4): The use of vantage techniques from coastal locations.
- Active remote sensing techniques (Section 5.5): This includes the use of radar and Light Detection and Ranging (LiDAR) equipment.
- Telemetry tracking systems (Section 5.6): The attachment of telemetry devices to marine birds, including radio tags, satellite transmitters, environmental sensors and Global Positioning System (GPS).

The applicability, key procedures, main analytical techniques and limitations of each technique is discussed in greater detail in each section.

Some of the survey techniques highlighted focus on collecting standardised measures of distribution and abundance. Other methods are more specialised and better suited to collecting data to address more specific questions. The methods that are appropriate will depend on the factors highlighted in Sections 5.2 to 5.6. In summary, in order to derive distribution and abundance estimates for large scale survey areas, such as those associated with commercial scale offshore windfarms, aircraft based digital aerial survey methods are recommended. These techniques can effectively cover large areas in a relatively short time frame. Boat-based transect methods also collect abundance and distribution data and are generally considered the most appropriate technique for collecting data for smaller scale survey areas both inshore and offshore, such as those associated with demonstration scale tidal stream projects. Boat-based transect methods are considered more effective at deriving densities and identifying to species level than aerial surveys for certain species (e.g. auks) and behavioural observations can also be recorded in these surveys. However, boat-based transect methods are not recommended for species sensitive to disturbance such as Common Scoter and Red-throated Diver. Coastal based vantage point surveys are generally not recommended in most circumstances due to a range of limitations including problems associated deriving accurate density estimates.

In addition, other survey methods are available for investigating in more detail fine scale movements and behaviour. This includes UAVs which have been applied to a range of distribution mapping and research applications on species behaviour in recent years. However, concerns about disturbance effects and limited operating distances currently limits the application of this technology. Tracking studies (such as boat-based following surveys and tagging based telemetry studies) can be used to understand the connectivity of a development area with functionally important areas for birds (such as breeding colonies, foraging areas etc). Other techniques include, radar and LiDAR are capable of collecting accurate, high-resolution data on bird height and flight paths.

5.2 Aerial surveys

5.2.1 Fixed-wing aircraft

5.2.1.1 Applicability

Aerial survey methods have been an established survey approach to collect data on the abundance and distribution of birds for many years, particularly with respect to offshore windfarm developments. One of the main advantages of this technique is the large area of sea that can be covered in a relatively short space of time. The speed and efficiency of aerial surveys also means that it is possible to more effectively utilise short weather windows that boat-based surveys may find difficult to exploit (particularly if the site is located offshore, far from ports or harbours).

Aerial data was traditionally collected based on direct observation (visual) methods from aircraft flying at relatively low altitudes. However, in more recent years there has been a shift towards using digital imagery (stills or video) to record information as technology has advanced. Digital techniques have been shown to provide higher numbers of bird sightings and identified species, and higher spatial accuracy than visual aerial surveys. In addition, digital methods eliminate bird disturbance due to aircraft flying at higher altitudes, reduce observer bias and allow for the provision of raw data for quality assurance purposes (Žydelis *et al*., 2019; Buckland *et al.,* (2012); Clough *et al.,* 2012; Skov *et al.,* 2016; MMO, 2014; Natural England, 2019). Furthermore, higher numbers of direct bird sightings at a higher spatial resolution during digital surveys ensure better statistical analyses (including distribution modelling) of more species for the same survey effort (Žydelis *et al.,* 2019). Digital methods also result in the recording of sightings across the whole width of the surveyed area meaning that analysis to account for reduced detectability with distance is not required (Sparling *et al.,* 2015). On this basis, this section has focused on digital methods. However, visual aerial survey methods using a line transect method are discussed further in Camphuysen *et al.,* (2004) if reference to this technique is needed.

5.2.1.2 Key survey considerations and procedures

There are two approaches to digital aerial survey, using either digital video camera or digital stills camera technology. Rapid advances in technology means that technical specifications are regularly changing. Previous protocols such as those developed by Thaxter and Burton (2009) have become dated. This section, therefore, describes aerial methods used as part of recent offshore windfarm baselines and a review by Webb and Nehls (2019).

The main factor which influences image quality in digital aerial surveys is the image resolution on the ground. This is measured as the ground sample distance (GSD), which is the dimensions of the image on the ground for each pixel. The focal length of the camera, distance to the object or ground and the physical size of the camera sensor pixels all determine GSD. Most digital aerial surveys are now operated at an image resolution of 2-3 centimetres GSD or less. This is generally considered sufficient to identify most birds to species level.

Digital aerial surveys are usually undertaken using either a transect-based or quadrat (also known as plot) approach for sampling bird densities at sea, with a transect-based sampling method most common place. Both sampling approaches require that individual samples (transects or plots) are equally spaced. The transect strip width or dimensions of the plot are determined by the size of the image (which is set by the number of pixels in the sensor and the image resolution). Transect based sampling is well suited to large survey areas but can cause lower precision in abundance estimates at small sites when there is a small number of transects or samples (fewer than 13) (Buckland *et al*., 2001). Plot-based sampling works well for very abundant species, but less well when there is a low encounter rate (Buckland *et al.*, 2001).

Suitably qualified and experienced image analysts as well as image analysis software are used to determine species identification, abundance, distribution and other relevant information.

The flight height of birds derived from digital imagery is estimated using trigonometry (based on the assumption that the size of the bird is directly proportional to the distance from the camera lens). Species-specific bird measurements, image GSD and the height of the aircraft at the time that the image is taken is used within flight height calculations using reference sizes of each species to estimate flight height.

With video footage, the flight height of each bird is estimated by comparing the speed at which the bird passes the plane to the speed of the sea surface. This is calculated for each successive pair of video frames that contain an individual bird and the mean height across each pair is used as the estimate. Confidence intervals are calculated by bootstrapping the different pairs of frames and calculating a new mean for each bootstrapped sample (Johnston and Cook, 2016; Thaxter *et al.,* 2015). The limitations of these techniques are discussed below in Section 5.2.1.4.

Birds should be identified to species level where possible and a confidence assessment assigned to the identification. There should be a quality-assurance (QA) process. This typically consists of a double-blind review or identification of either 10% or 20% of the material and requiring at least 90% agreement between the first and second reviews.

Precision in abundance estimates is affected by the amount of survey coverage. For example, a minimum target coverage of 10 % of the offshore study site has been required in the UK (Webb and Nehls, 2019).

More detailed information on digital video and digital still videos techniques are provided below.

Digital video

All digital video surveys are currently based on the HiDef method' (first developed by HiDef Aerial Surveying Ltd in the UK).

The surveys are flown in twin-engine aircraft types, usually flown at a height between 270 and 550 metres depending on the requirements of the video equipment (a minimum altitude of 270 metres ensures that there is no risk of flushing those species known to be easily disturbed by aircraft noise). Surveys should be flown in conditions of moderate to high cloud with no precipitation and clear visibility.

Typically, the survey aircraft is equipped with four HiDef Gen II cameras with sensors set to a resolution of 2 centimetres GSD. Each camera samples a strip of 125 metres width, separated from the next camera by approximately 25 metres (providing a combined sampled width of 500 metres within a 575 metres overall strip). This comb pattern with gaps between the cameras is employed to ensure that no individual birds are double counted between cameras and to target a wider area for detection of birds than the limits of the camera strip width, thus increasing the encounter rate for rarer species that occur in dense flocks.

Digital stills

Surveys are conducted using high definition digital still imagery. Flight planning software is often used to programme the survey flight lines and define the required flying altitude and speed according to the camera, lens and required image resolution. The camera is pointed directly downwards from the camera hatch of the aircraft with the camera system using forward-motion compensation to reduce image blur. Resolution is typically set to 2 or 3 centimetres GSD.

5.2.1.3 Analytical techniques

Estimates of abundance and density are usually required as an output of aerial surveys. Design-based abundance estimates can be calculated for birds in flight and in the sea by summing the raw counts from geo-referenced imagery and dividing this number by the total number of transects of the survey area. Non-parametric bootstrap methods can then be used to provide confidence limits. Measures of precision can then be calculated to obtain a 'coefficient of variation' (CV) based on the relationship of the standard error to the mean. This can help determine the number of image samples to detect a change in the population of a particular species (Clough *et al.,* 2012).

For pursuit diving bird species (such as auks and divers), which spend a proportion of time underwater, it is also important to correct for 'availability bias' (which occurs as a result of these 'snapshot surveys' not detecting all animals present). For these species, a correction factor should be presented, and both corrected and un-corrected data should be provided in assessments (Natural England, 2019).

Model-based statistical approaches such as General Additive Models (GAMs) can be used to produce density surface maps over the survey area. These maps display areas of density, based on model predictions and can include environmental parameters such as bathymetry and geological substrate in the model (Mackenzie *et al.,* 2013; Clough *et al.,* 2012; Skov *et al*., 2016).

5.2.1.4 Limitations

As discussed above, comparison of the size of a flying bird in the image with known or reference sizes of each species has been used to estimate the flight height of a bird. This can provide empirical measurements for use in collision risk modelling as part of offshore windfarm assessment. However, inaccuracy can occur if flying birds appear shortened, such as if looking downward when searching for food, or their body is angled upward or downward. Imprecision can also occur as a result of natural variation when compared to the reference size of each species. Furthermore, measurement error is greatest at distances furthest away from the aircraft (in the zone where birds are recorded at or below collision risk height, where greatest precision is needed) (Webb and Nehls, 2019). Because of this inaccuracy, both HiDef and APEM's new techniques for measuring flight heights are currently unproven. There are other potential methods of detecting flight height eg RADAR and LiDAR.

In addition, for certain species, boat based transect methods are considered more effective at deriving accurate densities and identifying to species level. Behavioural characteristics (such as detailed feeding observations) are also more effectively captured as a result of direct visual observation methods from boats.

5.2.2 Unmanned Aerial Vehicles

5.2.2.1 Applicability

UAVs which are also referred to as drones, are being increasingly used for research and survey. With specific respect to seabirds, they have been used widely in recent years for the monitoring of seabird colonies, particularly for inaccessible colonies that are difficult to view using ground observers (Hodgson *et al*., 2018; Rush *et al.,* 2018; Brisson-Curadeau *et al*., 2017; Ornithological Council, 2018). However, a number of research and pilot studies have also used UAVs to collect data on birds at sea. This includes mapping the spatial extent of tern foraging around tidal stream structures (Lieber *et al.,* 2019), investigating the foraging habitat of European Shags (Graham, 2019) and trials of UAVs to monitor coastal seabird and waterbird species (Drever *et al.,* 2015). However, CAA regulations, concerns about battery life, disturbance effects and limited operating distances (Section 5.2.2.4), currently limits the application of this technology.

5.2.2.2 Key survey considerations and procedures

There are currently no specific protocols or established guidance for the use of UAVs to survey birds at sea. It is possible to achieve GSDs of <1 centimetre using drones which is considered suitable to be able to identify most marine birds to species level (Drever *et al.,* 2015; Hodgson *et al*., 2018). However, the application of this technology on a commercial basis is currently limited, with most surveys undertaken for specific research purposes rather than as part of licence requirements for a development. This is partly due to drone technology being relatively new, compared to more established techniques such as fixed wing aerial surveys and boat surveys, but also due to potential disturbance and logistical constraints (described in more detail below).

As part of any survey, Civil Aviation Authority (CAA) regulations for commercial unmanned aircraft and drone operations should be followed. In addition, NRW guidance on the use of UAVs to survey birds and their nests should also be followed. This highlights relevant legislation and principles in respect to disturbance and acting lawfully with regard to the Wildlife and Countryside Act (1981) and using drones within SPAs and SSSIs.

5.2.2.3 Analytical techniques

Given that the current application of UAVs is heavily research focused, there are no standard or recommended analytical techniques which should be used. Instead, appropriate techniques tailored towards specific research questions should be applied.

5.2.2.4 Limitations

The main limitations are the logistical constraints associated with drone battery life and operating distance limiting the application for this technology offshore due to the requirement to operate within the limits of a support vessel or other survey platform as well as following CAA regulations. With respect to using UAVs for surveying birds at sea there is the potential risk of causing disturbance as a result of drones generally needing to be flown at low altitudes. However, as surveying birds at sea with drones is still a relatively new field, further research is required to confirm that the commercial application of this technology will not adversely impact species at sea. In addition, it is important to confirm that behavioural responses observed during a drone survey (such as diving behaviour) are part of normal activity rather than as a direct result of the presence of a drone.

