BTO RESEARCH REPORT 791

A review of the Biologically Defined Minimum Population Scale (BDMPS) approach and methodology to apportioning non-breeding season impacts on seabirds arising from offshore wind farms

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BTO Birds Science People

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Foreword, by Natural England

Natural England supports the government's targets for green energy and have published our Approach to Offshore Wind where we strive for "Thriving marine and coastal nature alongside low impact offshore wind energy, tackling both climate and biodiversity emergencies".

Ornithological offshore wind farm impact assessments are complicated, with many steps and associated uncertainty. One of these steps involves the apportioning of predicted impacts on species to relevant Special Protection Areas (SPAs) where they are designated features for Habitats Regulations Assessments (HRA). In the non-breeding season, Biologically Defined Minimum Population Scale (BDMPS) data provide information on the composition of populations in specific sea areas. This information can be used to inform the apportioning of impacts to SPAs. However, the information underpinning this approach requires periodic updates to incorporate new evidence. To address this, Natural England, on behalf of the other Statutory Nature Conservation Bodies (SNCBs), and with funding from the Department for Environment, Food and Rural Affairs (DEFRA), commissioned the British Trust for Ornithology (BTO) to carry out an independent review of the BDMPS approach. The aim of this review is to inform methodological refinements and identify contemporary sources of data for use in an update. This review has taken into consideration the evidence requirements of the SNCBs and has engaged with a representative cross-section of industry stakeholders. This evidence will be used to inform a subsequent update of the original BDMPS work for specified seabird species that will contribute to new guidance and best practice for future offshore wind farm impact assessments.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive Summary

1. UK Statutory Nature Conservation Bodies (SNCBs) require estimates of seabird populations during the non-breeding season to apportion impacts of offshore wind farm developments to Special Protected Areas (SPAs). Furness (2015) formed the Biologically Defined Minimum Population Scales (BDMPS) method, the primary tool in apportioning impacts of offshore wind farms to SPAs for Habitats Regulation Assessments (HRAs) during the non-breeding season. The outputs of the report have also been used to inform reference population values for Environmental Impact Assessments (EIA) and seasonal definitions for assessments.
2. This review (Phase 1) aims to evaluate the methods used within the original Furness (2015) report. We highlight potential refinements to the current BDMPS approach, including methods, definitions, and data resources, to improve future ease of use and accuracy of estimates. The review included workshops to consult SNCBs and industry stakeholders to discuss refinements to populations, seasons, and regional designations within the BDMPS framework.
3. Where feasible, we propose the use of a quantitative and hierarchical approach (based on resolution of available data) for defining regions and seasons. Designation of regions should be informed by tracking data (geolocators, GPS) and updated ring recovery data from repositories such as SEATRACK (**https://seatrack.net**) and The Eurasian African Bird Migration Atlas (**https://migrationatlas.org**). Seasonal definitions may incorporate monthly data to allow greater flexibility in assessments.
4. We suggest that the assessment of uncertainty in population estimates uses a quantitative approach, moving from expert judgement to a data-driven assessment of confidence based on the availability and quality data.
5. Case studies updating population estimates of Guillemots and Great Black-backed Gulls display the application of updated demographic data and highlight the importance of updating proportions of overseas populations in future, for example, using updated population models and tracking data.
6. Discussions within the workshops highlighted the challenge in balancing high-resolution data, biologically meaningful population estimates, and the need to make apportioning based on BDMPS methods practical, ensuring that assessments remain ecologically meaningful and compliant with regulations.
7. Specific discussions focused on potentially adopting a gridded approach to defining BDMPS regions, allowing for finer-scale apportioning of impacts. Additionally, there was discussion on how different SNCBs apply BDMPS data, with some using bespoke seasonal and regional definitions, which potentially require standardisation. Consideration was also given to the different seasonal definitions being used by SNCBs. The need to address cross-border impacts was discussed, particularly in relation to the future inclusion of the Republic of Ireland given the increasing offshore wind development within the Irish Sea.
8. Future work (Phase 2 and beyond) should implement the suggested updates to the BDMPS methodology, address knowledge gaps, update data sources, and provide guidelines on how stakeholders should interpret and use updated BDMPS data to maintain consistency in impact assessments.
9. Ongoing collaboration between conservation bodies, researchers, and industry stakeholders is needed to facilitate updates to the BDMPS methodology and application in future impact assessment.

1. Introduction

The UK Statutory Nature Conservation Bodies (SNCBs) — the Joint Nature Conservation Committee (JNCC), Natural England (NE), Natural Resources Wales (NRW), NatureScot (NS), and the Northern Ireland Environment Agency (NIEA) — need to understand the compositions of seabird populations in the non-breeding season to inform apportioning of impacts to specific components, specifically to make decisions around the consent process for the offshore wind farm industry. The report *Non-breeding season populations of seabirds in UK waters* (Furness 2015), commissioned by Natural England, has been a key piece of work that provides information on the origins and sizes of seabird populations that use UK waters during the non-breeding season, considering their division into appropriate regions (Biologically Defined Minimum Population Scales (BDMPS)). The Furness (2015) report extensively reviewed the most recent data and evidence available at that time. This work has subsequently provided data on reference populations for Environmental Impact Assessments (EIAs), including projects considered within cumulative and in-combination assessments, and apportioning of impacts in the non-breeding season to Special Protection Areas (SPAs) for Habitats Regulation Assessments (HRAs).

The BDMPS approach to apportioning impacts consists of identifying the following information by species (Furness 2015): a) breeding range and taxa; b) non-breeding component of the population; c) phenology of breeding seasons; d) defined seasons; e) movements of birds from UK populations; f) movement of birds from overseas into UK waters; g) numbers of adults and immatures in UK waters; h) proportion of UK population from UK breeding SPAs; i) definition of BDMPS areas for UK waters; j) proportion of UK SPA birds in each BDMPS; and k) spatial distribution of UK breeding SPA birds across the BDMPS. These data are presented in a comprehensive set of tables (Annex A of Furness 2015) that include a species-specific inventory of all UK and overseas populations with some connectivity to UK waters. Furthermore, UK populations are broken down into SPA and non-SPA populations. These UK and overseas populations are apportioned to relevant BDMPS regions in each defined non-breeding season period. The resulting summary tables therefore provide the total number of adult and immature birds present in each BDMPS during different periods (migration and wintering) of the non-breeding season and their origin populations. Furthermore, while not directly provided in Furness (2015), these outputs can be used to calculate SPA apportioning values by estimating the contribution of breeding adults from specific SPAs to total BDMPS populations, which is critical for impact assessments.

Whilst other approaches to apportioning impacts on birds during the non-breeding season, for example, using geolocator data, are being investigated, data are currently restricted to a limited number of species and colonies (i.e. Guillemot *Uria aalge* and Razorbill *Alca torda* from colonies in Scotland; The Carbon Trust 2024) and it may be inappropriate to apply associated methods more widely. Thus, the BDMPS apportioning method remains a relevant and important tool for impact assessments. Further, the seasonal definitions provided by Furness (2015) also provide a reference that is often used by SNCBs in their guidance on assessing separate seasonal impacts on seabirds.

The original Furness (2015) report noted that the outputs, including the tables which facilitate apportioning of non-breeding impacts, would need to be updated as new census data became available and new evidence on migrations and winter distributions was published (e.g. Fayet et al. 2017, Buckingham et al. 2022). This would ensure the continued improvement of the precision and accuracy of the quantification of the proportions of populations estimated to be present within defined spatial areas. Now that the latest seabird census data for Britain and Ireland have been published (Seabirds Count; Burnell et al. 2023), there is an opportunity to update the Furness (2015) work to ensure that the most recent and reliable evidence is used to inform SNCB guidance and reduce uncertainty in impact assessment estimates and consenting decisions. Consequently, Natural England commissioned the British Trust for Ornithology (BTO) to carry out a review of the methodology and approach used in Furness (2015) with input from technical experts and stakeholders.

Due to time and resource constraints, the update to the Furness (2015) report was split into two phases:

- Phase 1 aims to review the original methods used in Furness (2015), clarify SNCB evidence needs, identify possible methodological refinements and contemporary data sources, and ensure industry stakeholders are consulted on the outcomes of the review and given the opportunity to steer the updates.

- Phase 2 (subject to funding) should provide a full update of the BDMPS outputs for a set of agreed species using the methods and sources of data set out in Phase 1. An additional third phase may be necessary in due course but has not been scoped out at this time.

This report relates to Phase 1 of the project, which has the following objectives

1. Agree the key evidence needs of the SNCBs, review the original report and refine methods, definitions, parameters, and outputs (including development of the draft template);
2. Host a workshop to discuss the outcomes of the review and draft template, and agree methods;
3. Develop updated definitions, parameters, and provide worked examples for two species (one data-rich and one data-poor).

2. Components of the BDMPS approach: current use and recommended updates

To identify where updates could be applied to the original BDMPS method, we reviewed Furness (2015) to identify the original analytical steps which contributed to the initial approach; these were then presented within a flow diagram (Figure 1). The diagram separates out primary resources which contribute to each analytical step, followed by the order in which each analytical step is applied to the components used to calculate the BDMPS population estimate. Therefore, the flow chart contains four distinct elements: data source; analytical step; component of estimate; and final population estimate. The approach was applied to 21 species out of a total possible 25 commonly breeding seabird species in the UK, with notable exceptions of some gull and procellariiform species. For each component of the analysis, we review the existing resources and methods used to derive spatial, temporal or demographic definitions. We provide recommendations for enhancing these definitions through updated resources or analytical methods.

In addition, we sought input from SNCBs which use Furness (2015) within their guidance and advice around impact assessments. A consultation meeting with representatives from each SNCB was held, discussing each component of the analysis (see Appendix A). Following this consultation meeting we organised a half-day workshop to obtain further input from relevant experts (e.g. academics and consultants) and stakeholders (e.g. eNGOs and developers) to provide an opportunity for those with an interest in the BDMPS to help steer the project at this information-gathering stage (see Appendix B).

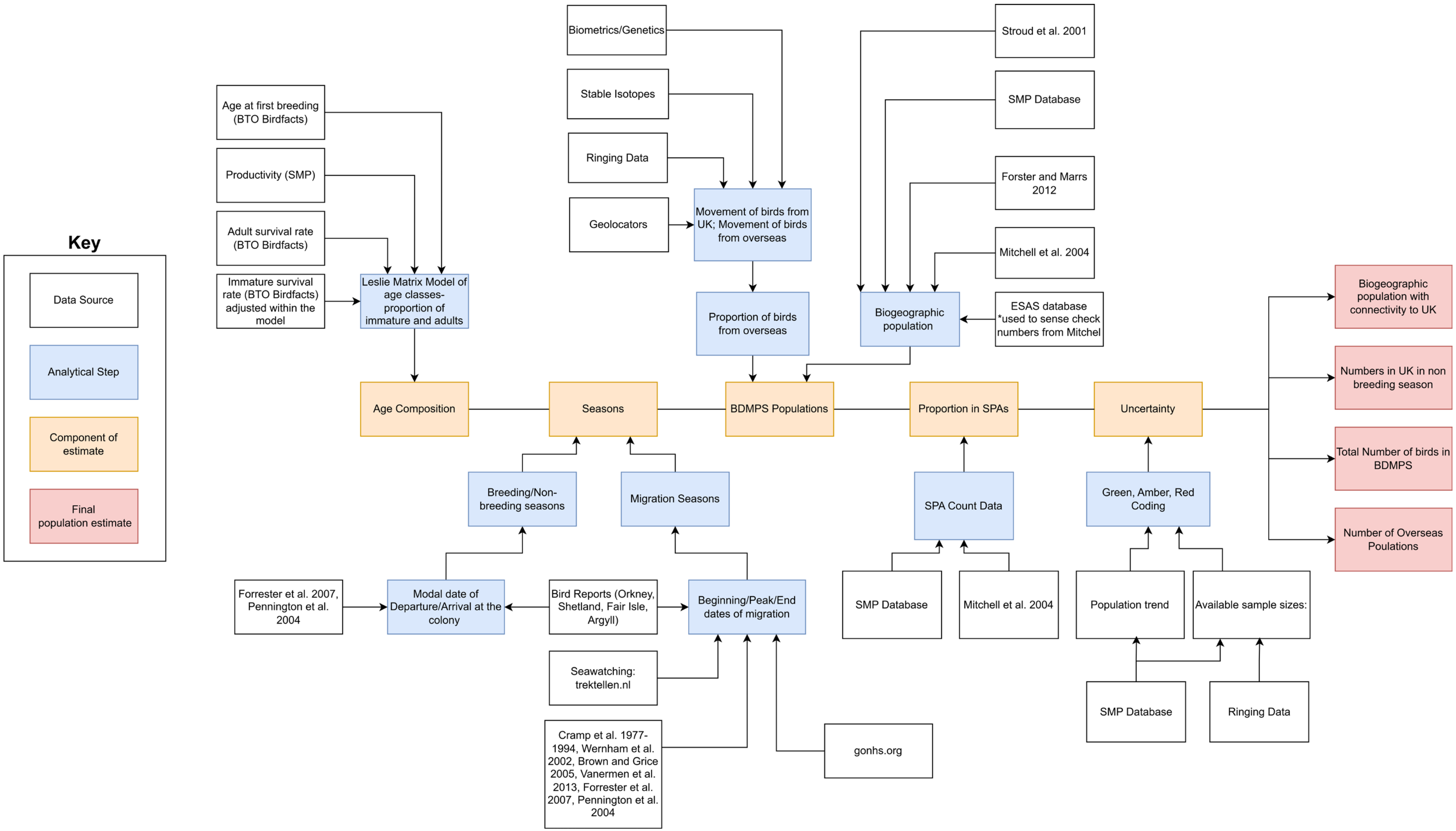
2.1. Definitions of biogeographic population sizes