5.3 Vessel based surveys

5.3.1 Transect based boat surveys

5.3.1.1 Applicability

Vessel based transect surveys are used to collect information on the abundance and distribution of both birds on the sea surface and in flight. This approach is a widely established technique that can be applied to both inshore and offshore areas.

5.3.1.2 Key survey considerations and procedures

Vessel based transect surveys should be based on the standardised survey method highlighted in Camphuysen *et al.,* (2004) and Maclean *et al.,* (2009) and these should be referred to for a more detailed description of methods. In summary, the key points of the approach are summarised below:

- Line-transect methodology is recommended with a strip width of 300 metres maximum on one side and ahead of the ship. The vessel should motor along pre-defined transect routes at a constant speed. A speed of about 10 knots is recommended (range 5-15 knots). Observations should not be undertaken when conditions are more than World Meteorological Organization (WMO) Sea State Code Four.
- Survey time intervals are recommended to be one or five minute intervals (range 1-10 minutes). Longer time intervals are acceptable when less resolution of data is required; short intervals are preferred in small study areas), with mid-positions (Latitude, Longitude) to be recorded or calculated for each interval.
- Birds should be detected with the naked eye. Surveys should record all birds seen in a 90 degree scan, to one side of the transect line only, noting species, number, age, behaviour, and flight direction and time (by minute intervals). The method can be extended to record from both sides of a vessel by using additional surveyors. GPS positions of the vessel should be recorded at regular intervals (e.g. every minute).
- Birds on the sea are allocated to one of five distance bands: A, 0-50 metres; B, 50-100 metres; C, 100-200 metres; D, 200-300 metres and E, >300 metres. Birds

beyond 300 metres away (Band E) are usually recorded but are not used in later analyses to calculate density estimates. Surveyors should pay particular attention to detection of birds in Distance Band A (0-50 metres) as distance sampling analytical methods assume that all individuals are detected in this band.

- Flying bird density should be recorded by taking ‘snapshots’ at regular intervals and noting if birds in flight are ‘in transect’ at that moment. Flying birds are considered to ‘in transect’ if they are inside a 300 metres x 300 metres box extending forwards from the vessel and to either the left or right of the transect line (depending which side is being watched).
- Estimated flying height of birds may be recorded by using height bands. However, this information is only usually required for windfarm developments. More accurate information on flight heights can be recorded using optical rangefinders (Borkenhagen *et al*., 2018).
- The vessel should have a forward-looking observation deck that gives surveyors an eye height of between 5 metres and 25 metres above water level (5 metres is considered the absolute minimum).
- Two competent observers are required per observation platform, one undertaking observations and the other recording the data.

Information should be recorded on standardised datasheets. Separate forms are recommended for recording data on conditions/effort and records of species. All recording forms must be suitably cross-referenced.

5.3.1.3 Analytical techniques

Deriving robust estimates of abundance and density are typically one of the main analytical requirements of boat-based transect methods. It is possible to derive simple density estimates by dividing the counts of birds seen in each transect (or other spatial unit) by the survey effort applied and combining the values. An average density and measure of variance can then be estimated for a survey area. However, detection can be influenced by a range of factors (such as sea state and sun glare). This can be particularly the case for small species. This can, therefore, result in negatively biased population estimates as a result of decreases in detectability of animals with distance (Ronconi and Burger, 2009).

Distance analysis is commonly used to correct the numbers of birds observed for imperfect detectability (Mackenzie *et al*., 2013). Distance analysis is usually undertaken in specially designed statistical software such as ‘Distance 7.3’ (Thomas *et al.* 2010) or the ‘Distance’ package) in ‘R’ (Miller 2017) to analyse variations in the detectability of birds and correct density estimates accordingly. Further, detailed information on the theory and application of distance sampling and analysis can be seen in Buckland *et al*., (2001) and Buckland *et al*., (2004). In general, more than 60 observations per species are needed to generate a reasonable model with distance analysis. Where observations are less, correction factors can be used to determine densities estimates from raw count data (Stone *et al*., 1995).

5.3.1.4 Limitations

While transect based surveys are considered widely applicable there are several limitations to using this technique. These limitations include:

- Bias can occur when using boat-based platforms to survey Common Scoter and Red-throated Diver as they area known to be particularly sensitive to disturbance from vessels (Schwemmer *et al.,* 2011; Furness *et al.,* 2013; Dierschke *et al*., 2017). In important areas for these species this technique is, therefore, not recommended, with other techniques potentially more suitable in terms of minimising disturbance.
- Weather constraints can cause a delay to survey programme if conditions are considered unsuitable for surveying or dangerous. This can be a problem in larger survey areas, particularly in the winter months caused by prolonged periods of adverse weather conditions and more limited daylight working conditions.
- This technique relies on real-time human observations which can cause observer bias effects (unlike digital aerial methods-Section 5.2) (Natural England, 2019).

5.3.2 Visual tracking (following) surveys

5.3.2.1 Applicability

The visual tracking of individual birds using a vessel to follow a focal bird has the potential to provide valuable data on the relative importance and functionality of different areas for birds at sea. This includes foraging movements from colonies and at-sea behaviour in relatively localised areas or in species with short foraging ranges such as terns (Perrow *et al.,* 2011). In this respect, this technique can provide an alternative technique to remote techniques such as tagging using radio and satellite-telemetry and GPS dataloggers (Section 5.6).

5.3.2.2 Key survey considerations and procedures

It is recommended that the survey methods highlighted in Perrow *et al.,* (2010) and Perrow *et al*., (2011) are used as a basis when designing a visual tracking survey. These surveys were originally developed for the tracking of terns at colonies. The main points of the procedure are as follows:

- The appropriate number of birds of a focus species to track should be defined through consultation with NRW.

- A high-speed vessel (such as a rigid inflatable boat (RIB)) that is sufficiently fast and manoeuvrable to allow birds to be tracked visually should be used.

- The survey should use a three-person team (consisting of a skipper, observer and data recorder). The observer should keep the terns in sight, relaying instructions on the direction of the tracked bird to the driver. The driver should also keep visual contact with the bird where possible. The lead observer should also call out observations of the bird’s behaviour throughout the flight to the data recorder. This should include information on foraging behaviour (such as shallow plunge diving, surface dipping etc.), the number and type of any other birds present, and, when possible, the size and type of prey.

- A distance of approximately between 50 metres and 200 metres should be maintained between the boat and the bird being tracked i.e. close enough to allow accurate observations but sufficiently distant to prevent changes to the bird’s behaviour due to observer presence.

- The location of the bird should be recorded using a hand-held GPS at approximately one-minute intervals (based on the assumption the vessel passed an almost identical location a few seconds later than the bird).
- In areas where a boat cannot follow a focal bird (such as in very shallow water or near navigational hazards) or in areas in which disturbance to other species could occur (such as when birds are feeding in association with other species), the approximate distance (in metres, estimated by eye) and compass bearing of the bird from the vessel should be recorded. Locations can then be determined using Global Information System (GIS) software.
- If information about flight height is required, it is recommended that height bands are used. For example, Perrow *et al*., (2010) used categories of 0 (on water), 0-1 metres, >1-20 metres, 20-120 metres and >120 metres.
- If a focal bird is lost from view prior to completing a foraging trip (i.e., before the bird returned to the colony) or whist still in an area of interest, the reason for the loss (e.g., the bird flying faster than we could follow, flying over a physical obstruction, or confusion with other birds) should be noted.

5.3.2.3 Analytical techniques

The GPS derived positional data should be georeferenced in a GIS database. Behavioural data associated with each position should also be incorporated into the database. Depending on the scale and purpose of the study and sample size, appropriate statistical analysis might be appropriate (such as Wilcoxon rank sum W tests) to test for possible differences in various parameters such as total distance travelled, maximum distance offshore and the duration of tracking of individuals between different colonies or locations. Generalised Linear Models (GLMs) can also be potentially used to explore the relationships between different variables such as tidal state or time of day (Perrow *et al*., 2011).

5.3.2.4 Limitations

Due to logistical constraints, the technique can only be applied to certain species (such as short-ranging, day-active seabirds) and cannot be used to quantifying longer movements. In addition, the technique can only be used when sea states and visibility levels are appropriate.

5.4 Coastal based vantage point surveys

5.4.1 Applicability

Vantage point (VP) surveys from a position on the coastline can provide data on the distribution, abundance and behaviour of birds at sea occurring nearby to the coastline. This technique is therefore most applicable to potential developments in nearshore locations (Fox *et al*., 2018). However, there can be significant limitations to the quality of data obtained from VP surveys (Section 5.4.3) and as a result of these limitations, VP surveys are generally not recommended.

5.4.2 Key survey considerations and procedures

Established VP survey protocols have been developed by Scottish Natural Heritage (SNH) for onshore windfarm developments and bird species generally. These standardised surveys comprise a series of watches from a fixed location to quantify the flight activity of birds at a proposed development site to provide data to estimate collision risk (SNH, 2014; SNH, 2005). There are no standardised protocols specifically for undertaking VP surveys of birds at sea. Instead, it is often common practice to adopt (and adapt where necessary) the SNH protocols. Guiding principles to consider when designing a VP survey for seabirds at sea were summarised in Jackson and Whitfield (2011).
VP surveys are typically used to collect the following types of data:

- Survey area utilisation: Counts on the number and distribution of birds specifically using the survey area. This should focus on birds recorded on the water and foraging birds in flight (i.e. birds foraging on the wing).
- Bird flight surveys: Surveys focused specifically on the rate that flying birds pass through the survey area watched from a VP, typically using height bands to estimate flight height.
- Species focused surveys: Surveys targeted on a specific species (or low number of focus species) to provide data to address a specific assessment or research gap (such as diving behaviour to inform underwater collision risk assessment).

Additional data can also be recorded as part of these surveys, (such as recording anthropogenic activity). VP surveys are typically undertaken out to a maximum of 1-1.5 kilometres from the coast and rely on high quality optical equipment such as binoculars and spotting scopes to observe and identify species. To measure the bearing and distance of species from the VP, clinometers, laser rangefinders or ornithodolites have all been successfully used (Jackson and Whitfield, 2011; Cole *et al*., 2019).

5.4.3 Analytical techniques

It is considered more difficult to produce standardised estimates of density from VP surveys compared with digital aerial survey methods using aircraft (Section 5.2.1) and boat based transect surveys (Section 5.3). This is because it is not possible to assume that species' density is an average constant with increasing distance from a VP (with oceanographic factors such as tides, currents or biophysical factors likely to result in varying densities with distance from the shore). For this reason, the approach used in distance analysis to correct for detection bias (Thomas *et al.,* 2010) is not valid as the underlying assumptions are violated (Jackson and Whitfield, 2011). However, Mackenzie *et al.,* (2013) stated that methods that adjust for imperfect detectability can be employed. For example, by collecting information on the radial distance and the angle for each detected animal it is possible to both estimate a detection function and animal densities (Cox *et al.,* 2013; Mackenzie *et al.,* (2013). VPs can also be used in conjunction with other survey techniques in post construction monitoring, but this is dependent on project type, location and scale.

5.4.4 Limitations

VP methods are restricted to recording birds in inshore, coastal areas due to the limitations of detecting and identifying bird species at distance using optical equipment from a static land-based location. Jackson and Whitfield (2011) suggest that the problems of detecting relatively small bird species effectively limits the use of shore-based VP methods to areas within approximately 1.5 kilometres of VPs. However, exposed areas can be subject to strong wind conditions (which can cause excessive shake to optics) and stormy sea conditions (reducing detectability rates) (Fox *et al.,* 2018). Therefore, in reality, the area that is covered by a VP survey is likely to be much closer to the coastline (<1 kilometres).