In Furness (2015), the biogeographic populations defined by Stroud et al. (2001) were refined to the UK and those overseas populations that have connectivity to UK waters at some point in the year, as populations not present in UK waters were not relevant to EIAs and HRAs. The most recent published counts of breeding birds at national scales were taken from Seabird 2000 (Mitchell et al. 2004), but more recent sources were also included, such as species-specific surveys, data presented by NatureScot (Foster & Marrs 2012), the Seabird Monitoring Programme (relevant JNCC reports) and a review by Lewis et al. (2012), the latter being used with caution.

2.1.1. Recommendations

Seabirds Count, the most recent census of UK breeding seabirds largely undertaken between 2015 and 2021 (Burnell et al. 2023), would be the most important source of population count data to be used in an update to the BDMPS report (Phase 2). It includes not only the most recent population counts from the UK (including SPAs), but also covers other countries which have populations that use UK waters during the non-breeding period. Additional sources of data may be accessed to get the most recent counts from overseas populations such as other national monitoring schemes (e.g. SEAPOP **https://seapop.no/en/activities/population-sizes**), BirdLife International DataZone (**https://datazone.birdlife.org**), the *European Breeding Birds Atlas 2* (Keller et al. 2020), or species-specific studies (e.g. Langlois Lopez et al. 2023). Importantly, some species have undergone rapid population declines (notably Great Skua *Stercorarius skua* and Gannet *Morus bassanus*) due to High Pathogenicity Avian Influenza (HPAI) since the last seabird census (Burnell et al. 2023). Therefore, updated population counts for the populations of species that are known to have been heavily impacted by HPAI in the UK should be considered where data are available.

Figure 1. Diagram of the methods used within Furness (2015) to estimate population sizes. Outlined are the resources used (white boxes); analytical steps (blue); main components of the population estimates (orange); and the final population estimates produced for each species (red).



Tremlett et al. (2025) provides estimated population changes in UK seabirds following the HPAI epidemic in 2021–2022 and its use would therefore be recommended.

The example case studies presented in the Excel workbook (Appendix C) are produced using the updated population estimates reported within Burnell et al. (2023).

2.2. Definitions of species-specific seasons

In Furness (2015), seasons were defined in the context of the UK breeding season, with the remaining part of the year defined as the non-breeding season, which was sometimes further divided (see below). These seasons were species-specific and generally defined using modal arrival and departure dates at breeding colonies (Furness 2015). A wide range of sources were consulted to identify the timing of breeding and migratory movements, notably *The Migration Atlas* (Wernham et al. 2002), *Birds of Scotland* (Forrester et al. 2007), *Birds of Shetland* (Pennington et al. 2008), annual bird reports, the Gibraltar migration watch website, and Trektellen. The non-breeding season was also further divided, where possible, into the following components of the annual cycle:

- Spring migration was defined as the months when birds moved through UK waters towards breeding grounds, which may overlap with the UK breeding season as birds from overseas populations, particularly those from high latitudes, migrate later in the year than UK birds.
- Autumn migration was defined as the months when movements of the species through UK waters away from breeding colonies was evident.
- The wintering period was considered to be the period between autumn and spring migrations.

Inter-annual variation in seasonal movements by birds was considered to be greater than any differences in the timing of movements between UK populations due to latitudinal differences. Therefore, seasonal definitions in Furness (2015) were kept consistent across all BDMPS regions, based on the phenology of UK breeding populations. Outputs in the form of the estimated number of birds in a BDMPS region were presented for each season, which were a set of lumped months. However, it is important to note that inter-annual variation in phenology poses an important challenge when defining seasons for BDMPS, which is further compounded by latitudinal differences in phenology within the UK and between the UK and overseas populations. A conservative approach that defines seasons considering the phenological movements of both UK and overseas seabirds is likely most appropriate where a fixed approach to seasonal definitions is used.

2.2.1. Recommendations

An update to the Furness (2015) report should consider updating the sources of phenological data used in Furness (2015) and including new sources of information such as BirdTrack (**www.birdtrack.net**). Furthermore, implementing a hierarchical approach based on data quality and availability to define the species-specific non-breeding seasons would be beneficial, making the definition process more quantitative and replicable. For example, standardised sources of phenological data would be given priority over opportunistic observations or expert opinion, resulting in the following hierarchy for each species: Trektellen > BirdTrack > birds reports > expert opinion.

The numbers and exact definitions of seasons vary between species in Furness (2015), and these are generally defined as a block of months. Consultations with SNCBs have highlighted that seasonal definitions are important for the current assessment process, but also that these may vary between different regions where better evidence exists, for example between Scotland and England. This has led to challenges when considering assessments that span more than one country and different seasonal definitions and associated months of the years are used by the relevant SNCBs. We therefore recommend presenting outputs at a monthly resolution, whilst also providing standardised species-specific seasons (autumn migration, winter, spring migration, breeding; although some species may not be present in UK waters during some of these thus will have no data). These outputs would have the same information as in Furness (2015), but also higher resolution monthly data that can be grouped to define different seasons where necessary, making them more flexible to accommodate future updates.

Additionally, presenting outputs at a monthly resolution would align the BDMPS with other aspects of the assessment process such as at-sea site characterisation surveys and collision risk modelling, although not the current approach to assessing displacement impacts using matrices which relies on mean peak seasonal abundance estimates. An example table of how outputs may be presented can be seen in Table 1.

Outputs in the Excel workbook (Appendix C) are presented at a monthly resolution following the recommended guidelines mentioned above. However, the seasonal definitions have not been revised from Furness (2015), as this would have required additional analysis that was not within the scope of this project.

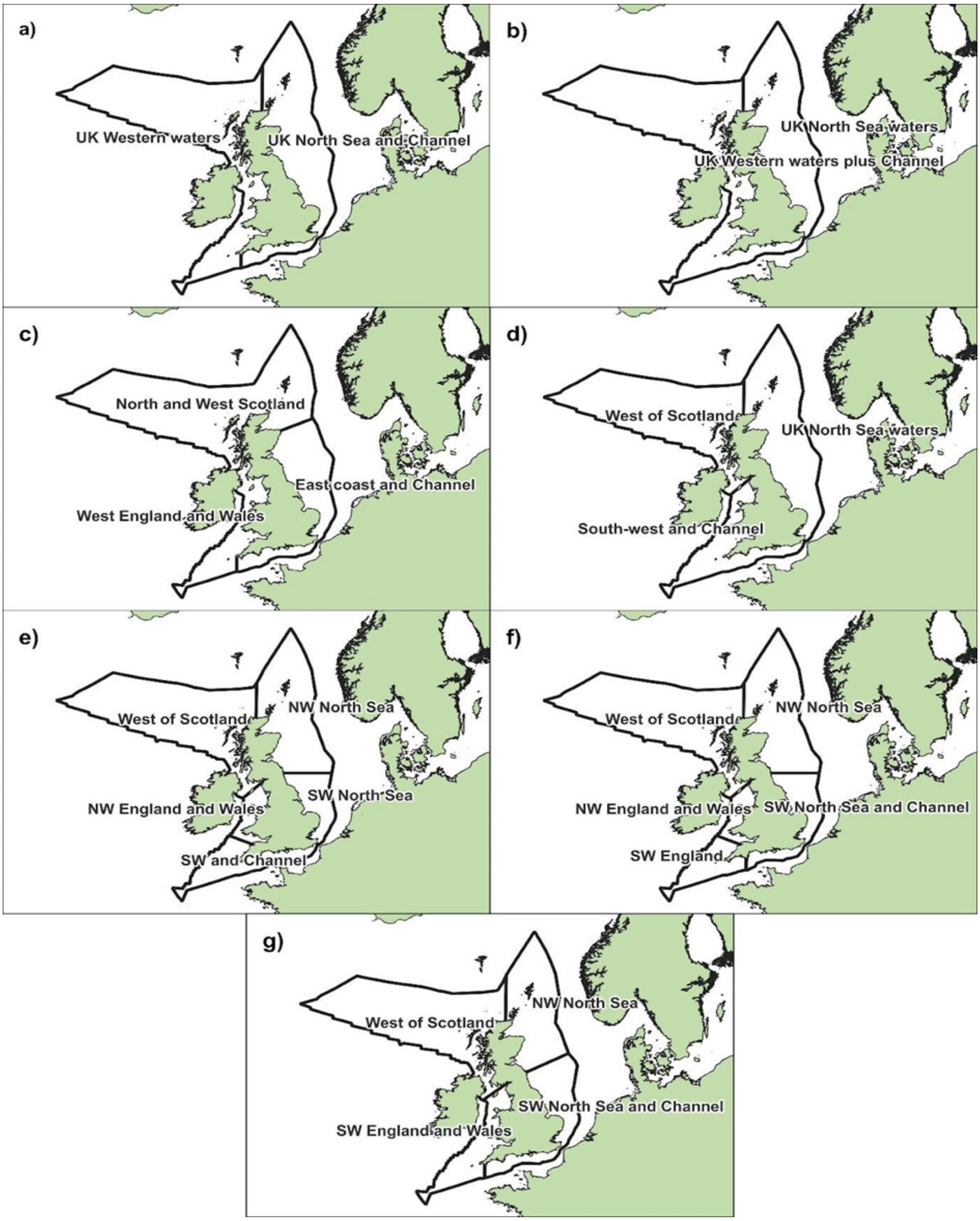
Table 1. Example of how BDMPS outputs may be presented in an update of Furness (2015). The estimated total number of birds, and 95% Confidence Intervals (CIs) in each BDMPS region is presented for every month, with seasonal definitions alongside them. CIs could be based on a weighted assessment of the amount and quality of survey, tracking, and ringing data available.

Month	Season	Region	Total no. of birds of a species in BDMPS region (mean)	Total no. of birds of a species in BDMPS region (95% CIs)
January	Winter	UK Western Waters	100	50–200
February	Winter	UK Western Waters	50	25–100
March	Spring migration	UK Western Waters	10	0–20
April	Spring migration	UK Western Waters	10	0–20
May	Spring migration	UK Western Waters	10	0–20
June	Breeding	UK Western Waters	10	0–20
July	Breeding	UK Western Waters	10	0–20
August	Breeding	UK Western Waters	10	0–20
September	Autumn Migration	UK Western Waters	50	25–100
October	Autumn Migration	UK Western Waters	50	25–100
November	Autumn Migration	UK Western Waters	100	50–200
December	Winter	UK Western Waters	100	50–200

2.3. Definitions of BDMPS regions

BDMPS regions as defined in Furness (2015) were intended to reflect the presence of seabird metapopulations based on migration, site fidelity, and dispersal within UK waters, using knowledge of movement from studies based on ringing recoveries (Wernham et al. 2002), geolocators (GLS) (Guilford et al. 2009, Harris et al. 2013), surveys (Forrester et al. 2007), and biometrics (Weir et al. 1996). For most species, two main BDMPS regions are defined, broadly comprising the North Sea and the Atlantic (e.g. Fulmar *Fulmarus glacialis*, Great Skua, Manx Shearwater *Puffinus puffinus*, tern spp, auk spp – see Figures 2a–g). These regions were further delineated by north and south where relevant for some species (e.g. Red-throated Diver *Gavia stellata*, Shag *Gulosus aristotelis*, Cormorant *Phalacrocorax carbo* – see Figures 2d–g).

Figure 2. Original definitions of BDMPS regions from Furness (2015), showing boundaries for: a) Puffin, Guillemot, Razorbill, Little Tern, Arctic Tern, Common Tern, Herring Gull, Lesser Black-backed Gull, Arctic Skua, Great Skua and Gannet, b) Manx Shearwater, Fulmar and Kittiwake, c) Roseate Tern, D) Great Black-backed gull, e) Red-throated Diver, f) Great Northern Diver, and g) Cormorant and Shag. Note that the outer boundaries are defined by the UK's Exclusive Economic Zone (EEZ). Shapefiles for each region were provided by JNCC and had been produced as part of the JNCC report *Review and Update Of Seabird Demographic Rates For Use In Population Modelling* (in press).



2.3.1. Recommendations

We recommend the use of a spatial analysis approach to the identification of regions. Novel or updated resources should be used to assign BDMPS regions in a hierarchical manner based on the resolution and propensity of the study data, following a structure of: Tracking data > ring recovery data > biometrics > surveys.

Both GPS and GLS tracking are potential resources for identifying winter movements for some seabird species, with data being provided through online portals such as the BirdLife Seabird Tracking Database (**https://data.seabirdtracking.org** – Fauchald et al. 2021) and Movebank (**https://www.movebank.org**). GPS tracking can obtain high resolution information on movements (10 s to 60 mins), but are limited in their applicability for most species in the winter periods by the functionality of long-term attachment methods. GLS provide a suitable long-term alternative and are applicable to a wider range of species based on their ability to be leg mounted (Buckingham et al. 2022); however, the temporal and spatial resolution is coarse with mean errors of 186 +/- 114 km (Phillips et al. 2004). An updated method would also benefit from up-to-date ring recovery/resighting data such as those presented in the open access Eurasian African Bird Migration Atlas (**https://migrationatlas.org** – Spina et al. 2022).

Outputs in the Excel workbook (Appendix C) are presented using the same BDMPS regions as in Furness (2015), since defining new regions relies on data analysis which was not within the scope of Phase 1 of the project.

2.3.1.1. Examples of species-specific updated resources

Red-throated Divers were assigned five wintering regions by Furness (2015), which were consolidated into two broader migration regions. These regions are based on ringing recoveries (Wernham et al. 2002) and survey count data (O'Brien et al. 2008, Dillon et al. 2009), which indicated that Scottish populations stayed closer to their breeding areas, while comparative populations from Fennoscandia and Greenland were presumed to disperse further afield. Identification of regions for Red-throated Diver would benefit from available GPS tracking studies within the North-east Atlantic (**https://www.divertracking.com**), GLS tracking (Duckworth et al. 2022) and updated ring recovery data (Spina et al. 2022).

Great Northern Divers *Gavia immer* were divided into five non-breeding regions, with the highest concentrations suggested to be in the west of Scotland and north-west North Sea, largely based on the wintering preferences of birds from Iceland and Greenland based on biometric studies (Weir et al. 1996, Camphuysen et al. 2010). There is a current knowledge gap for the winter movements of Great Northern Divers in UK waters.

For Fulmars, due to their highly pelagic nature, their metapopulation likely encompasses all of UK waters; however, for practical purposes they were assigned two regions largely based on ring recovery data (Wernham et al. 2002). However, GLS tracking of Fulmars has increased in availability (Dupuis et al. 2021, **https://seatrack.net/seatrack.net**), potentially providing high resolution data of winter movements alongside updated ring recoveries (Spina et al. 2022).

Manx Shearwaters were assigned two migration regions, but no wintering BDMPS, as they leave UK waters entirely during winter, as evidenced by ring recovery and GLS studies (Wernham et al. 2002, Guilford et al. 2009). Updated regions can be informed by further availability of GLS data (**https://data.seabirdtracking.org/dataset/1087; https://data.seabirdtracking.org/dataset/1091**).

Gannets were categorised into two regions for each spring and autumn migration, reflecting migration routes in the North Sea and Atlantic (Kubetzki et al. 2009, Garthe et al. 2012). Region allocation for Gannets can benefit from both GLS (Atkins et al. 2023) and GPS (Garthe et al. 2024) tracking studies, and metapopulation studies (Jeglinski et al. 2023) published in the interim since the last report.

Cormorants were divided into four regions based on high site fidelity of resident birds and inland movements of continental birds, particularly in south-east England, during the non-breeding season (Wernham et al. 2002, Brown & Grice 2005). Shags were also regarded as largely sedentary, exhibiting limited dispersal, and therefore assigned four regions (Harris & Swann in Wernham et al. 2002). While very few advances have been made to our knowledge of Cormorant winter dispersal, colour ring data may be a potential resource. Shags have benefited from GLS studies within the North Sea and west of Scotland (**https://seatrack.net/species/european-shag**), and have been subject to intensive colour ringing studies during the non-breeding season in some locations, specifically on the east coast of Scotland.

Both skua species were assigned two regions reflective of the North Sea and Atlantic (Wernham et al. 2002, Furness 2010). Spring and autumn seasonal distinctions for Arctic Skuas *Stercorarius parasiticus* are based on seawatching data which suggest that birds undertake a more westerly migration around the UK in spring than in autumn. Great Skuas were additionally assigned a winter season, with UK breeding birds suggested to be present in both regions at this time of year within the UK, in comparison with Icelandic and Norwegian populations which winter further north (Forrester et al. 2007, Magnusdottir et al. 2012). Recent GLS tracking of Arctic Skuas (O'Hanlon et al. 2024, van Bemmelen et al. 2024) and Great Skuas (**https://seatrack.net/species/great-skua**) may be applied to future regional designations for the species.

Lesser Black-backed Gulls *Larus fuscus* and Herring Gulls *L. argentatus* were assigned two regions based on the North Sea and Atlantic. Lesser Black-backed Gulls are primarily migratory, with some overwintering inland (Wernham et al. 2002, Camphuysen 2013). Regional designations for Herring Gulls are potentially unreflective of limited movements between coastal and inland sites (Wernham et al. 2002, Camphuysen 2013). Both Lesser Black-backed Gulls and Herring Gulls have been the subject of high-resolution GPS year-round tracking studies during the non-breeding period which can directly inform regional definitions (Thaxter et al. 2019, O'Hanlon et al. 2022), in addition to the use of colour ringing data (Walker et al. 2021).

Great Black-backed Gulls *L. marinus* were assigned three regions, inferring that Barents Sea birds primarily winter in the North Sea, while UK birds remained local (Wernham et al. 2002, Hammer et al. 2014). GPS tracking over the non-breeding season have has been carried out on Great Black-backed Gulls (Langlois Lopez et al. 2024, **https://ecowende.nl/en/news/great-black-backed-gulls-tagging-with-gps**), though with a caveat around the representability of these data.

Kittiwakes *Rissa tridactyla* were split into North Sea and Atlantic populations, with resident UK populations mixing with populations from Russia, Norway, and the Barents Sea (Wernham et al. 2002, Frederiksen et al. 2012). Kittiwakes have been the subject of a number of GLS tracking (**https://seatrack.net/species/black-legged-kittiwake**), genetic, and metapopulation studies.

Common Tern *Sterna hirundo*, Arctic Tern *S. paradisaea*, Little Tern *Sternula albifrons* and Sandwich Terns *Thalasseus sandvicensis* were assigned to North Sea and Atlantic regions. Sandwich Tern regions were reflective of the migration of European birds through UK waters (Stienen & Brenninkmeijer 1998, 2002, Wernham et al. 2002). The North Sea region for Common Tern reflected migrating eastern colonies and continental Europe, while the Atlantic region contained migrating birds from western UK colonies (Wernham et al. 2002, Meissner & Krupa 2007). Little Tern migration had limited connectivity to non-UK populations (Wernham et al. 2002, Trektellen dataset). Roseate Terns *S. dougallii* had three regions, based on connectivity to Irish colonies (Wernham et al. 2002, Brown & Grice 2005). Further knowledge on tern migration can be informed by GPS and GLS tracking (**https://seatrack.net/species/arctic-tern**), and the potential use of colour ring studies.

For auks, Guillemots, Razorbills and Puffins *Fratercula artica* were assigned two regions, comprising the North Sea and Channel, and Western Waters. Regions for Guillemot were justified by birds breeding on eastern and western coasts of the UK with birds exhibiting distinct dispersal patterns; however, movements vary by colony, broadly with North Sea birds remaining within the region, while western birds disperse into the Atlantic (Wernham et al. 2002, Forrester et al. 2007). Similar regions for Puffins were supported by tracking data showing that western birds undertake long-distance migrations, while some eastern birds remain in the North Sea (Guilford et al. 2009, 2011, Harris & Wanless 2011). In contrast, Razorbills were divided into migration and winter periods, these divisions reflected greater dispersal behaviour compared to Guillemots (Buckingham et al. 2022). These three auk species have been the subject to large scale GLS tracking projects, all of which can provide further information on winter movements and proportion of overseas birds within UK waters during the winter (**https://seatrack.net**).

Black Guillemots *Cepphus grylle*, being highly sedentary, were assigned a single BDMPS within 20 km of breeding sites (Ewins & Kirk 1988, Mitchell et al. 2004). Their extreme site fidelity meant larger spatial scales were unnecessary. Further knowledge of Black Guillemot dispersal behaviour using ring recovery data during the winter may challenge preconceptions of their sedentary nature during the winter (Johnston et al. 2018).

2.4. Proportion of populations (all ages) within each BDMPS region in each season

The apportioning of UK and overseas seabird populations to different BDMPS regions is one of the most challenging aspects of this work due to the lack of data and knowledge about the extent of movements from different populations and differences in movements between adults and immatures. Furness (2015) carried out extensive species-specific literature reviews and used multiple sources of data to define the proportion of adults and immatures from the biogeographic population that used each BDMPS region at different times of the year. The data sources considered were ringing recoveries, tracking, and seawatching, but also genetics, stable isotopes, and biometrics. *The Migration Atlas* (Wernham et al. 2002) was the primary resource used to inform apportioning decisions, supported by more recent studies where these were available (Furness 2015). This approach can be considered as expert opinion based on extensive literature review. However, it was highlighted in Furness (2015) that the allocation of numbers of seabirds, especially from overseas populations, to UK waters is rather uncertain for most species, creating a major constraint to the estimation of the total number of birds in BDMPS regions and the relative contribution of UK (including individual SPAs) and overseas populations in each.

2.4.1. Recommendations

A recommended update to the apportioning of the biogeographic population to BDMPS regions is the use of a hierarchical approach based on data availability and quality for each species to implement a more replicable and quantitative method. For example, ringing data > tracking data > published literature > expert opinion.

Ringing recovery data at a European scale still offer the best approach to estimating the proportion of individuals from different populations that use UK waters since these generate data from all age classes. Known biases arising from ringing and recovery effort can be accounted for where there are sufficient data (see Korner-Nievergelt et al. 2014), and many species such as gulls and terns have large amounts of ringing data generated by colour-ringing projects where birds can be resighted (see **https://cr-birding.org**).