A further constraint is that VP surveys also require suitably elevated land and are most effective where cliffs or hills close to the sea provide uninterrupted views over the entire survey area. Jackson and Whitfield (2011) recommend that for surveys aimed at recording birds up to 1 kilometre away, VPs need to be at least 5 metres above sea level and ideally 10-15 metres. For surveys aimed at recording birds out to 1.5 kilometres, VP heights should be at least 10 metres and ideally 20-30 metres above sea level. Where suitable natural VPs are not available, a raised platform (such as a scaffold tower) might need to be used.

Finally, there are a range of statistical issues with respect to deriving density estimates from VP surveys (as described above) which reduce the effectiveness of this technique for projects in which this information is required.

5.5 Active remote sensing techniques

For the purpose of this review, active remote sensing techniques are considered to be those systems that provide their own source of energy to illuminate the objects they observe. An active sensor emits radiation in the direction of the target to be investigated. The sensor then detects and measures the radiation that is reflected or backscattered from the target[1]

5.5.1 Applicability

A range of active remote sensing techniques have been developed in recent years to collect ornithology data. This includes;

- adapted marine radar (vertical or horizontal) which is primarily used to monitor positions of birds and/or flocks of birds (Walls *et al.,* 2009; Assali *et al.,* 2017)
- active tracking radars which is used to monitor movements of individual birds (Skov *et al*., 2018)
- LiDAR which is used to measure flight height of birds (Cook *et al*., 2018)
- integrated optical-stereo cameras to record bird movements with video footage for species identification purposes, triggered by radar (Adams *et al.,* 2017)

Radar has been an established technique for monitoring for decades whereas the other techniques are considered newer technologies (Gauthreaux and Belser, 2003; Dokter *et al*., 2013; Hüppop *et al*., 2019). The majority of the systems referenced in this section are used for the offshore wind sector or are still at an academic research stage. Recent advances in technology have included specific systems that monitor birds around marine structures remotely (e.g. with minimal or no human input). Coarse scale 2D densities can be ascertained from long-range (<150 kilometres) surveillance radar, whereas fine scale

[1] https://earthdata.nasa.gov/learn/remote-sensors.

3D movement (including species identification, speed measurements, flight height) can be ascertained from close range (<2 kilometres) tracking radars.
One of the largest scale examples of the application of active remote sensing techniques was as part of the Offshore Renewables Joint Industry Programme (ORJIP) Bird Collision Avoidance (BCA) Study at Thanet offshore wind farm (OWF). The study used multiple radars and thermal imagery to assess how birds showed macro, meso and micro avoidance of the OWF (macro), the individual turbines (meso) and the individual blades (micro) (Skov *et al*., 2018). This post-consent monitoring was only possible due to the offshore structures acting as a stable platform for the fine-scale tracking radar.

5.5.2 Key survey considerations and procedures

Due to the unique nature of these monitoring techniques there is no standardised approach for monitoring with procedures largely determined by project or research specific requirements and the technology used. However, Walls *et al*. (2009) produced best practice guidance for remote ornithological monitoring. Key considerations highlighted included:

- active remote sensing techniques are not applicable in all cases
- clear goals must be scoped, stated and agreed at the start of the assessment process by all stakeholders (statutory, non-statutory and environmental consultancies) for all bird monitoring requirements
- the importance of a stated clear goal for the integration of monitoring techniques with the aim of standardised outputs and conclusions
- remote techniques should be used to provide complementary information to standard ornithological monitoring techniques
- the limited availability of equipment and suppliers must be borne in mind
- the specialist involvement of experienced specialist practitioners must be ensured

5.5.3 Analytical techniques

Radar systems collect a large amount of data when operational. Several computer programmes or artificial intelligence (AI) computer models have now been created to interpret this data to separate bird passes from background noise (Rosa *et al.*, 2016). However, the type of analysis applied will depend on the type of data collected. For example, if the key aim of the monitoring is to understand the main periods of movement through a site (non-species specific), off the shelf software could undertake this analysis. However, more complex analysis is likely to require a higher degree of human involvement to the analytical process.

5.5.4 Limitations

The cost of these systems can be high with custom-built designs often required (Nilsson *et al*., 2018). Furthermore, it is not possible to identify birds to species level with radar or LiDAR technology without supplementary data being collected. This reduces the automated nature of the technology and is, therefore, typically only considered a supplementary technique to more established methods at present.

5.6 Telemetry sensors

5.6.1 Applicability

The application of telemetry sensors can provide important information on the wide scale movements and spatial ecology of marine birds (Masden *et al.,* 2015b). In particular, it can provide valuable complimentary data to abundance and distribution data collected using boat or aerial techniques. The use of telemetry sensors to monitor seabirds and other species has increased in recent years due to technological advances (including the miniaturisation of tags, making it possible for them to be attached to a wider range of species). This technology has also generally reduced in cost, making this technology available to a larger number of studies and allowing a greater number of devices to be deployed in each study (Wilson and Vandenabeele, 2012; Harcourt *et al*., 2019; Thaxter and Perrow, 2019). With specific respect to understanding potential impacts of marine development, telemetry devices can provide information on:

- connectivity and movements between different areas of functional importance (such as breeding colonies) and the development footprint
- the proportion of time birds spend in an area (i.e. site fidelity)
- Behaviour of individual animals, e.g. flight height, dive depth, length of dive and position within the water column
- environmental parameters of where the bird is located, for example, flow speed, temperature, turbidity, oxygen content
- health and physiology indicators such as body temperature, heart rate and blood pressure

There are multiple types of telemetry sensors that can be housed within animal-borne tags. Early uses of telemetry sensors were focussed on using pressure sensors to understand diving behaviour of seabirds. However, more recent developments include positioning, environmental and animal health sensors, and emerging technologies are now being developed using MOTUS or PIT tags with receivers placed within offshore windfarms.

The most common use of telemetry sensors is gathering locational data (in both fine and broad scale). This is the most relevant to offshore developments. Fine scale measurements are gained from GPS tags which provide < 5 metre accurate positions. Other positioning systems (e.g. geolocators and the Argos network of satellites) do not typically provide data at such a fine scale resolution.

There are two ways that data can be received back from a device - archival or transmitting. Archival tags store all of the information within the tag on a memory card, this means you will need to recapture the bird to retrieve any data (such as at a nest). The second way of receiving data from the tag is via a transmitting tag. This may be via radio or satellite. Radio transmitters need to have a specific base station that will receive the data from the tags as a bird flies past or returns to a nest. For example, radio transmitting tags can be used if the bird is a central place forager and will return to a known area. Satellite transmitters allow remote download anywhere and can be integrated with user friendly online mapping tools (e.g. Move Bank). Satellite transmitting of data can also be done through “traditional” satellite networks (e.g. Argos system), and more recently the use of

the Global System for Mobile (GSM) network, which provides worldwide coverage wherever there is a mobile network.
One of the key potential benefits of telemetry studies is that it allows data to be collected over a wide range than can be monitored with other techniques such as vessel or aerial based surveys (Carroll *et al*., 2019; Phillips *et al*., 2019).

Several recent studies have included a historical review of telemetry sensors and how they have been used to monitor seabird populations to date. Please refer to these papers for background information and for a more detailed description on the application of telemetry sensors (Masden, 2015b; Harcourt *et al*., 2019; Thaxter and Perrow, 2019; Yoda, 2019).

5.6.2 Key survey considerations and procedures

There are currently no specific protocols or established guidance for the use of telemetry devices to survey birds at sea. However, when undertaking new telemetry studies, one of the main considerations is the bird's welfare (Green *et al*., 2019). Deployment of attached devices is highly regulated by the BTO which provides licences to trained ringers via a special panel. For example, it might not be considered ethical to attach devices to certain species due to the risk of causing injury or increased mortality to the individual (e.g. due to its weight or because it restricts flight).

When applying to the BTO for permission to attach telemetry device, they will need to understand the experience of the team undertaking the tagging study, the questions you are trying to answer and the specifications of the tag that will be used (including attachment methodology).

It is important that the specific research question is clearly identified. Each sensor placed within a device increases the weight and battery drain, both of which are limited. The standard practice is that the device is no more than 3% of a bird mass (Vandenabeele *et al*., 2012; Thaxter and Perrow, 2019), whilst shape and aerodynamics are considered to be equally as critical (Green et al, 2019).

5.6.3 Analytical techniques

The analytical techniques applied will be dependent on the specific area of research which is being investigated. Analytical methods include:

- Generalized Linear Mixed Models (GLMMs) or GAMs to produce regression lines to look at a relationship between a particular independent variable and the expected outcome (e.g. seabird distribution and an environment parameter). For example, a GLMM was produced to understand sea path tortuosity and speed of Northern Gannet off Grassholm (Votier *et al.*, 2010).
- Mixed model of Gaussian curves to understand the mean and variance of behavioural traits (e.g. foraging and sitting) (Guilford *et al.*, 2008).
- Kernel-density analysis to understand hotspots of bird distribution. The kernel colour presents the core and outer areas of a bird's range (Cook *et al*., 2016).

Further information on analytical methods for telemetry studies are provided in Thaxter and Perrow (2019).

5.6.4 Limitations

The use of telemetry devices can be an expensive technique to collect data (despite an overall reduction in cost in recent years). This can lead to the potential risk of the sample size not being representative of the population of interest. For example, the foraging movements of a limited number of tagged individuals might not be representative of all individuals of a nesting colony population. There is also a relatively high risk of data loss. This could occur as a result of tags falling off before being retrieved (if using archival system), the bird may also move away from a transmitter (if using a relay system), the bird may not be recaptured (if using archival system) and there is also the potential for the tags to malfunction (Wilson and Vandenabeele, 2012; Harcourt *et al*., 2019; Thaxter and Perrow, 2019). A further limitation of deploying telemetry devices could be the size of the bird species being too small to be able to carry a device.

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7 Appendices

Appendix A - Overview of marine birds and other species recorded at sea in Welsh waters

This section provides a broad overview on marine birds and other species recorded at sea in Welsh waters. The section highlights information on the protection and conservation status of species (Section A.1 and section A.2) as well as summary information on the main species recorded in Welsh waters (Section A.3). This includes information on the ecology, distribution and abundance of species.

A.1 Species protection

A.1.1 Legislation

The following sections outlines the main protection afforded to bird species within Wales. NRW Guidance Note GN13 provides further information on nature conservation protection. The following relevant legislation is described in more detail below.

- The Wildlife and Countryside Act 1981
- The Birds Directive
- The Conservation of Habitats and Species Regulations 2017
- The Conservation of Offshore Marine Habitats and Species Regulations 2017
- Ramsar Convention
- The Environment (Wales) Act 2016

A.1.1.1 The Wildlife and Countryside Act 1981

The Wildlife and Countryside Act 1981 (as amended) prohibits the intentional killing, injuring or taking of any wild bird (with certain exceptions) and the taking, damaging or destroying of a wild bird’s nest or eggs. Birds listed on Schedule 1 receive additional protection: it is an offence to intentionally or recklessly disturb these birds or their young at, on or near an ‘active’ nest. Seabird species in Wales listed under Schedule 1 are Little Tern, Roseate Tern and Mediterranean Gull.

SSSIs are nationally important sites, notified under the Wildlife and Countryside Act (1981), as amended by the Countryside and Rights of Way Act (2000). SSSIs can be designated for either geological or biological features including marine and coastal bird species. Further information on SSSIs in Wales can be seen in Section A.1.2.

A.1.1.2 The Birds Directive

All naturally occurring wild bird species, their eggs, nests and habitats are also strictly protected under the Directive 2009/147/EC (The Birds Directive) within the European Union. This directive sets broad objectives for a wide range of activities, although the precise legal mechanisms for their achievement are at the discretion of each Member State. One of the main provisions of the directive includes the identification and classification of SPAs for rare or vulnerable species listed in Annex I of the Directive, as well as for all regularly occurring migratory species, paying particular attention to the protection of wetlands of international importance (Article 4). Further information on the location of SPAs in Wales can be seen in Section A.1.2.
In the UK, the provisions of the Birds Directive are implemented through the Wildlife and Countryside Act 1981 and the Conservation of Habitats and Species Regulations 2017 as well as well as other legislation related to the uses of land and sea. A very wide range of other statutory and non-statutory activities also support the implementation of the Birds Directive in the UK[1]. This includes national bird monitoring schemes and bird conservation research.