Similarly, the number of projects that have tracked seabirds year-round with GLS has increased substantially in recent years for several species, although not all colonies will be represented and thus their representativeness will likely vary between species according to tracking effort. These data may be used to estimate the number of birds that move into UK waters from overseas populations during the non-breeding season. Notably the SEATRACK database holds tracking data from several seabird species from colonies throughout the North Atlantic (**https://seatrack.net**). Other tracking data sources include Movebank (**https://www.movebank.org/cms/movebank-main**) or BirdLife International's Seabirds Tracking Database (Fauchald et al. 2021, Carneiro et al. 2024; **https://www.seabirdtracking.org**) where some data are publicly available, or data requests can be made.

Tracking studies could be used in combination with ringing data as tracking data are generally limited to breeding adults, and immatures are known to often differ in their behaviour and distributions to adults (Fayet et al. 2015). European Seabirds at Sea (ESAS 2025) or digital aerial surveys data can also be used to compare against tracking studies to potentially reveal differences in distribution between immatures and adults where the distribution of adult birds is known through tracking. Overall, the analysis of ringing and tracking data offers the most robust and quantitative approach to quantifying the extent of movements of UK and overseas birds into UK waters. However, sourcing, managing, and analysing such data is time consuming even when publicly available. Furthermore, such data may not be available for some species, and thus reverting back to expert opinion based on published literature, as in Furness (2015), will likely be necessary in some cases.

Outputs in the Excel workbook (Appendix C) are presented using the same estimated proportions as in Furness (2015) since estimating the extent of birds' movements into UK waters with new data requires analysis which was not within the scope of Phase 1 of the project.

Furthermore, estimating the number of adult and immature birds in any BDMPS during the breeding season provides helpful reference population information for EIAs as, for some species, there are more birds in a BDMPS during breeding than during non-breeding. During the breeding period, birds in a particular BDMPS are likely to originate from UK breeding colonies located in that BDMPS. However, there may be some mixing of immature and sabbatical birds across BDMPS regions and with overseas populations during the breeding season. There is currently a lack of evidence to support the calculation of the non-breeding (sabbatical) and immature populations that are likely to be found within a BDMPS region during the breeding season. Thus, the current approach, recommended by Natural England, simply relies on the summing of the adult and estimated (from population models) immature components as defined for all colonies that fall within a relevant BDMPS. Such estimates were not provided in Furness (2015), but worked examples are provided in the Excel workbook (Appendix C).

2.4.1.1. Apportioning SPA birds to BDMPS

Further to estimating the proportion of birds from populations with connectivity to UK waters that spend some time of the year in each BDMPS, it is then also necessary to estimate the contribution from each SPA in the UK to the total number of birds in a BDMPS. The current apportioning method recommended by Natural England estimates the proportion of the total number of birds in a BDMPS comprised of breeding adults from a particular SPA. Example calculations are presented in the Excel workbook (Appendix C) for the two case study species.

2.5. Population estimates (all ages) for relevant components of the biogeographic population

Only the breeding adult component of seabird populations is counted at breeding colonies since immatures do not typically visit these until several years old in many species. However, when considering the number of individuals in a BDMPS, these must include the immature non-breeding component of the population as well, which in some cases may be larger than the adult breeding component. In addition, abundance counts also do not cover birds of breeding age that are not actively breeding that year (e.g. taking a sabbatical). Furness (2015) used Leslie matrices to build simple population models that represented the population structure of the species of interest to estimate the size of the immature non-breeding population. The stable age structure was extracted from these models to estimate the proportion of immatures and breeding adults in the biogeographic population, which could then be translated into absolute numbers of immatures and adults in each BDMPS. These models required species-specific demographic parameters (survival of all age classes, maximum brood size, productivity, and age of first breeding) that were obtained from BTO Birdfacts (**www.bto.org/learn/about-birds/birdfacts**). However, the survival parameters were adjusted (with survival rates always increasing with age up to the adult survival rate) to achieve a stable population (i.e. a zero rate of population growth) in all species, rather than building models that represented known population trends (Furness 2015). This approach was considered to be precautionary in that an increasing population will tend to have a higher ratio of immatures to breeding adults than will be present in a stable population, whereas a declining population may or may not differ in ratio of immatures to adults depending on which age classes are exposed to elevated mortality rates that are causing the population decline (Furness 2015).

2.5.1. Recommendations

Since the Furness (2015) report was published, there has been an extensive review of demographic parameters for seabirds that breed in the UK (Horswill & Robinson 2015), with another expected update in 2025. These sources of demographic parameters are more appropriate than BTO Birdfacts, as the origin of some of the data in BTO Birdfacts was uncertain and unlikely to represent the most up-to-date information (Furness 2015).

Using Leslie matrices to build Population Viability Analyses (PVAs; or simple population models as referred to in Furness 2015) remains a widely used and appropriate method to model the population dynamics of seabirds as long as their demographic rates and population trends remain fairly consistent (Akçakaya & Sjögren-Gulve 2000, Searle et al. 2022). Deterministic PVAs (where no variance in demographic parameters is applied in the model) can be easily run in R (R Core Team 2021) with the Natural England Population Viability Analysis (NEPVA) tool (**https://github.com/naturalengland/Seabird_PVA_Tool/tree/master**). However, it is important that model outputs are validated against empirical population counts to ensure that PVAs are as representative as possible of real populations (Searle et al. 2022, Langlois Lopez et al. 2023). Therefore, a more appropriate approach to quantifying the proportions of breeding adults and immatures would be to build PVAs that represent the population trend of the study species at an appropriate scale, rather than modelling all populations as stable (as done in Furness 2015).

Where input parameters obtained from the literature do not produce models that match, the survival of adults and immatures can be adjusted (increased or reduced) to produce modelled trends that match observed trends based on seabird census data. Once this is achieved and final demographic parameters are identified, the population age structure can be obtained using the popbio R package (Stubben & Milligan

2007). The R code used to produce the estimated age structure of all species would be provided as an output of Phase 2 of the project.

Selecting an appropriate spatial scale to define PVAs is important as there may be differences in population trends between different components of the biogeographic population (e.g. declines in UK breeding Great Black-backed Gulls but stability in Norway; Langlois Lopez et al. 2023), and thus their population structures may be different (the proportion of immatures may be different among populations with different trends; Furness 2015). Where population trends are known at national scales and demographic data are available, separate PVAs could be built to calculate the number of immatures in each respective population, although this would be more time consuming than building a single PVA, particularly if there are several populations with connectivity to UK waters. Alternatively, the trend of the UK population (based on the two most recent seabird censuses; Mitchell et al. 2004 and Burnell et al. 2023) could be used, particularly if most of the birds in UK waters originate from UK populations (e.g. Guillemot). Such an approach offers flexibility depending on data availability, and the best approach can be selected on a species-by-species basis. For example, the PVA used to estimate the age structure of Guillemots in the Excel workbook (Appendix C) was based on the UK trend since most Guillemots in UK waters come from UK colonies. However, for Great Black-backed Gulls, their population structure was extracted from a PVA that represented the population trend at a European scale since most birds present in UK waters during non-breeding come from overseas European populations.

2.6. Methods for providing indicative levels of confidences in the outputs for each species

The level of uncertainty in BDMPS population estimates in Furness (2015) was determined using a traffic light system, categorising assessments as green (low uncertainty, numbers accurate to ±30% to ±50% of reported estimate), amber (moderate uncertainty, up to ±50% to ±80%), or red (high uncertainty, exceeding ±80%). Categories were based on expert judgment, taking into account the availability of census data, accuracy of at-sea survey estimates, tracking data, ringing data, and the trajectory of known population trends.

The primary considerations in assigning uncertainty included the extent of population surveys available for a species and number of years since the survey was conducted. For example, many species relied on census data from Seabird 2000 which covered the years 1998 to 2002 (Mitchell et al. 2004), as more up–to-date counts were limited at the time of the report. Another consideration was the amount of data available to examine migration patterns due to limited availability of ring recovery/resighting data, which was often biased or incomplete for pelagic species. Some uncertainty existed in the at-sea counts, used to validate estimates, as some species may have been difficult to detect at sea due to diving behaviour or winter dispersal. A key consideration was the extent of knowledge on the proportion of overseas populations using UK waters, potentially introducing uncertainty due to poorly monitored overseas colonies and making it difficult to assess their contribution to the UK BDMPS. Coastal species with stable populations and frequent monitoring tended to have lower uncertainty while pelagic, migratory, and poorly studied species often faced high uncertainty.

2.6.1. Species-specific uncertainty

The UK biogeographic population estimate of Red-throated Diver was assigned low uncertainty, as this species was well-surveyed during the winter season, with stable numbers and coastal wintering behaviour making them accessible to count. Numbers from overseas estimates were assigned moderate uncertainty due to limited ring recovery data (Wernham et al. 2002). Great Northern Divers do not breed in the UK, and ring recovery information from overseas populations was lacking at the time of the report. Estimates of non-breeding birds were assigned a moderate level of uncertainty, this was based on dedicated surveys which potentially were underestimates, while biogeographic populations with connectivity to the UK are highly uncertain and inferred mainly from biometrics (Camphuysen et al. 2010).

Fulmar population estimates were of moderate uncertainty as they were based on colony counts (Seabird 2000), which indicated a population decline. Overseas populations were regarded as highly uncertain due to their pelagic behaviour, limited ring recovery data, and few tracking studies.

In Manx Shearwater, there was moderate uncertainty in birds from the western UK as numbers were based on recent colony counts undertaken using novel survey methods, which led to a large increase in the population (Perrins et al. 2012). In the North Sea there was high uncertainty in the number of migrants passing through UK waters due to a lack of data.

UK populations of Gannet had low uncertainty as they were well-surveyed and matched at-sea surveys. However, numbers of overseas birds were of moderate uncertainty as they likely originated from relatively small populations, with a lack of tracking studies from Norwegian/Icelandic populations. For Cormorant, UK populations were well-documented and therefore had low uncertainty, however, there was high uncertainty in the number of birds from overseas due to limited data.

Declining populations of UK Arctic Skuas meant there was moderate uncertainty in the estimates, while overseas populations were highly uncertain as passage numbers may fluctuate, for example, with weather (Forrester et al. 2007). The population of migrant Great Skuas from both the UK and overseas had high uncertainty due to lack of recent censuses, and limited ring recoveries and tracking studies.

There was moderate uncertainty in Lesser Black-backed Gull, Herring Gull and Great Black-backed Gull UK populations, which had good colour ringing coverage and were well monitored but had variable populations. In the estimates of overseas populations of Great Black-backed Gull and Lesser Black-backed Gulls, despite the availability of colour ringing studies, there was high uncertainty in the number of birds which passed through UK waters. In contrast, Herring Gulls lacked extensive colour-ring or GLS studies from overseas, though overseas populations were stable, therefore leading to moderate uncertainty.

Sandwich, Common, and Roseate Tern UK numbers are well-monitored, but overseas migration was poorly documented, relying on limited ringing data, and were assigned moderate uncertainty. UK numbers and overseas populations of Arctic Tern were highly uncertain due to major declines, lack of non-SPA counts, and potential bias in ring recoveries. The Little Tern population had low uncertainty as UK and Irish breeding numbers are well monitored and migrants from Ireland to the UK are well studied.

UK populations of Guillemot and Razorbill were assigned moderate uncertainty as they are relatively well known, but overseas populations were assigned high uncertainty as they are poorly understood. Both UK and overseas population estimates of Puffins were highly uncertain due to difficulties in colony censuses, at-sea surveys, and biased ring recovery data.

2.6.2. Recommendations

We recommend that the assessment of uncertainty in BDMPS population estimates be updated using a quantitative approach taking into account the number of surveys, tracking studies, and number of ringing recoveries available to form a population estimate. Uncertainty can be represented by a score calculated using the extent of available data within up-to-date colony counts (Burnell et al. 2023), GLS (Fauchald et al. 2021) and GPS tracking studies (Thaxter et al. 2019), and through the presence of at-sea distribution data (Waggitt et al. 2019). This would produce a weighted numeric value to represent the level of uncertainty, providing a greater level of detail to inform reliability of measurements used in assessments.