A.1.1.3 The Conservation of Habitats and Species Regulations 2017

The Habitats Regulations 2017 transpose elements of the Birds Directive in England and Wales.

A.1.1.4 Ramsar Convention

Ramsar sites are wetlands of international importance that have been designated under the criteria of the Ramsar Convention on Wetlands for containing representative, rare or unique wetland types or for their importance in conserving biological diversity. The designation of UK Ramsar sites has generally been underpinned through prior notification of these areas as SSSI). Many sites designated as Ramsar's are also SPAs.

A.1.1.5 Section 7 of the Environment Act (Wales) 2016 (formerly Section 42 of the NERC Act 2006 / UK BAP Habitats and Species)

Certain habitats and species (including a range of marine bird species) are identified by the National Assembly for Wales under Section 42 of the Natural Environment and Rural Communities Act (2006) as being of "principal importance for conserving biodiversity" in Wales. This list has now been transposed to form the Section 7 list for the Environment (Wales) Act. Section 6 of the

[1] http://archive.jncc.gov.uk/default.aspx?page=1373

Act places a duty on public authorities to ‘seek to maintain and enhance biodiversity’ so far as it is consistent with the proper exercise of those functions. In so doing, public authorities must also seek to ‘promote the resilience of ecosystems’.

A.1.2 Protected sites in Wales

There are currently 11 SPAs that are considered to be part of the Welsh MPA network (NRW, 2018). In summary these are;

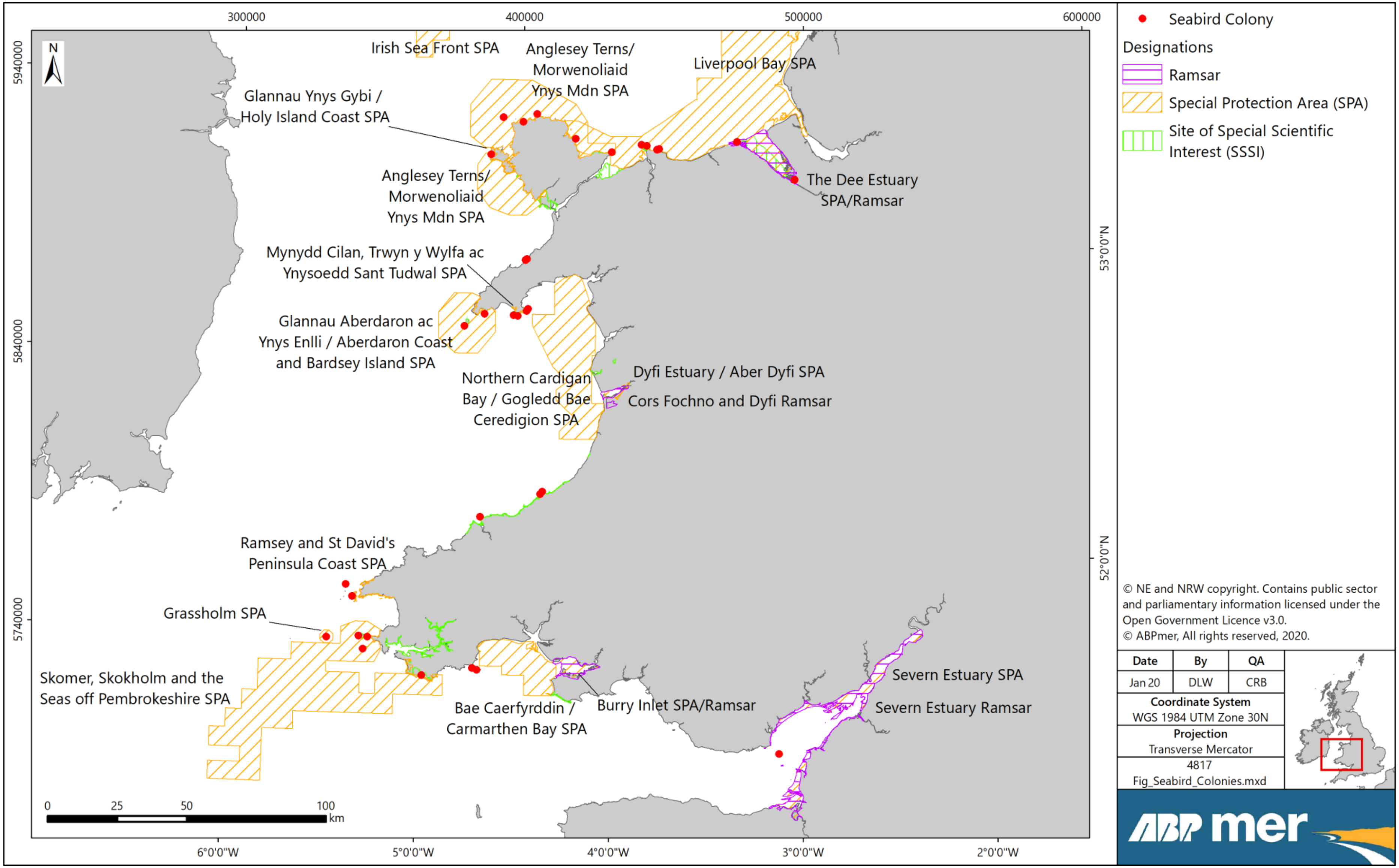
- The Dee Estuary
- Liverpool Bay
- Traeth Lafan
- Anglesey Terns
- Aberdaron Coast and Bardsey Island
- North Cardigan Bay
- Skomer, Skokholm and the Seas off Pembrokeshire
- Grassholm
- Carmathern Bay
- Burry Inlet
- Severn Estuary

In addition, the Dyfi SPA and Puffin Island SPA also support bird features that partly or wholly rely on the marine environment to complete their life cycles.

The location of these sites can be seen in Figure . More information on the individual sites can be found on the NRW website (including maps, qualifying features and conservation objectives), Welsh Government data portal Lle or the JNCC website where you can find more information on marine SPAs across the UK (including Natura 2000 standard data forms). As functional linkages between SPAs and potential development locations need to be considered during the consenting process, other SPAs outside of Welsh waters may also be relevant.

In addition, a number of SSSIs also support seabirds and other species occurring at sea (Vanstone *et al.,* 2012). The location of these sites can be seen in Figure .

Figure A1. Designated sites for marine birds and major seabird breeding colonies in Wales



A.2 Conservation status

Birds of Conservation Concern (BoCC) (the Red List for Birds) is a review that highlights the conservation status of birds in the UK based on a set of objective criteria. Birds that breed or overwinter in the UK are placed on a Green, Amber or Red list. The review which is undertaken by UK's leading bird conservation organisations uses up to date information on the status of birds in the UK and elsewhere in their ranges, drawing on data collated through the UK's bird monitoring schemes. BoCC 4 which was undertaken in 2015 and provides the most recent assessment (Eaton *et al.,* 2015).

The BoCC W assessment highlights the conservation status of bird species specifically within Wales. The bird species that breed or overwinter in Wales are assessed against a set of objective criteria and then placed on either the Red, Amber or Green list, to indicate the level of conservation priority for those populations. The most recent lists were published in the September 2016 edition of the Welsh Ornithological Society Journal Birds in Wales (Johnstone and Bladwell, 2016). The research for BoCCW3 was undertaken by the Royal Society for the Protection of Birds (RSPB) in partnership with NRW and the British Trust for Ornithology (BTO). The review was supported by the Welsh Ornithological Society (WOS), Rare Breeding Birds Panel (RBBP), National Trust and Wildfowl and Wetland Trust (WWT). The BoCC W status of commonly occurring marine birds in Welsh waters is shown in Table A1.

A.3 Distribution, abundance and ecology

This section highlights key existing data sources available (Section A.3.1) as well as a summary of the distribution, abundance and ecology of key species within welsh waters (Section A.3.2).

A.3.1 Key data sources

A range of existing data sources provide information on the distribution and abundance of seabirds in Welsh waters. NRW Guidance Note (GN006) highlights marine ecology datasets and information sources owned or recommended by NRW. With specific respect to marine ornithological, this includes:

- Seabirds at Sea Evidence Base: Geographic Information System (GIS) layers showing the abundance and distribution of seabirds in Welsh waters. The dataset consists of the raw data showing observations of all seabirds and derived grids showing the density of flying and sitting species on a 3 kilometre grid scale throughout. The two main sources of seabird distribution and abundance data for Welsh waters are held in JNCC's European Seabirds at Sea (ESAS) database (described below) and the Wildfowl and Wetlands (Consulting) Ltd marine aerial surveys database. The data can be downloaded from the Welsh Government data portal Lle.
- European Seabirds at Sea: This database includes data on abundance and distribution of seabirds at a UK and north-west European level. The data can be requested from the JNCC.
- Seabird Monitoring Programme (SMP): This is an ongoing annual monitoring programme, established in 1986, of 25 species of seabird that regularly breed in

Britain and Ireland. It aims to ensure that sample data on breeding numbers and breeding success of seabirds are collected, both regionally and nationally, to enable their conservation status to be assessed. The data includes information on seabird colonies in Wales. Annual reports are available which document trends in population numbers and breeding success, productivity, survival and diet of breeding seabirds. Data are managed by JNCC and can be viewed and downloaded from the SMP online database.

- The SMP also includes periodic breeding seabird censuses to assess seabird population health and conservation status; the effects of climate change on marine environments; and to inform marine planning. The current census, Seabirds Count, is being coordinated by JNCC and survey work began in 2015, with results expected in 2021.
- Wetland Bird Survey (WeBS) and Non-Estuarine Waterbird Survey (NeWS): Both of these are co-ordinated by the BTO. WeBS involves regular counts of wintering, non-breeding waterbirds in coastal, wetland and intertidal areas. These surveys include observations of birds recorded at sea near the shoreline (such as grebes, divers etc.). NeWS completes periodic counts (approximately decadal) of non-estuarine sections of coastline not covered by WeBS. You can browse WeBS and NeWS data using the WeBS and NEWS online reports. Data can also be requested from BTO.

Other data sources include the aforementioned SeaMaST, and a study undertaken by Waggit *et al.,* (2019). The research produced seabird distribution maps for the North East Atlantic as part of a Natural Environment Research Council (NERC)/ Department for Environment, Food and Rural Affairs (Defra) funded Marine Ecosystems Research Programme study. The distribution outputs were developed through creating species distribution models (SDM) based on the analysis of over 2.68 million kilometres of survey data in the North-East Atlantic between 1980 and 2018. The RSPB have also recently produced seabird hotspot maps based on bird tracking data collected as part of the Future of the Atlantic Marine Environment (FAME) project and STAR (Seabird and Tracking Research) project. Data from these projects have been used to develop predictive species distribution models and high-density usage maps for a variety of species (Wakefield *et al*., 2017; Cleasby *et al.,* 2018). In addition, data on the foraging ranges of seabirds based on tracking data is summarised in Woodward *et al*., (2019).

Key data sources are also highlighted in the RSPB report ‘The use of bird data in marine planning and licensing’ (RSPB, 2019).

In addition to the data sources highlighted above, data from surveys undertaken at a more site-specific scale (such as to inform project assessments or as part scientific research) should also be reviewed where applicable.

A.3.2 Key species in Welsh waters

Wales supports internationally important populations of breeding seabirds and other marine birds. Summary information on the ecology of commonly recorded species in Welsh waters is provided in Table A1. This includes information on the foraging ranges, habitat, diet, feeding behaviour and distribution of these key species.

In the breeding season, large numbers of seabirds are recorded nesting at colonies on offshore islands and along the Welsh mainland coast including Manx Shearwater, Storm

Petrel, Gannet, Puffin, Razorbill, Guillemot, Cormorant, Shag, tern species and gulls. The largest seabird breeding colonies are found at Skomer, Skokholm and Grassholm in Pembrokeshire, sites around Anglesey (such as South Stack, Cemlyn Bay, Puffin Island and the Skerries), Bardsey Island and Carreg y Llam (Llŷn Peninsula) and New Quay Head in Cardigan Bay (NRW, 2018). The location of the main seabird colonies in Welsh waters can be seen in Figure .

The highest densities of foraging seabirds within Welsh waters occur offshore from major breeding areas (such as the Pembrokeshire coast and islands, Anglesey and the Llŷn Peninsula (Cleasby *et al*., 2018; Wakefield *et al*., 2017; Waggit *et al*., 2019; DECC, 2016; NRW Seabirds at Sea Evidence Base[1]). The distribution of seabirds at sea based on the Seabirds at Sea Evidence Base and RSPB data can be seen in Appendix B - Seabirds at Sea evidence base maps and Appendix C – Royal Society for the Protection of Birds (RSPB) distribution maps respectively.

Wales also supports large aggregations of wintering seaduck, diving duck, divers (*Gaviidae*) and grebe (*Podicepididae*). Important areas for these species include Liverpool Bay (for Red-throated Diver and Common Scoter), Conwy Bay (Great-crested Grebe and Red-breasted Merganser), northern Cardigan Bay (Red-throated Diver) and Carmarthen Bay (Common Scoter) (NRW, 2018; DECC, 2016).

In addition, large numbers of coastal waterbirds and terrestrial bird species are recorded in flight at sea each year annually on migrations (DECC, 2016; Griffin *et al.,* 2011; Flegg, 2004).

[1] https://lle.gov.wales/catalogue/item/SeabirdsAtSea/?lang=en

Table A1.Summary ecological information on species commonly recorded at sea in Welsh waters

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference)		Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
	Mean Max +1SD.	Exception				
Common Scoter (*Melanitta nigra*) Moderate conservation concern Moderate conservation concern	N/A	N/A	Coastal	Bivalves such as mussels, clams and cockles. Periwinkles, *Hydrobia* and other crustaceans.	Diver. Max 25 m, mean 7 m	Internationally important flocks (designated as SPA) regularly occur in north Wales (e.g. Liverpool Bay, the Dee Estuary; Colwyn Bay) as well as in Carmarthen Bay and northern Cardigan Bay. Lower numbers are found elsewhere.
Red-breasted Merganser (*Mergus serrator*) Moderate conservation concern	N/A	N/A	Coastal	Fish such as cod, sandeel. Insects and crustaceans.	Diver.	Resident species and winter visitor. Largest flocks occur around Anglesey and in the Dee Estuary.
Red-throated Diver (*Gavia stellate*) Moderate conservation concern	N/A	N/A	Coastal	Predominantly of fish as well as crustaceans, molluscs, small marine insects etc.	Pursuit diver. Max 10 m, mean 4 m	Winter visitor with the largest populations occurring in Liverpool Bay, northern Cardigan Bay, Carmarthen Bay and around Anglesey.

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference)		Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
	Mean Max +1SD.	Exception				
Great Northern Diver (*Gavia immer*)* Moderate conservation concern	N/A	N/A	Coastal	Predominantly of fish as well as crustaceans, molluscs, small marine insects etc.	Pursuit diver. Max 70 m, mean 7 m	Winter visitor with largest flocks occurring in Caernarfon Bay. Very few recorded elsewhere.
European Storm Petrel (*Hydrobates pelagicus)* Moderate conservation concern	336	N/A	Offshore	Small fish, squid and crustaceans.	Surface feeder, with small plunge dives. Max 5 m, mean 1 m	Summer breeder with the largest population on the Pembrokeshire islands (Grassholm, Skomer and Skokholm).
Northern Fulmar (*Fulmarus glacialis*) Moderate conservation concern	1200.2	N/A	Coastal and offshore	Sandeel, sprat, zooplankton, squid, fish discards and offal.	Surface feeder. Also splash dives. Max 5 m, mean 0 m	Resident species, with breeding occurring throughout Wales. The largest populations are on Skomer and Ramsey Island. At sea distribution is patchy with species recorded throughout Welsh waters

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference) Mean Max +1SD.	Exception	Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
Manx Shearwater (*Puffinus puffinus*) Moderate conservation concern	2365.5	N/A	Coastal and offshore	Small fish and squid.	Surface feeder and surface diver. Max 26 m, mean 1 m	Summer breeder with the largest populations in Pembrokeshire (on Skomer and Skokholm) and Bardsey Island in North Wales. Patchy at sea distribution with highest abundance close to Pembrokeshire islands.
Great Crested Grebe (*Podiceps cristatus*) Least conservation concern	N/A	N/A	Coastal	Insects and small fish.	Diver. Max 30 m, mean 3 m	Resident species. Breeds on shallow, inland lakes in the area and recorded in sheltered coastal sites. Largest numbers are found in winter on the Dee Estuary, Swansea Bay and off Anglesey.
Northern Gannet (*Morus bassanus*) Moderate conservation concern	509.4	Exception applied: Forth Is SPA 590km; Grassholm SPA 516.7km; St Kilda SPA 709km	Coastal and offshore	Mackerel, herring, sandeel, gadoids fish discards.	Plunge diver. Max 34 m, mean 8.8 m.	Resident species with only breeding population on Grassholm (approximately 30,000 pairs). At sea, the species is present throughout Welsh waters, with birds travelling large distances.

Species (taxonomic order)	**Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference)** Mean Max +1SD.	Exception	**Foraging habitat [1]**	**Diet [1]**	**Foraging behaviour [1], Dive depth [3]**	**Distribution within Wales [4, 5, 6, 7, 8, 9]**
European Shag (*Phalacrocorax aristotelis*) Moderate conservation concern	23.7	N/A	Coastal	Sandeel, gadoids, gobies, flatfish, clupeids and sea scorpions.	Pursuit diver. Max 80 m, mean 33 m.	Resident species. Largest breeding population is on Puffin Island (approximately 300 nests). At sea distribution is highest within 10 km of breeding sites.
Great Cormorant (*Phalacrocorax carbo*) Least conservation concern	33.9	N/A	Coastal	Flatfish, blennies, gadoids, sandeel, salmonid and eels.	Pursuit diver. Max 35 m, mean 12 m.	Resident species. Largest breeding population is on Puffin Island (approximately 600 nests) and Little Orme (approximately 400 nests). Highest distribution based on sea surveys is along the north Wales coastline.
Black-legged Kittiwake (*Rissa tridactyla*) Moderate conservation concern	300.6	N/A	Coastal and offshore	Sandeel and clupeids.	Surface feeder; dipping or shallow plunge diving.	Resident species, with breeding occurring throughout Wales with the largest breeding population is on Skomer. Widely distributed at sea throughout Wales with high densities around breeding colonies.

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference)		Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
	Mean Max +1SD.	Exception				
Black-headed Gull* (*Chroicocephalus ridibundus*) Greatest conservation concern	N/A	18.5 (Max/MM)	Coastal and offshore	Worms, insects, small fish, crustacea and carrion.	Surface feeder.	Resident species, with breeding occurring throughout Wales, largest breeding populations are at Burton Mere Wetlands and Cemlyn Bay.
Little Gull (*Larus minutus*) Moderate conservation concern	No data	?	Mainly coastal; sometimes offshore	Insects, and on occasion other invertebrates and fish.	Surface feeder.	Passage visitor in low numbers throughout Wales.
Mediterranean Gull* (*Ichthyaetus melanocephalus*) Moderate conservation concern	N/A	20 (Max/MM)	Coastal and offshore[4]	Breeding: gastropods, insects, some fish, rodents. Not breeding: marine fish, molluscs, insects, berries, seeds and offal.	Surface feeder.	Resident species, with largest counts occurring in October at the end of passage months. Small numbers of birds breeding around Wales, within Black-headed Gull/tern colonies.

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference)		Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
	Mean Max +1SD.	Exception				
Common Gull* (*Larus canus*) Greatest conservation concern	N/A	50 (Max/MM)	Coastal and offshore	Worms, insects, carrion, fish, small birds and, small mammals, eggs, berries.	Surface feeder.	Mainly a winter visitor, with largest flocks within Carmarthen Bay, the Dee Estuary and Seven Estuary.
Great Black-backed Gull (*Larus marinus*)* Greatest conservation concern	N/A	73 (Max/MM)	Coastal and offshore	Carrion, seabirds, small mammals, fish and shellfish.	Surface feeder, kleptoparasitism.	Resident species. Largest breeding populations are on the islands off Pembrokeshire and Anglesey. Patchy at sea distribution with highest numbers in southern Liverpool Bay.
European Herring Gull* (*Larus argentatus*) Greatest conservation concern	85.6	N/A	Coastal and offshore	Omnivorous-fish, discards, offal; also other seabirds, small mammals.	Splash diver, kleptoparasitism.	Resident species. Largest breeding populations are on the islands off Pembrokeshire. Nationally important number of birds occur in winter at on the Dee Estuary. Patchy at sea distribution with highest numbers in southern Liverpool Bay.

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference)		Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
	Mean Max +1SD.	Exception				
Lesser Black-backed Gull (*Larus fuscus*) Moderate conservation concern	236	N/A	Coastal and offshore	Omnivorous- fish, discards, offal. Mainly coastal in summer.	On surface or shallow plunge dives.	Resident species. Largest breeding populations are on the islands off Pembrokeshire. Nationally important number of birds occur in winter at on the Dee Estuary. At sea distribution is highest off Pembrokeshire.
Sandwich Tern (*Sterna sandvicensis*) Moderate conservation concern	57.5	N/A	Coastal	Clupeids, gadoids and sandeel.	Plunge diver. Max 2 m, mean 1 m.	Summer breeder with the only breeding colony at Cemlyn Lagoon in Anglesey.
Little Tern (*Sterna albifrons*) Greatest conservation concern	N/A	5 (Max/MM)	Coastal	Small fish such as clupeids and sandeel. Small invertebrates.	Shallow plunge diver.	There is currently one colony in Wales, along the north coast at Gronant. The population has been increasing since the 1980's and now supports over 100 pairs.

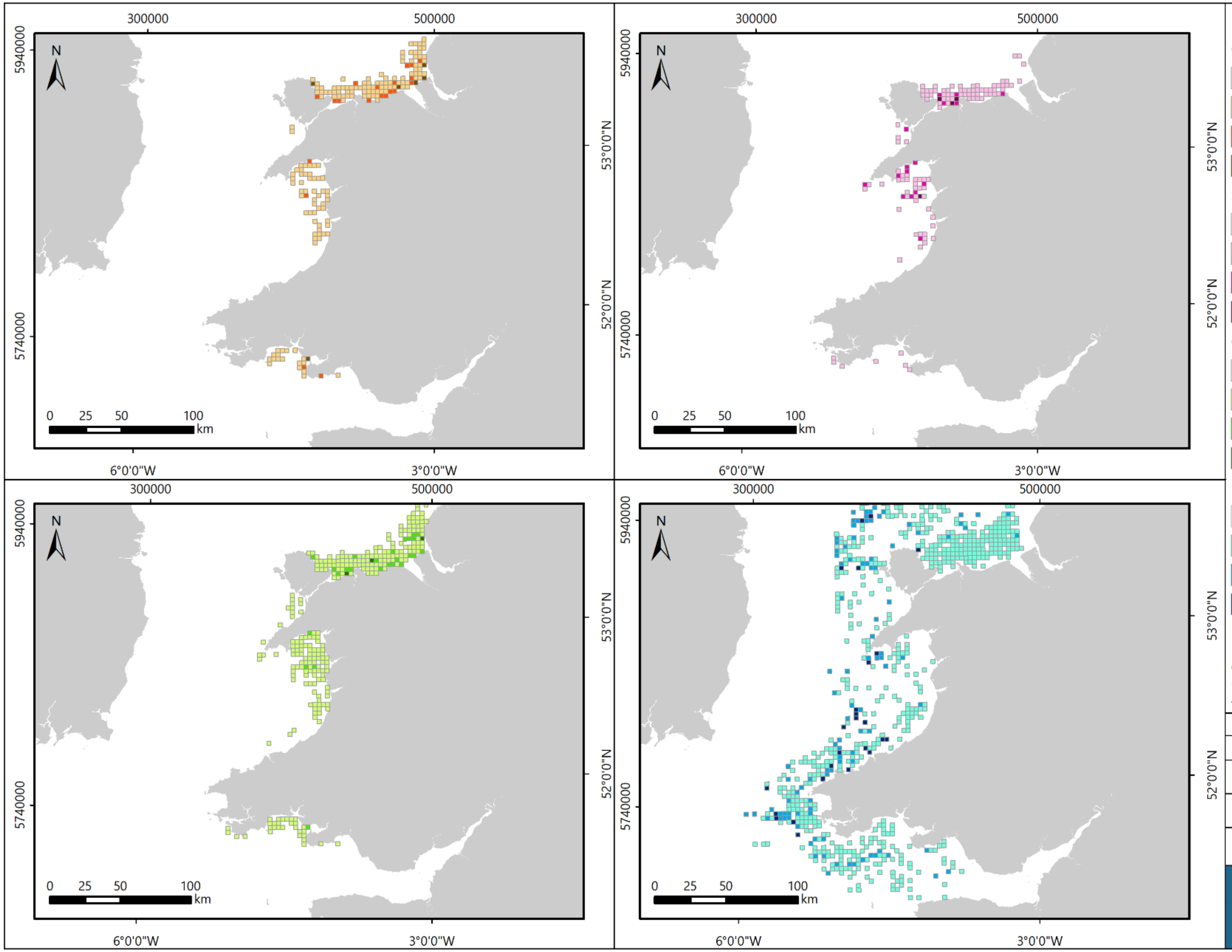
Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference) Mean Max +1SD.	Exception	Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
Common Tern (*Sterna hirundo*) Moderate conservation concern	26.9	N/A	Coastal	Small marine and freshwater fish and aquatic invertebrates.	Shallow plunge diver.	Summer breeder with large breeding colonies on the Skerries Islands off Anglesey and at the Shotton Steel Works in North Wales.
Artic Tern (*Sterna paradisaea*) Greatest conservation concern	40.5	N/A	Coastal	Small marine and freshwater fish and aquatic invertebrates.	Shallow plunge diver.	Summer breeder with the largest breeding colony on the Skerries off Anglesey (largest in the UK) and Ynys Feurig.
Roseate Tern (*Sterna dougallii*) Greatest conservation concern	23.2	N/A	Coastal	Clupeids, gadoids and sandeel.	Shallow plunge diver.	Summer breeder but only a handful of breeding pairs (mainly on the Skerries).