Uncertainty may also be reduced in the future due to the increased number of published GLS studies (Duckworth et al. 2020, Fauchald et al., 2021) and GPS tracking data (Kranstauber et al. 2011, Welcker & Nehls 2016, Thaxter et al. 2019), and updated census data (Burnell et al. 2023). Specifically, in recent years GLS studies for a number of species (e.g. Manx Shearwater, Shag, Gannet, Fulmar, Arctic Skua, Great Skua, Herring Gull, Lesser Black-backed Gull, Kittiwake, Arctic Tern, Guillemot, Razorbill, Puffin) have become more extensive, with data centralised in projects such as SEATRACK (**https://seatrack.net** – Fauchald et al. 2021) and repositories such as the Seabird Tracking Database (**https://www.seabirdtracking.org** – Carneiro et al. 2024). Such studies are applicable in examining both the number of UK and overseas populations within UK waters in the non-breeding season. Additionally, greater availability of colour and metal ring recovery data since the previous report may better highlight potential countries of origin, through the use of resources such as the recently published Eurasian African Bird Migration Atlas (**http://migrationatlas.org** – Spina et al. 2022).

Due to the large amount of GLS, GPS, and ringing data available to inform future BDMPS population estimates for some species, how uncertainty in BDMPS is assessed in future could be based on amounts of data available. This would require a hierarchical approach, weighting certainty by the geographical extent, resolution of data, and how recently the data was collected. Using these measures, either a similar traffic light approach to Furness (2015) could be formed based on thresholds of data, or a weighted index which indicates the measure of certainty based on the amount of data available to inform population estimates. An index can be calculated by scoring each available dataset against weighted criteria, for example: the date of the study, spatial and temporal coverage, sample size, and the method used. A measure of uncertainty can then be calculated using the sum of the weighted scores across criteria (Johnston et al. 2025).

Outputs in the linked Excel workbook (Appendix C) are presented without uncertainty estimates, since generating these requires data analysis which was not within the scope of Phase 1 of the project.

3. Case study species

In the original Furness (2015) report, all outputs were provided as tables either in the main text or appendix that do not allow for easy data manipulation such as filtering to extract the information of interest. A recommended update is to create an Excel workbook which contains all required outputs from which the desired information can be filtered and extracted. To demonstrate how the updated data outputs would be presented in the Excel workbook (Appendix C), two case study species are presented: Guillemot (as a data-rich species) and Great Black-backed Gull (as a more data-limited species). These case studies are presented following some of the new recommendations regarding biogeographic populations, seasonal definitions, and population age structure highlighted above. We do not, however, implement recommendations around changes in regional definitions or uncertainty which were out of scope for Phase 1. Therefore, the case studies Excel workbook presents examples of how outputs from Phase 2 may look but should not yet be used as a replacement of Furness (2015).

The Excel workbook consists of a summary tab (equivalent to the main output tables in Furness (2015) where the primary outputs are presented per species, including the BDMPS region, season, month of year, UK and overseas population size in each BDMPS, and total population size in each BDMPS. This summary tab allows for easy filtering by any of the variables mentioned above to allow easier data extraction from a species, BDMPS region, or season. Furthermore, there are species-specific tabs (equivalent to the appendix tables in Furness 2015) where higher resolution data are stored and that automatically feed into the summary tab. The species-specific tabs include population sizes broken down into all overseas populations (at a national level) and all SPA and non-SPA populations in the UK, including the year and reference of when those populations were last counted. Populations are split into the number of breeding adults and immature birds, as well as the estimated proportion of birds that move into each BDMPS. Furthermore, SPA to BDMPS apportioning values are also included in the species tabs, calculated as the proportion of the total number of birds in a BDMPS that is made up by breeding adults from any particular SPA.

3.1. Great Black-backed Gull

3.1.1. Biogeographic population with connectivity to UK waters

Stroud et al. (2001) defined the biogeographic population as that of the European population. A recent global assessment in 2021 estimated the European population to be 97,693 breeding pairs (Langlois Lopez et al. 2023), whilst the UK breeding population was counted in 2015–2021 resulting in 8,021 Apparently Occupied Nests (AONs, see Burnell et al. 2023).

UK breeding birds are predominantly sedentary, spending the non-breeding period in proximity to their colonies or along UK coasts. Overseas populations with connectivity to UK waters include Ireland, Faroe Islands, and Norway, although the populations of the Faroe Islands and Ireland are also generally sedentary (Wernham et al. 2002). The number of Great Black-backed Gulls breeding in France increased to approximately 10,000 pairs by 2021 (Langlois Lopez et al. 2023), and thus there is potential connectivity to the southern coast of the UK which could be assessed using ringing data in future. Unlike the other larger gulls, however, there is a lack of year-round tracking studies for Great Black-backed Gulls as harness attachments may negatively impact their breeding success (Langlois Lopez et al. 2024) and therefore this is not currently an option for the provision of annual movement data. The greatest number of overseas Great Black-backed Gulls in UK waters originate from northern Norway and Russia (Wernham et al. 2002). Therefore, the overseas populations considered to have connectivity to UK waters remain as Ireland, Faroe Islands, and Norway, as proposed by Furness (2015). Given the little movement shown by Great Black-backed Gull populations at temperate latitudes, and the known large movements of individuals from northern Norway and Russia, the apportioning of populations to the different BDMPS in the UK remain the same as in Furness (2015) (see case studies Excel workbook for such data; Appendix C) until a more formal analysis of ringing recoveries can be carried out during future phases of this project.

3.1.2. Non-breeding component of the population (population age structure)

Great Black-backed Gulls have declined in recent decades at a global scale. In Europe, the population is estimated to have fallen from 137,195 pairs in 1985 to 97,693 in 2021, a decline of 28% over 35 years (Langlois Lopez et al. 2023). Given that declines occurred at such large scales, it was considered appropriate to build a population model (deterministic PVA based on a Leslie matrix) that followed the population dynamics of the European population, in order to estimate the population age structure and thus the size of the immature non-breeding immature population. Adult survival was sourced from a recent study by Layton-Matthews et al. (2024) in Norway, whereas the remaining parameters (age of first breeding, productivity, first-year immature survival) were sourced from Horswill & Robinson (2015). The adult survival from Horswill & Robinson (2015) of 0.930 was not used as it produced an unrealistic population increase that did not match observed declines in European populations. Older immature survival (second to fourth year) were not available in the literature and were therefore set to be slightly lower than adult survival while ensuring the output trend matched the 28% decline over 35 years that has been estimated for the European population. The final demographic parameters that best represent the dynamics of Great Black-backed Gulls at a European scale are presented in Table 2. Such a population structure produced a ratio of immatures to adults of 1.68.

Table 2. Demographic parameters from Great Black-backed Gulls that best represented the dynamics of the European population between 1985 and 2021, and that were used to estimate the size of the non-breeding component of the population.

Demographic parameters	Value	Reference
Adult survival	0.819	Layton-Matthews et al. (2024)
First year immature survival	0.729	Horswill & Robinson (2015)
Second to Fourth year immature survival	0.810, 0.810, 0.810, 0.810	Manually specified as not available in literature
Productivity	1.026	Horswill & Robinson (2015)
Age of first breeding	5	Horswill & Robinson (2015)
Skipped breeding rate	0.350	Assumed same as in Herring Gull (Horswill & Robinson 2015)

3.1.3. Phenology

The phenology used in the updated Great Black-backed Gull case study remains the same as defined by Furness (2015), with the non-breeding period spanning September to March. However, following the recommended standardised seasonal splits, using the migration timings referred to in Furness (2015), the non-breeding period was further split into autumn migration (September to November), winter (December to January), and spring migration (February to March). During future phases of this project, these seasonal definitions may be refined using the hierarchical approach described in section 2.2. Until further analysis and review of phenological data is undertaken during Phase 2, it is assumed that the number of birds in each BDMPS during autumn migration, winter, and spring migration, is the same as proposed by Furness (2015).

3.1.4. BDMPS regions

BDMPS regions were defined as in Furness (2015). These regions were the UK North Sea, UK West of Scotland, and the UK South-west and Channel. A graphical representation of these areas can be found in Figure 2.

3.1.5. Number of birds in UK waters during the non-breeding period

The biogeographic population with connectivity to UK waters comprises the populations of the UK, Ireland, Faroe Islands, and Norway, totalling an estimated 144,840 individuals (adults and immatures) that are estimated to use UK waters, based on the most recent sources of population estimates (see Appendix C) and updated population modelling that matched the European population trend. Of these, 42,096 individuals are estimated to originate from the UK population, and the remaining 102,744 individuals from overseas populations (see case studies worksheet, Appendix C).

3.1.6. Number of birds from SPAs in each BDMPS during the non-breeding period

There are six SPAs in the UK where Great Black-backed Gulls are designated as a feature. Large declines in breeding numbers have been recorded between 1998–2002 and 2015–2021 at these SPAs, except for East Caithness Cliffs and the Isles of Scilly (Burnell et al. 2023). The total number of AONs in SPAs in the most recent census (Burnell et al. 2023) was 1,281 AONs, representing ~16% of the UK breeding population. Given the sedentary nature of UK populations, in the North Sea BDMPS, birds from North Sea SPAs would make up around 0.003% of total birds (UK and overseas) during the non-breeding season in the North Sea BDMPS. The equivalent figure for the UK West Coast of Scotland BDMPS would be around 1.4% given large declines at North Rona and Sula Sgeir SPA. Lastly, birds from UK South-west and Channel SPAs would comprise around ~50% of the UK South-western and Channel BDMPS. In the case studies workbook (Appendix C), the non-SPA component of the population was calculated by removing the SPA populations from the total population censused in each BDMPS region using counts from Burnell et al. (2023).

3.1.7. Number of birds in each BDMPS during the breeding period

The number of adult and immature birds present in each BDMPS was estimated following Natural England guidance by pooling all adults and immatures from breeding colonies within each BDMPS to reach a BDMPS total.

3.2. Guillemot

3.2.1. Biogeographic population with connectivity to UK waters

The breeding population of Guillemots in the UK is well-monitored through periodic complete censuses and annual monitoring of a subset of sites by the Seabird Monitoring Programme (SMP; Harris et al. 2024). Numbers of overseas populations that use UK waters are less well known, but Furness (2015) listed that some birds from Norway, Ireland, Germany, Denmark, and the Faroe Islands use UK waters during the non-breeding season, detected through ringing data (Wernham et al. 2002). Populations with connectivity to UK waters therefore include the most recent estimates of the UK (1,265,888 individuals), Faroe Islands (200,000 individuals), Norway (150,000 individuals), Germany (5,622 individuals), and Denmark (7,000 individuals) (see Appendix C for data sources). However, Guillemots are generally sedentary, particularly breeding adults, spending the non-breeding period in proximity to their breeding colonies, although immatures are known to move and disperse further than adults (Wernham et al. 2002, Furness 2015, Buckingham et al. 2022). As such, most of the Guillemots found in UK waters at any time of the year originate from UK colonies. Guillemot is also an example of a species where the specific location of a wind farm may influence the suitability of the use of the BDMPS apportioning approach outside of the breeding season. For example, projects sited close to major breeding colonies are likely to have a higher proportion of birds with connectivity to those specific colonies, particularly immediately before and after the breeding season. In such cases, the assumption of random mixing of the component populations of the BDMPS are clearly violated and a more bespoke approach to apportioning may be required based on the available evidence.