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference) Mean Max +1SD.	Exception	Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
Common Guillemot (*Uria aalge*) Moderate conservation concern	95.2	All Northern Isle SPAs 153.7	Coastal and offshore	Sandeel, sprats herring and small gadoids.	Pursuit diver. Max 200 m, mean 90 m.	Summer breeder with cliff nesting colonies around Wales. Some of the largest colonies being on Skomer, Carreg y Llam and Elegug Stacks (approximately 10,000 pairs at each). At sea distribution is highest close (<100 km) to the breeding colonies.
Razorbill (*Alca torda*) Moderate conservation concern	122.2	All Northern Isle SPAs 164.6	Coastal and offshore	Sandeel, sprat, herring and rockling.	Pursuit diver. Max 140 m, mean 41 m.	Summer breeder with cliff nesting colonies around Wales, the largest being on Skomer (approximately several thousand pairs) but many SSSI are also designated to protect this species. At sea distribution is highest near (<100 km) to the breeding colonies but widely recorded throughout Welsh waters.

Species (taxonomic order)	Foraging range from colony [1,2] (mean max +1SD unless data deficient, in which case use mean max, max, mean in order of declining preference) Mean Max +1SD.	Exception	Foraging habitat [1]	Diet [1]	Foraging behaviour [1], Dive depth [3]	Distribution within Wales [4, 5, 6, 7, 8, 9]
Atlantic Puffin (*Fratercula arctica*) Greatest conservation concern	265.4	N/A	Coastal and offshore	Sandeel, sprat, herring, rockling and small gadoids.	Pursuit diver. Max 70 m, mean 37 m.	Summer breeder with multiple colonies around Wales, the largest being on Skomer (approximately 10,000 pairs). At sea distribution is highest off the Pembrokeshire coast.
Derived from: [1] BirdLife International, 2020; [2] Woodward *et al.*, 2019; [3] Furness *et al.*, 2012; [4] State of Birds in Wales 2018; [5] Seabird Monitoring Programme, 2020; [6]BTO Birdtrack, 2020; [7] Seabirds at Sea Evidence Base data; [8] RSPB utilisation data; [9] NRW SPA Review, 2018						
‘Conservation concern’ is based on the category each species was placed within Birds of Conservation Concern in Wales 3 (Johnstone and Bladwell, 2016).						
*Indicates that the species is not a cited marine SPA feature in Wales. However, these birds are still protected under the waterbird assemblage feature.						

Appendix B - Seabirds at Sea evidence base maps (some areas in Wales may have poor coverage both temporally and spatially)

Figure B1. Indicative abundance of Great Cormorant, Shag, Cormorant spp and Kittiwake based on combined European Seabirds at Sea evidence base and Wildfowl and Wetlands Trust data



Date	By	QA
Jan 20	CRB	DLW

Coordinate System
WGS 1984 UTM Zone 30N

Projection
Transverse Mercator

4817
Fig_Seabirds_at_Sea_1.mxd

Figure B2. Indicative abundance of Fulmar, Gannet, Puffin and Common Scoter based on combined European Seabirds at Sea evidence base and Wildfowl and Wetlands Trust data

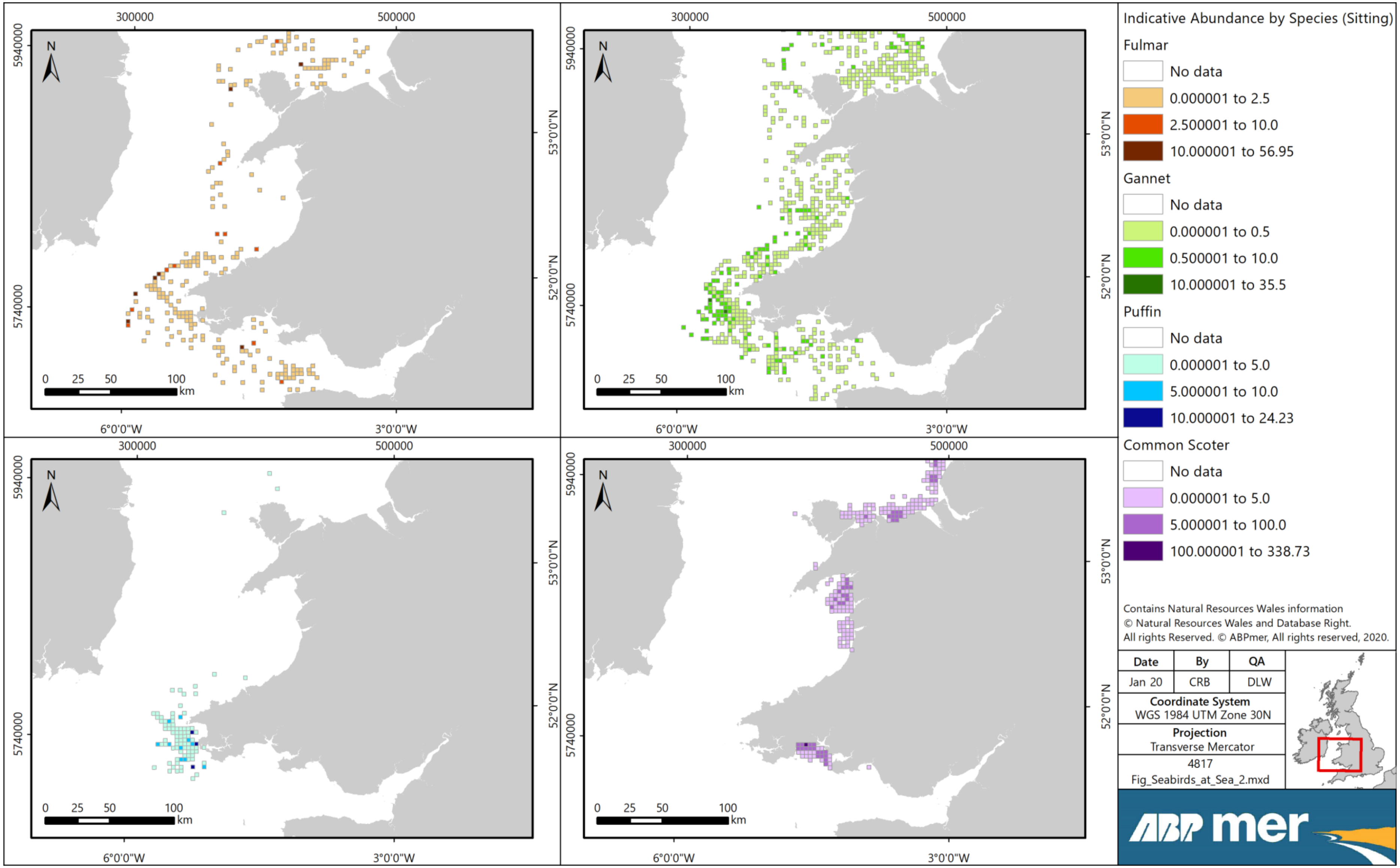


Figure B3. Indicative abundance of Razorbills, Auks, Manx Shearwater and Guillemot based on combined European Seabirds at Sea evidence base and Wildfowl and Wetlands Trust data

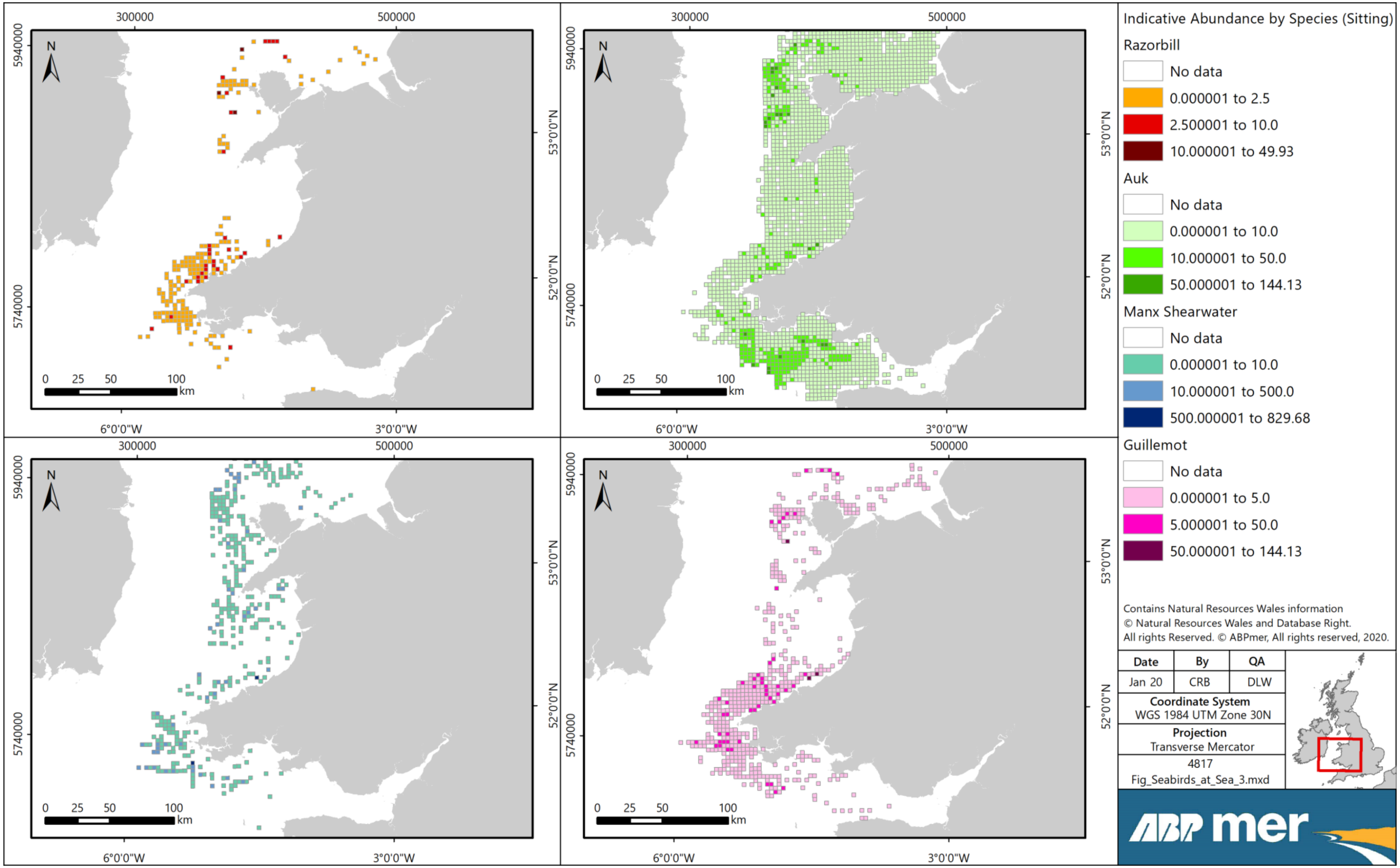


Figure B4. Indicative abundance of Lesser Black-backed Gull, Herring Gull, Common Gull and Great Black-backed Gull based on combined European Seabirds at Sea evidence base and Wildfowl and Wetlands Trust data