The UK population was estimated at 1,265,888 breeding individuals during the 2015–2021 census (Burnell et al. 2023), and the combined overseas populations that have connectivity to UK waters (Germany, Denmark, Norway, and Faroe Islands) 362,622 individuals, producing a total of 1,628,510 breeding individuals with connectivity to UK waters (see Appendix C for data sources). Given the dispersive rather than migratory nature of Guillemots, most UK Guillemots are apportioned to UK waters during non-breeding, whereas only small proportions of overseas populations are apportioned to UK waters (Furness 2015). Here, the same apportioning values (see Appendix C) were used as in Furness (2015), but a more refined approach may be possible during Phase 2 due to the new tracking and ringing data available for this species. It is important to note that the population from Ireland does not appear to be apportioned to UK waters in Furness (2015), but may be considered when carrying out Phase 2.

3.2.2. Non-breeding component of the population (population age structure)

Since the vast majority of Guillemots in UK waters during non-breeding originate from UK colonies, it was considered appropriate to build a PVA that reflected the UK population trend in order to estimate the proportion of the non-breeding immature population. Guillemots have declined by 11% in the UK between 1998–2002 and 2015–2021, from 1,426,282 to 1,265,888 individuals (Burnell et al. 2023). We sourced all demographic parameters from Horswill & Robinson (2015) to build deterministic PVAs. Since the survival figures from Horswill & Robinson (2015) overestimated population growth compared to census data, immature survival of older ages classes was reduced slightly so that modelled trends matched the 11% decline observed in the UK population between the last two censuses. The final demographic parameters (Table 3) produced a population structure with a ratio of immatures to adults of 0.85.

Table 3. Demographic parameters from Guillemots that best represented the dynamics of the UK population between 1998–2002 and 2015–2021, and that were used to estimate the size of the non-breeding component of the population.

Demographic parameters	Value	Reference
Adult survival	0.90	Horswill & Robinson (2015)
First year immature survival	0.560	Horswill & Robinson (2015)
Second to gourth year immature survival	0.792, 0.792, 0.792, 0.850	Horswill & Robinson (2015) but adjusted
Productivity	0.672	Horswill & Robinson (2015)
Age of first breeding	5	Horswill & Robinson (2015)
Skipped breeding rate	0.07 - assumed negligible in PVAs	Horswill & Robinson (2015)

3.2.3. Phenology

Without yet using updated data, the phenology used in the Guillemot case study remains the same as defined by Furness (2015), with the non-breeding period spanning August to March. However, further division of the non-breeding period into the recommended standardised seasons (autumn migration, winter, spring migration, breeding) was undertaken using the migration timings referred to in Furness (2015), based largely on Wernham et al (2002). As such, the non-breeding period was further split into autumn migration (August to September), winter (October to December), spring migration (January to March), and breeding (April to July).

3.2.4. BDMPS regions

BDMPS regions were defined as in Furness (2015). Where data allow, a more refined, quantitative approach to defining such regions based on ringing and tracking data may be possible during future phases, especially as Guillemots have been heavily tracked using GLS in recent years (e.g. Buckingham et al. 2022). Due to the continuity of Guillemot colonies along UK coasts, a divide beyond east and west waters is likely inappropriate at this stage. Thus, the two BDMPS defined by Furness (2015) were used: UK North Sea and Channel, and UK Western Waters. A graphical representation of these areas can be found in Figure 2.

3.2.5. Number of birds in UK waters during the non-breeding period

The biogeographic population with connectivity to UK waters comprises the breeding populations of the UK, Ireland, Faroe Islands, Germany, Denmark, and Norway. This produces an estimated 2,073,221 individuals that are present in UK waters during the non-breeding season, based on the most recent sources of population estimates and updated population modelling that matched the UK trend. Of these, 1,985,030 individuals are estimated to originate from UK colonies, and the remaining 88,191 individuals from overseas populations (see Appendix C).

3.2.6. Number of birds from SPAs in each BDMPS during the non-breeding period

The 34 SPAs with breeding Guillemots as a feature together held 1,066,934 individuals in the 2015–2021 census (Burnell et al. 2023), which represented ~85% of the UK breeding populations. In the North Sea and Channel BDMPS, birds from North Sea SPAs represented ~89% of all Guillemots in the North Sea and Channel BDMPS, and birds from West Coast SPAs represented ~76% of all birds present in the UK Western Waters BDMPS during the non-breeding period. In the case studies worksheet, the non-SPA component of the population was calculated by removing the SPA populations from the total population censused in each BDMPS region using counts from Burnell et al. (2023).

3.2.7. Number of birds in each BDMPS during the breeding period

The number of adult and immature birds present in each BDMPS was estimated following Natural England guidance by pooling all adults and immatures from breeding colonies within each BDMPS to reach a BDMPS total.

4. Discussion

This review assessed the BDMPS approach originally developed by Furness (2015) and its application in impact assessments of seabirds for offshore developments. The original methodology relied on expert opinion in the definition of seabird population regions based on their seasonal distributions, and connectivity to UK waters. With the greater availability of tracking data and updated census data, the information applied to the original framework can be updated. The prevalence of updated data supports a shift in methods to a more quantitative and repeatable approach. The findings of this review should inform Phase 2 which will apply, across all species, the updated resources and aspects of the refined methods discussed within the case-studies of Guillemot and Great Black-backed Gull. It is anticipated that future updates (i.e. a possible Phase 3) will further refine the methodology of calculating population estimates, with consideration of an accessible interface for conducting apportionment. Throughout these phases, relevant stakeholders, specifically the SNCBs, should be consulted to obtain feedback on proposed updates to the method, outputs, and best-practice for application.

4.1. Overview of workshop

The outcomes of the workshop are largely reflected in the recommended approaches going forward, particularly regarding the incorporation of new data from GPS tracking, ringing recoveries, and recent censuses. There was broad support for presenting BDMPS data at a monthly resolution, while retaining seasonally defined groupings. Participants also supported a hierarchical approach to using data to define regions and seasons based on extent and quality of the available resources. This approach will allow for potential data gaps which exist among species to be accounted for. There was agreement on the need to improve how immature birds are accounted for and updating the precautionary models used in Furness (2015) with more realistic population models based on contemporary demographic data. This was a key discussion topic as immatures can form a significant part of non-breeding populations but are often underrepresented in survey data. Longer-term aspirations such as adopting a spatially refined approach which does not generalise to such large regions or interactive tools like Shiny apps were discussed. However, concerns were raised around complexity and practicality of use, as well as ongoing maintenance costs, and availability of the data of a suitable resolution. Several stakeholders indicated the desire to introduce Ireland into any updated regions going forward, although concerns over the implications of this for future assessments were raised. Overall, there was agreement on the need to balance novel methods based on high-resolution data and practicality of use, while still ensuring population estimates are ecologically representative.

4.2. Overview of Recommendations

We provide recommendations for updating six key components of the BDMPS population estimates which include: biogeographic population sizes; species specific seasons; BDMPS regions; proportion of populations; population age structure; and assessment of uncertainty. Across these components we recommend the use of a hierarchical approach that accounts for the quality and availability of data, using the latest census, ringing, and tracking data where available; with literature and expert opinion used where data are lacking.

4.2.1. Biogeographic populations

In relation to biogeographic population sizes, we recommended that the most recent seabird census data from 2015–2021 (Burnell et al. 2023) be used alongside information from international datasets (SEAPOP, BirdLife International, European Breeding Bird Atlas 2). Individual studies should also be considered, specifically where species have recently been affected by HPAI, and therefore require the most up-to-date survey data.

4.2.2. Seasons

To allow seasons to be standardised and allow stakeholders to tailor seasons based on regional or phenological variation, seasons should be presented at a monthly resolution based on a hierarchy of data from Trektellen, BirdTrack, bird reports, and expert opinion.

4.2.3. Regions

The hierarchical approach used in the definition of BDMPS regions would be based on spatial analysis informed by tracking, ring recovery/resighting, biometrics, at-sea distribution data. This would take advantage of openly accessible tracking data (e.g. **https://seabirdtracking.org/; https://movebank.org**); updated ring recovery data (**https://migrationatlas.org**); and available studies that provide information on at-sea distribution of species (e.g. Waggitt et al. 2019).

4.2.4. Age classes

Estimation of the proportions of populations within each BDMPS should use information on age-classes present within ringing and tracking data. Estimation of the population age structure should be based on up-to-date demographic data (e.g. Horswill & Robinson, 2015 and the new expected update Tyler et al. in press) and PVAs that reflect population trends rather than assuming stability. Models should be validated against empirical count data with the possibility to develop separate PVAs for different biogeographic regions if needed and where suitable demographic parameter data are available. Where most individuals in UK waters originate from the UK population, a single PVA may suffice. Finally, assessing uncertainty in BDMPS estimates should move towards a more quantitative index based on data availability based on (arbitrary) thresholds of information.

4.3. Considerations including relevant EIA scales and populations

During this review and the stakeholder workshop, we considered whether the BDMPS outputs provide appropriate population scales and estimates for each species for use in EIAs. For EIAs, impacts need to be assessed on ecologically relevant regional populations, which include both UK individuals (adults and immatures) and those from overseas populations that migrate through or winter in UK waters. Furness (2015) highlighted that assessments can be made at a range of spatial scales. The largest scale is a species' biogeographical population, however using this would require cumulative assessments of all developments that could impact birds within this range, which is currently impractical. Instead, the BDMPS regions defined in Furness (2015) were proposed to represent smaller metapopulation scales, which are more practical for cumulative assessments. This was thought to be a compromise between using the biogeographical scale and a limited local scale. Although using smaller spatial scales reduces the number of developments which need to be considered within cumulative assessments, it increases uncertainty in the associated population values as the movements of adults and immatures of relevant populations within UK waters at any point in time and space are not well known for seabird species (Furness 2015). Since the publication of Furness (2015), the SNCBs have therefore recommended that the maximum BDMPS population size, from any season (including the breeding season), should be used as the reference population for EIA cumulative assessments.

During Phase 2 of the project, we will determine whether the updates in population sizes of seabirds within and outwith the UK, and data on seabird movements and distributions that have become available since the original Furness (2015) report, provide additional evidence for the most appropriate population scale to provide estimates for use in EIAs.

It is also important to consider that it may not always be appropriate to use the BDMPS approach to apportion impacts in the non-breeding season. For example, where available evidence suggests that the current assumption of random mixing of the various components of the BMDPS population is violated, which might be the case in close proximity to a breeding colony immediately prior to, or after, breeding. Therefore, it is important that species-specific movements across the annual cycle are considered when applying the BDMPS approach.

4.4. Connectivity with overseas developments

During the workshop, industry stakeholders indicated that as well as including the impacts of offshore wind developments within UK EEZ waters, we should also consider the impacts of offshore wind developments outwith the UK EEZ, especially in cross-border regions within the southern North Sea and Irish/Celtic Seas. With a number of developments planned, especially within the Irish Sea in the Republic of Ireland EEZ, stakeholders conducting impact assessments for these developments expressed interest that future updates to the BDMPS regions consider cross-border regions. However, it was acknowledged that this is challenging due to state differences in how surveys and impact assessments are carried out. Furthermore, at present, regulators only require the impacts to be assessed from developments within UK waters, therefore there is no necessity for consultants or developers to include this additional data. This approach currently ignores broader scale impacts on populations as a whole, limiting potential for conservation measures.

4.5. Conclusion

The method introduced within Furness (2015) for defining BDMPS is comprehensively researched, with full consideration to the multitude of ecological aspects contributing to populations outside the breeding season. It was founded on the best available evidence at the time, much of which remains unchanged. Key changes in the intervening period include updated population census data, a greater abundance of tracking data, and novel techniques for modelling age-classes. While applying these novel data and methods in updated estimates of the contributions of non-breeding populations within UK waters during Phase 2, a framework should be produced which is easily updatable should new information become available, with transparent analytical steps should the method itself need to be adjusted in future.

5. References

Akçakaya, H.R. & Sjögren-Gulve, P. 2000. Population viability analyses in conservation planning: an overview. *Ecological Bulletins* **48**: 9–21.

Atkins, K., Bearhop, S., Bodey, T.W., Grecian, W.J., Hamer, K., Pereira, J.M., Meinertzhagen, H., Mitchell, C., Morgan, G., Morgan, L., Newton, J., Sherley, R.B. & Votier, S.C. 2023. Geolocator-tracking seabird migration and moult reveal large-scale, temperature-driven isoscapes in the NE Atlantic. *Rapid Communications in Mass Spectrometry* **37**: e9489.