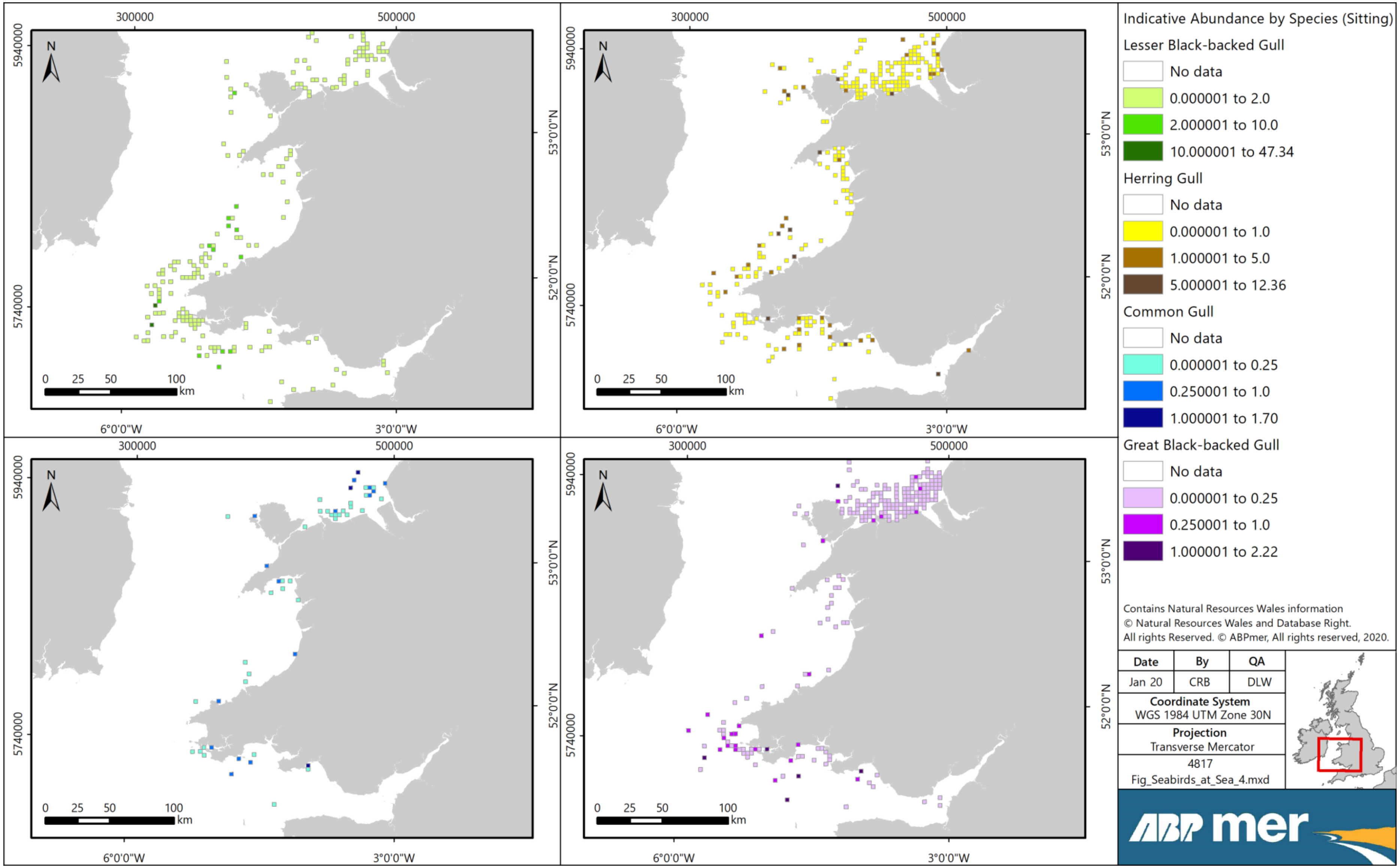
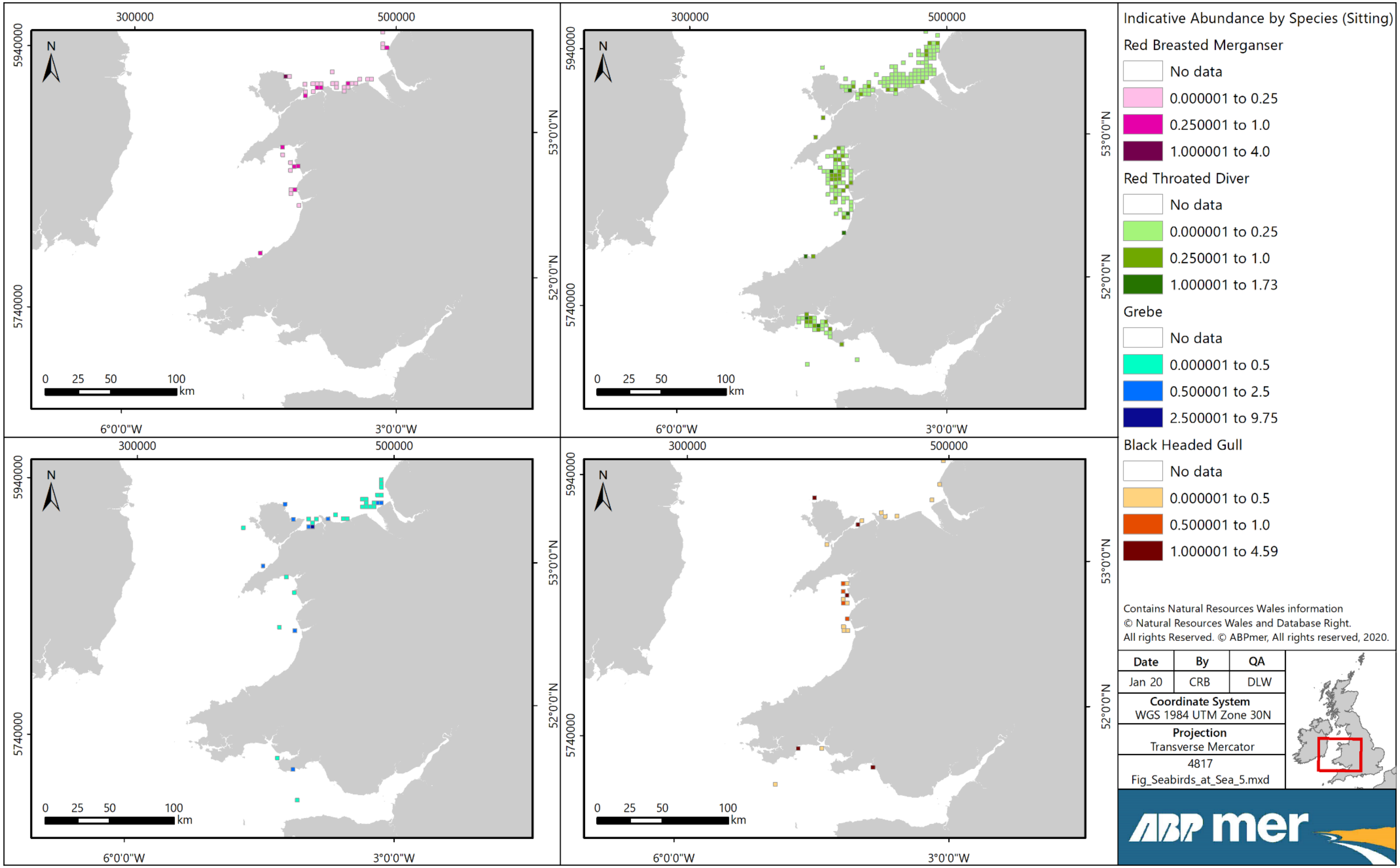


Figure B5. Indicative abundance of Red-breasted Merganser, Red-throated Diver, Great Crested Grebe and Black-headed Gull based on combined European Seabirds at Sea evidence base and Wildfowl and Wetlands Trust data