Brown, A. & Grice, P. 2010. *Birds in England.* A&C Black, London.

Buckingham, L., Bogdanova, M.I., Green, J.A., Dunn, R.E., Wanless, S., Bennett, S., Bevan, R.M., Call, A., Canham, M., Corse, C.J. & Harris, M.P. 2022. Interspecific variation in non-breeding aggregation: a multi-colony tracking study of two sympatric seabirds. *Marine Ecology Progress Series* **684**: 181–197.

Burnell, D., Perkins, A.., Newton, S.F., Bolton, M., Tierney, D. & Dunn, T.E. 2023. *Seabirds Count, A census of breeding seabirds in Britain and Ireland (2015–2021).* Lynx Nature Books, Barcelona.

Camphuysen, C.J. 2013. A historical ecology of two closely related gull species (Laridae): multiple adaptations to a man-made environment. PhD Thesis, University of Groningen.

Camphuysen, C.J., Bao, R., Fortin, M., Roselaar, C.S. & Heubeck, M. 2010. Post-mortem examination of Great Northern Divers *Gavia immer* killed in the Prestige oil spill, Galicia, Spain, 2002/03. *Seabird* **23**: 53–65.

Carneiro, A.P.B., Dias, M.P., Clark, B.L., Pearmain, E.J., Handley, J., Hodgson, A.R., Croxall, J.P., Phillips, R.A., Oppel, S., Morten, J.M., Lascelles, B., Cunningham, C., Taylor, F.E., Miller, M.G.R., Taylor, P.R., Bernard, A., Grémillet, D. & Davies, T.E. 2024. The BirdLife Seabird Tracking Database: 20 years of collaboration for marine conservation. *Biological Conservation*.

Dillon, I.A., Smith, T.D., Williams, S.J., Haysom, S. & Eaton, M.A. 2009. Status of Red-throated Divers *Gavia stellata* in Britain in 2006. *Bird Study* **56**: 147–157.

Duckworth, J., Green, J., Daunt, F., Johnson, L., Lehikoinen, J.P., Okill, D., Petersen, A., Petersen, I.K., Väisänen, R., Williams, J., Williams, S. & O'Brien, S. 2020. Red-throated Diver Energetics Project: Preliminary Results from 2018/19. JNCC.

Duckworth, J., O'Brien, S., Petersen, I.K., Petersen, A., Benediktsson, G., Johnson, L., Lehikoinen, P., Okill, D., Väisänen, R., Williams, J., Williams, S., Daunt, F. & Green, J.A. 2022. Winter locations of Red-throated Divers from geolocation and feather isotope signatures. *Ecology & Evolution* **12**: e9209.

Dupuis, B., Amélineau, F., Tarroux, A., Bjørnstad, O., Bråthen, V.S., Danielsen, J., Descamps, S., Fauchald, P., Hallgrimsson, G.T., Hansen, E.S., Helberg, M., Helgason, H.H., Jónsson, J.E., Kolbeinsson, Y., Lorentzen, E., Thompson, P., Thórarinsson, T.L. & Strøm, H. 2021. Light-level geolocators reveal spatial variations in interactions between Northern Fulmars and fisheries. *Marine Ecology Progress Series* **676**: 159–172.

European Seabirds At Sea (ESAS). Accessed on 21/03/2025. ICES, Copenhagen, Denmark. https://esas.ices.dk

Ewins, P.J. & Kirk, D.A. 1988. The distribution of Shetland Black Guillemots *Cepphus grylle* outside the breeding season. *Seabird* **11**: 50–61.

Fauchald, P., Tarroux, A., Amélineau, F., Bråthen, V.S., Descamps, S., Ekker, M., Helgason, H.H., Johansen, M.K., Merkel, B., Moe, B., Åström, J., Anker-Nilssen, T., Bjørnstad, O., Chastel, O., Christensen-Dalsgaard, S., Danielsen, J., Daunt, F., Dehnhard, N., Erikstad, K.E., Ezhov, A., Gavrilo, M., Hallgrimsson, G.T., Hansen, E.S., Harris, M., Helberg, M., Jónsson, J.E., Kolbeinsson, Y., Krasnov, Y., Langset, M., Lorentsen, S.H., Lorentzen, E., Newell, M., Olsen, B., Reiertsen, T.K., Systad, G.H., Thompson, P., Thórarinsson, T.L., Wanless, S., Wojczulanis-Jakubas, K. & Strøm, H. 2021. Year-round distribution of Northeast Atlantic seabird populations: applications for population management and marine spatial planning. *Marine Ecology Progress Series* **676**: 255–276.

Fayet, A.L., Freeman, R., Shoji, A., Padget, O., Perrins, C.M. & Guilford, T., 2015. Lower foraging efficiency in immatures drives spatial segregation with breeding adults in a long-lived pelagic seabird. *Animal Behaviour* **110**: 79–89.

Fayet, A.L., Freeman, R., Anker-Nilssen, T., Diamond, A., Erikstad, K.E., Fifield, D., Fitzsimmons, M.G., Hansen, E.S., Harris, M.P., Jessopp, M. & Kouwenberg, A.L. 2017. Ocean-wide drivers of migration strategies and their influence on population breeding performance in a declining seabird. *Current Biology* **27**: 3,871–3,878.

Forrester, R.W., Andrews, I.J., McInerny, C.J. & Scott, H.I., Scottish Ornithologists' Club. 2007. *The Birds of Scotland*. Scottish Ornithologists' Club, Edinburgh.

Foster, S. & Marrs, S. 2012. Seabirds in Scotland. Scottish Natural Heritage Trend Note 021.

Frederiksen, M., Moe, B., Daunt, F., Phillips, R.A., Barrett, R.T., Bogdanova, M.I., Boulinier, T., Chardine, J.W., Chastel, O., Chivers, L.S., Christensen-Dalsgaard, S., Clément-Chastel, C., Colhoun, K., Freeman, R., Gaston, A.J., González-Solís, J., Goutte, A., Grémillet, D., Guilford, T., Jensen, G.H., Krasnov, Y., Lorentsen, S.H., Mallory, M.L., Newell, M., Olsen, B., Shaw, D., Steen, H., Strøm, H., Systad, G.H., Thórarinsson, T.L. & Anker-Nilssen, T. 2012. Multicolony tracking reveals the winter distribution of a pelagic seabird on an ocean basin scale. *Diversity & Distributions* **18**: 530–542.

Furness, R.W. 2010. *The Skuas*. A&C Black, London.

Furness, R.W. 2015. Non-breeding season populations of seabirds in UK waters: population sizes for biologically defined minimum population scales (BDMPS). *Natural England Commissioned Reports* **164**. Natural England, Peteborough.

Garthe, S., Ludynia, K., Hüppop, O., Kubetzki, U., Meraz, J.F. & Furness, R.W. 2012. Energy budgets reveal equal benefits of varied migration strategies in northern gannets. *Marine Biology* **159**: 1,907–1,915.

Garthe, S., Peschko, V., Fifield, D.A., Borkenhagen, K., Nyegaard, T. & Dierschke, J. 2024. Migratory pathways and winter destinations of Northern Gannets breeding at Helgoland (North Sea): known patterns and increasing importance of the Baltic Sea. *Journal of Ornithology* **165**: 869–880.

Guilford, T., Meade, J., Willis, J., Phillips, R.A., Boyle, D., Roberts, S., Collett, M., Freeman, R. & Perrins, C.M. 2009. Migration and stopover in a small pelagic seabird, the Manx shearwater *Puffinus puffinus*: insights from machine learning. *Proceedings of the Royal Society B: Biological Sciences* **276**: 1,215–1,223.

Guilford, T., Freeman, R., Boyle, D., Dean, B., Kirk, H., Phillips, R. & Perrins, C. 2011. A dispersive migration in the Atlantic Puffin and its implications for migratory navigation. *PLoS One* 6: p.e21336.

Hammer, S., Madsen, J.J., Jensen, J-K., Petersen, K.T., Bloch, D. & Thorup, K. 2014 *Færøsk Trækfugleatlas: the Faroese Bird Migration Atlas*. Faroe University Press.

Harris, M.P., Daunt, F., Bogdanova, M.I., Lahoz-Monfort, J.J., Newell, M.A., Phillips, R.A. & Wanless, S. 2013. Inter-year differences in survival of Atlantic Puffins *Fratercula arctica* are not associated with winter distribution. *Marine Biology* **160**: 2,877–2,889.

Harris, S.J., Baker, H., Balmer, D.E., Bolton, M., Burton, N.H.K., Caulfield, E., Clarke, J.A.E., Dunn, T.E., Evans, T.J., Hereward, H.R.F., Humphreys, E.M., Money, S. & O'Hanlon, N.J. 2024. Seabird population trends and causes of change: 1986–2023, the annual report of the Seabird Monitoring Programme. *BTO Research Report* **771**. British Trust for Ornithology, Thetford.

Horswill, C. & Robinson, R.A. 2015. Review of seabird demographic rates and density dependence. *JNCC Report* No: **552**, JNCC, Peterborough.

Jeglinski, J.W., Wanless, S., Murray, S., Barrett, R.T., Gardarsson, A., Harris, M.P., Dierschke, J., Strøm, H., Lorentsen, S.H. & Matthiopoulos, J. 2023. Metapopulation regulation acts at multiple spatial scales: insights from a century of seabird colony census data. *Ecological Monographs* **93**: p.e1569.

Johnston, D.T., Furness, R.W., Robbins, A.M.C., Taggart, M.A., Tyler, G. & Masden, E.A. 2018. Variations in Black Guillemot *Cepphus grylle* natal dispersal and philopatry across Britain and Ireland. *Bird Study* **65**: 564–569.

Johnston, D.T., Humphreys, E.M., Davies, J.G., Evans, T., Howells, R. & Pearce-Higgins, J.W. 2025. Current understanding of how climate change affects seabirds varies between regions and species in the North-East Atlantic. *Marine Ecology Progress Series* **755**: 163–177.

Kays, R., Davidson, S.C., Berger, M., Bohrer, G., Fiedler, W., Flack, A., Hirt, J., Hahn, C., Gauggel, D., Russell, B., Kölzsch, A., Lohr, A., Partecke, J., Quetting, M., Safi, K., Scharf, A., Schneider, G., Lang, I., Schaeuffelhut, F., Landwehr, M., Storhas, M., van Schalkwyk, L., Vinciguerra, C., Weinzierl, R. & Wikelski, M. 2022. The Movebank system for studying global animal movement and demography. *Methods in Ecology and Evolution* **13**: 419–431.

Keller, V., Herrando, S., Voříšek, P., Franch, M., Kipson, M., Milanesi, P., Martí, D., Anton, M., Klvaňová, A., Kalyakin, M.V., Bauer, H.-G. & Foppen, R.P.B. 2020. *European Breeding Bird Atlas 2: Distribution, Abundance and Change*. European Bird Census Council & Lynx Edicions, Barcelona.

Korner-Nievergelt, F., Liechti, F. & Thorup, K. 2014. A bird distribution model for ring recovery data: where do the European robins go? *Ecology and Evolution* **4**: 720–731.

Kranstauber, B., Cameron, A., Weinzerl, R., Fountain, T., Tilak, S., Wikelski, M. & Kays, R. 2011. The Movebank data model for animal tracking. *Environmental Modelling and Software* **26**: 834–835.

Kubetzki, U., Garthe, S., Fifield, D., Mendel, B. & Furness, R.W. 2009. Individual migratory schedules and wintering areas of northern gannets. *Marine Ecology Progress Series* **391**: 257–265.

Langlois Lopez, S.L., Clewley, G.D., Johnston, D.T., Daunt, F., Wilson, J.M., O'Hanlon, N.J. & Masden, E. 2024. Reduced breeding success in Great Black-backed Gulls (*Larus marinus*) due to harness-mounted GPS device. *Ibis* **166**: 69–81.