Appendix C – Royal Society for the Protection of Birds (RSPB) distribution maps

Figure C1. Black-legged Kittiwake distribution

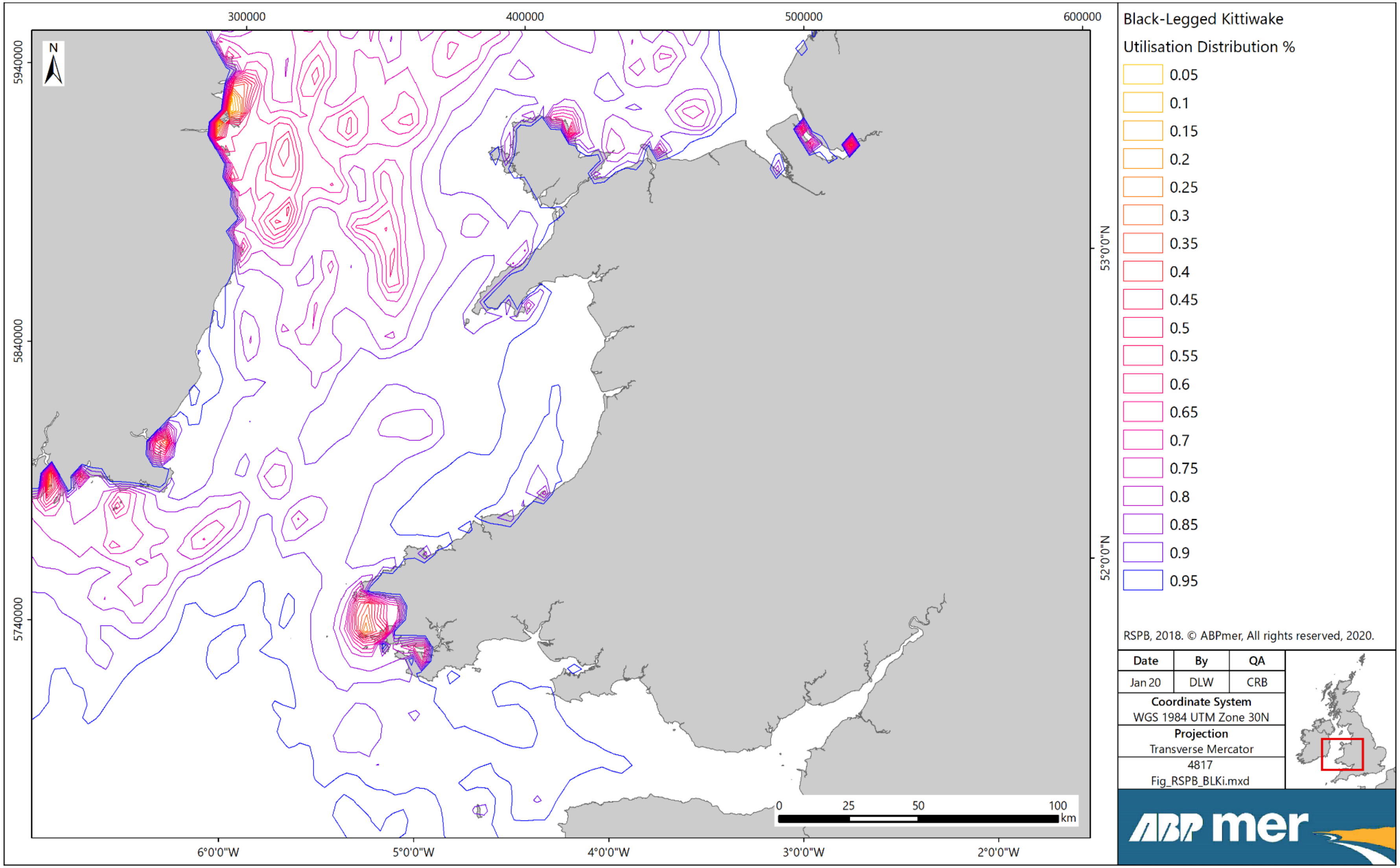


Figure C2. Common Guillemot distribution

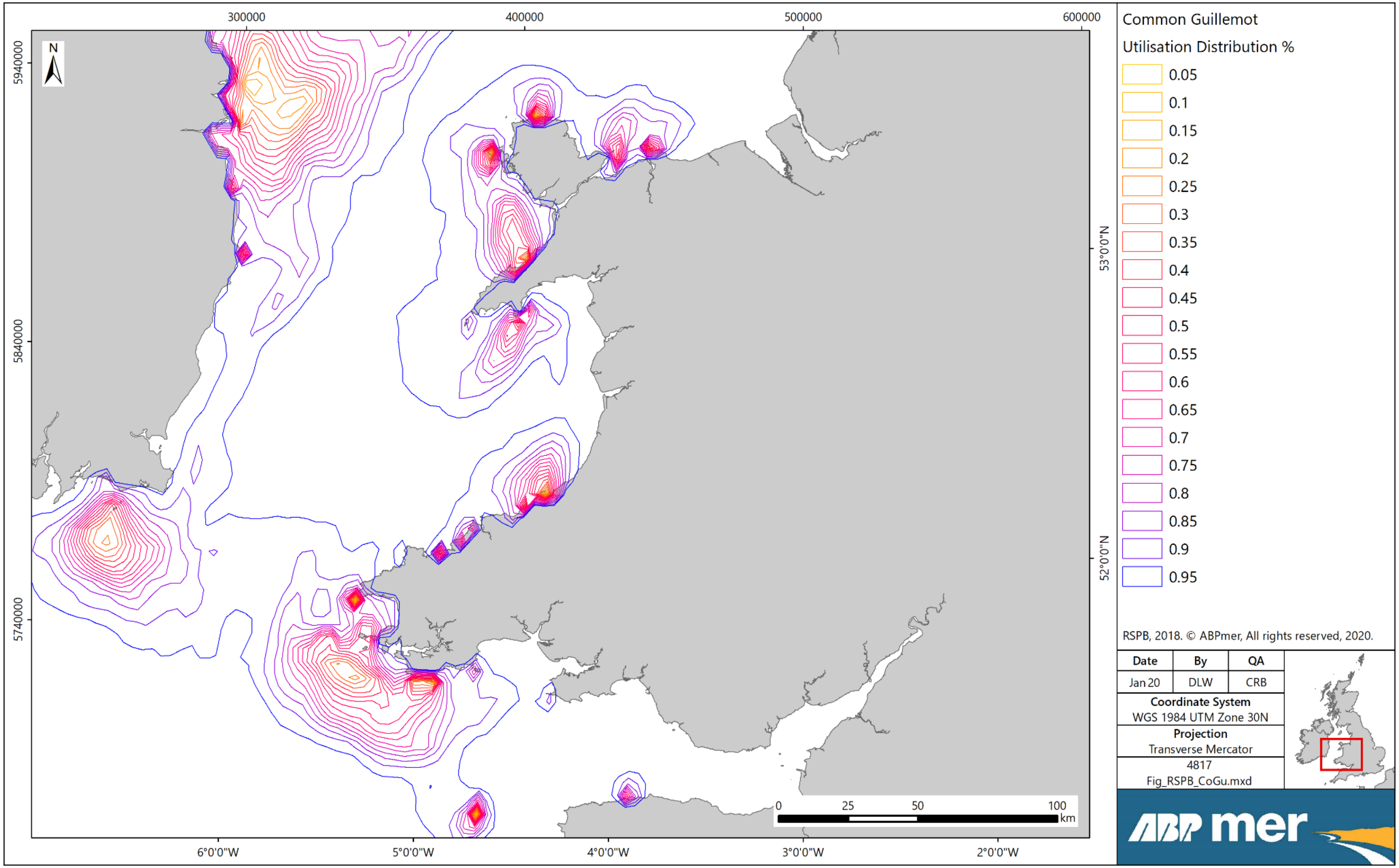


Figure C3. Razorbill distribution

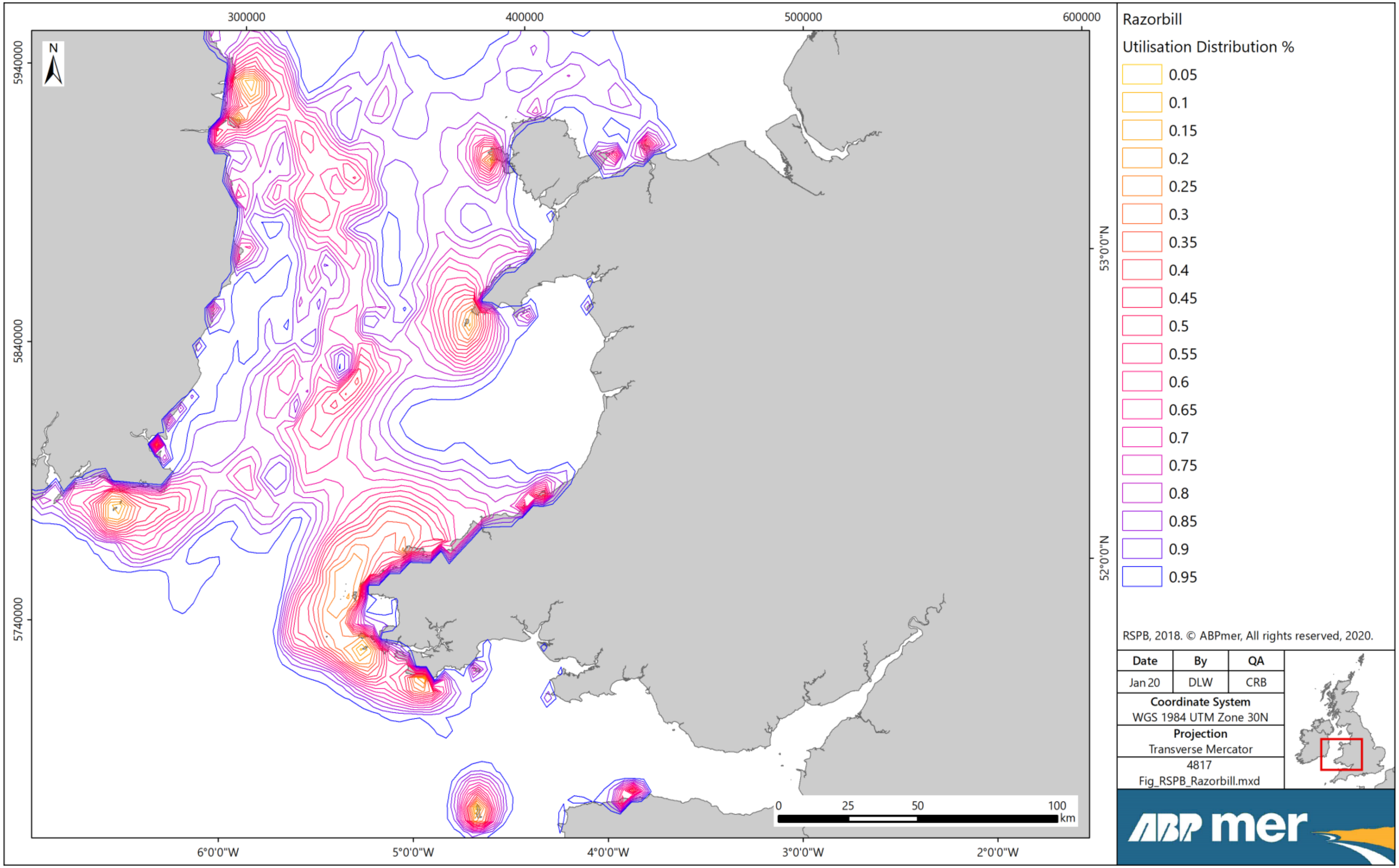
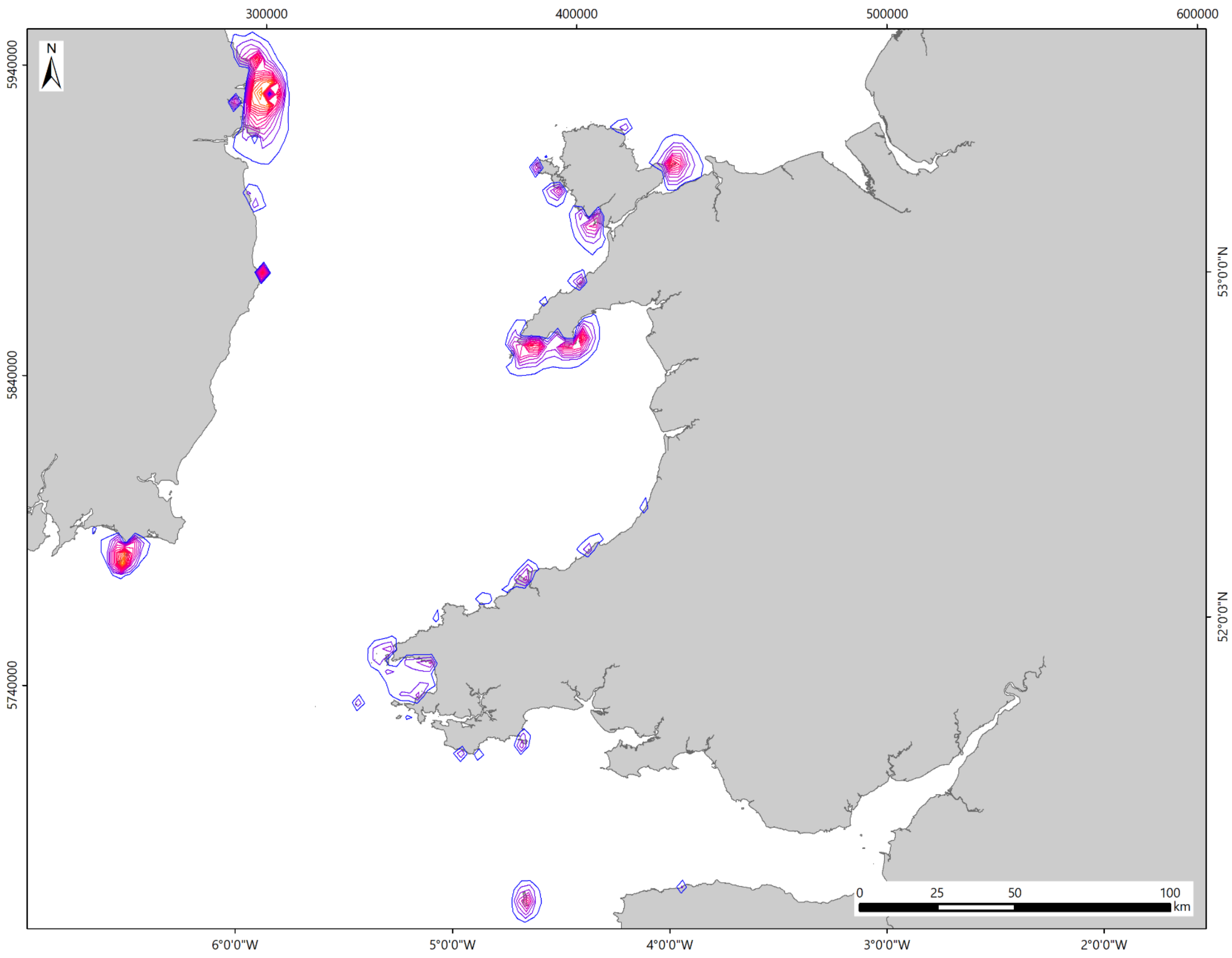


Figure C4. European Shag distribution



Date	By	QA
Jan 20	DLW	CRB

Coordinate System
WGS 1984 UTM Zone 30N
Projection
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Published by:
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