Langlois Lopez, S.L., Daunt, F., Wilson, J., O'Hanlon, N.J., Searle, K.R., Bennett, S., Newell, M.A., Harris, M.P. & Masden, E. 2023. Quantifying the impacts of predation by Great Black-backed Gulls *Larus marinus* on an Atlantic Puffin *Fratercula arctica* population: implications for conservation management and impact assessments. *Marine Environmental Research* **188**: e105994.

Layton-Matthews, K., Erikstad, K.E., Sandvik, H., Ballesteros, M., Hodges, K., Mesquita, M.D., Reiertsen, T.K., Yoccoz, N.G. & Bustnes, J.O. 2024. Path analysis reveals combined winter climate and pollution effects on the survival of a marine top predator. *Journal of Animal Ecology* **93**: 1,351–1,364.

Lewis, M., Lye, G., Pendlebury, C. & Walls, R. 2012. Population sizes of seabirds breeding in Scottish SPAs. Report to Marine Scotland. Natural Power Consultants, Castle Douglas.

Magnusdottir, E., Leat, E.H.K., Bourgeon, S., Strøm, H., Petersen, A., Phillips, R.A., Hanssen, S.A., Bustnes, J.O., Hersteinsson, P. & Furness, R.W. 2012. Wintering areas of Great Skuas *Stercorarius skua* breeding in Scotland, Iceland and Norway. *Bird Study* **59**: 1–9.

Meissner, W. & Krupa, R. 2007. Biometrics and primary molt of Common Tern and Sandwich Tern in autumn in Puck Bay, southern Baltic. *Waterbirds* **30**: 158–163.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. & Dunn, T.E. 2004. *Seabird Populations of Britain and Ireland: Results of the Seabird 2000 Census.* T & AD Poyser, London.

O'Brien, S.H., Wilson, L.J., Webb, A. & Cranswick, P.A. 2008. Revised estimate of numbers of wintering Red-throated Divers *Gavia stellata* in Great Britain. *Bird Study* **55**: 152–160.

O'Hanlon, N.J., Thaxter, C.B., Burton, N.H.K., Grant, D., Clark, N.A., Clewley, G.D., Conway, G.J., Barber, L.J., McGill, R.A.R. & Nager, R.G. 2022. Habitat selection and specialisation of Herring Gulls during the non-breeding Season. *Frontiers in Marine Science* **9**: 816881.

O'Hanlon, N.J., van Bemmelen, R.S.A., Snell, K.R.S., Conway, G.J., Thaxter, C.B., Aiton, H., Aiton, D., Balmer, D.E., Hanssen, S.A., Calladine, J.R., Hammer, S., Harris, S.J., Moe, B., Schekkerman, H., Tulp, I. & Humphreys, E.M., 2024. Atlantic populations of a declining oceanic seabird have complex migrations and weak migratory connectivity to staging areas. *Marine Ecology Progress Series* **730**: 113–129.

Pennington, M.G., Osborn, K., Harvey, P.V., Riddington, R., Okill, J.D., Ellis, P.M. & Heubeck, M. 2004. *The Birds of Shetland.* Christopher Helm, London.

Perrins, C.M., Wood, M.J., Garroway, C.J., Boyle, D., Oakes, N., Revera, R., Collins, P. & Taylor, C. 2012. A whole-island census of the Manx Shearwaters *Puffinus puffinus* breeding on Skomer Island in 2011. *Seabird* **25**: 1–13.

Phillips, R.A., Silk, J.R.D., Croxall, J.P., Afanasyev, V. & Briggs, D.R. 2004. Accuracy of geolocation estimates for flying seabirds. *Marine Ecology Progress Series* **266**: 265–272.

R Core Team 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Searle, K., Mobbs, D., Daunt, F. & Butler, A. 2022. A population viability analysis modelling tool for seabird species. *Natural England Report*. Natural England, Peterborough.

Spina, F., Baillie, S.R., Bairlein, F., Ambrosini, R., Fattorini, N., Fiedler, W., Franks, S., Funghi, C. & Thorup, K. 2022. *Eurasian African Bird Migration Atlas* – Executive Summary.

Stienen, E.W. & Brenninkmeijer, A. 1998. Population trends in Common Terns *Sterna hirundo* along the Dutch coast. *Vogelwellt* **119**: 165–168.

Stienen, E.W. & Brenninkmeijer, A. 2002. Variation in growth in Sandwich Tern chicks *Sterna sandvicensis* and the consequences for pre- and post-fledging mortality. *Ibis* **144**: 567–576.

Stroud, D.A., Chambers, D., Cook, S., Buxton, N., Fraser, B., Clement, P., Lewis, P., McClean, I., Baker, H. & Whitehead, S. (eds). 2001. *The UK SPA Network: its Scope and Content.* JNCC, Peterborough.

Stubben, C.J. & Milligan, B.G. 2007. Estimating and Analyzing Demographic Models Using the popbio Package in R. *Journal of Statistical Software* **22**: jss.v022.i11.

Thaxter, C.B., Ross-Smith, V.H., Bouten, W., Clark, N.A., Conway, G.J., Masden, E.A., Clewley, G.D., Barber, L.J. & Burton, N.H.K. 2019. Avian vulnerability to wind farm collision through the year: Insights from Lesser Black-backed Gulls (*Larus fuscus*) tracked from multiple breeding colonies. *Journal of Applied Ecology* **56**: 2,410–2,422.

The Carbon Trust. 2024. Apportioning seabirds seen-at-sea (AppSaS): Apportioning in the nonbreeding season tool (ANBS) User Guide to the ANBS tool.

Tremlett, C.J., Cleasby, I.R., Bolton, M. & Wilson, L.J. 2025. Declines in UK breeding populations of seabird species of conservation concern following the outbreak of high pathogenicity avian influenza (HPAI) in 2021–2022. *Bird Study* **71**: 1–18.

van Bemmelen, R.S.A., Moe, B., Schekkerman, H., Hansen, S.A., Snell, K.R.S., Humphreys, E.M., Mäntylä, E., Hallgrimsson, G.T., Gilg, O., Ehrich, D., Calladine, J., Hammer, S., Harris, S., Lang, J., Vignisson, S.R., Kolbeinsson, Y., Nuotio, K., Sillanpää, M., Sittler, B., Sokolov, A., Klaassen, R.H.G., Phillips, R.A. & Tulp, I.,2024. Synchronous timing of return to breeding sites in a long-distance migratory seabird with ocean-scale variation in migration schedules. *Movement Ecology* **12**: 1–15.

Waggitt, J.J., Evans, P.G.H., Andrade, J., Banks, A.., Boisseau, O., Bolton, M., Bradbury, G., Brereton, T., Camphuysen, C.J., Durinck, J., Felce, T., Fijn, R.C., Garcia-Baron, I., Garthe, S., Geelhoed, S.C.., Gilles, A., Goodall, M., Haelters, J., Hamilton, S., Hartny-Mills, L., Hodgins, N., James, K., Jessopp, M., Kavanagh, A.S., Leopold, M., Lohrengel, K., Louzao, M., Markones, N., Martinez-Cediera, J., O'Cadhla, O., Perry, S.L., Pierce, G.J., Ridoux, V., Robinson, K.P., Santos, M.B., Saavedra, C., Skov, H., Stienen, E.W.M., Sveegaard, S., Thompson, P., Vanermen, N., Wall, D., Webb, A., Wilson, J., Wanless, S. & Hiddink, J.G. 2019. Distribution maps of cetacean and seabird populations in the North-East Atlantic. *Journal of Applied Ecology* **57**: 253–269.

Walker, R.H., Robinson, R.A., Barimore, C.J., Blackburn, J.R., Barber, L.J., Bugg, N.R., Mccambridge, H.E., Grantham, M.J., Griffin, B.M., Leighton, K., Schäfer, S., Woodward, I.D., & Leech, D.I. 2022. Bird ringing and nest recording in Britain and Ireland in 2020. *Ringing & Migration* **36**: 26–67.

Weir, D.N., McGowan, R.Y., Kitchener, A.C., McOrist, S. & Heubeck, M. 1996. Effects of oil spills and shooting on Great Northern Divers which winter in Scotland. *Dansk Ornitologisk Forenings Tidsskrift* **90**: 29–33.

Welcker, J. & Nehls, G. 2016. Displacement of seabirds by an offshore wind farm in the North Sea. *Marine Ecology Progress Series* **554**: 173–182.

Wernham, C.V, Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R., 2002. *The Migration Atlas. Movements of the Birds of Britain and Ireland.* T. & A.D. Poyser, London.

Appendix A: SNCB consultation meeting summary

SNCB consultation meeting on the update to the BDMPS
Tuesday 11th February

A key part of Phase 1 of the BDMPS report update was consulting SNCB representatives who use the BDMPS to inform their guidance and advice around impact assessments. To gather their input, we arranged a consultation meeting to give SNCB representatives the opportunity to discuss and shape the proposed update and associated outputs to ensure they will be fit-for-purpose. The below provides a brief overview of the main points discussed during this consultation meeting.

Agenda

1. Introduction by NE/BTO
2. A summary of the BDMPS approach as reviewed by BTO
3. Issues around the current BDMPS regional definitions (what alternatives are used if any)
4. Issues around the current seasonal definitions (what alternatives are used if any)
5. Initial thoughts on the draft Excel workbook template
6. Next steps

Key points

General points to consider:

- Within the report it is important that terms used have clear definitions (especially where they might differ from those being used in other contexts).
- For Habitats Regulations Assessments (HRAs), the impacts on immatures or sabbatical and non-breeding adults are not currently considered separately.
- BDMPS is also used by some developers and consultants for age apportioning in some cases but that is generally something Natural England does not tend to condone.
- It is important that any updates i.e. to season definition by using monthly building blocks has associated user guidelines to ensure that everyone is using, and interpreting, the data in the same standardised way for which it was designed. Associated with this is thinking about how the consultancies/developers would generate what the SNCBs need, without variation in interpretation of data that makes it as easy as possible for SNCBs to check through impact assessments efficiently.
- NatureScot and Natural England both agreed that Guillemot would be an important case study (data-rich) species during Phase 1 and 2 because of the divided approach in how different SNCBs treat this species.

Different approaches between the SNCBs in how the BDMPS is used:

For a couple of species (i.e. gulls and Guillemot) NatureScot uses slightly different approaches from what is in the BDMPS where there is specific evidence that can be used in Scotland.

Natural England also stated that there might be some bespoke occasions where they might divert from the Furness (2015) report in terms of seasonal definitions.

Noted that NatureScot include 'moult' as a season in their definitions e,g. for auks. Moult is a very useful season to have, so if BTO uses monthly data to define season, one option is to simply tag on some months as 'moult' for relevant species.

General issues SNCBs highlighted

NatureScot stated two main issues they have with implementing BDMPS data.

First, is with the size of the BDMPS regions and cumulative impacts. Part of that issue is that the more sites that you apportion to, the more you reduce that impact and spread it around. Also, there are massive complications when looking at cumulative effects, for example, across the entire North Sea, with every development having to consider every other development and every SPA. Although the point was also made that it is important that the BDMPS regions are biologically accurate and biology driven. Can there be a balance between biologically accurate regions that are of a more manageable size i.e. to put the emphasis on a development having a bigger impact on fewer sites rather than having smaller impacts on multiple sites?

Second, is with the seasons. NatureScot uses their own dates for season but BDMPS data, which is not the perfect solution. One reason for this is that, even just in Scotland, there are seasonal differences between the West Coast and the Northern Isles. When the seasons occur over long extended periods it can also make it difficult for developers where their data do not match the BDMPS seasonal definitions. Therefore, it might be better if there was a way to allow those seasons to change slightly.

Additional thoughts from Natural England, firstly on the size of the BDMPS regions. Can we refine this process based on the quality of data we have to help resolve some of those issues, for example, have higher apportioning rates closer to a colony if that is what the evidence indicates? Secondly, on the seasons, can we get to a place where all SNCBs can agree on seasons for different areas or different projects that fall within different areas?

Considerations about non-breeding birds and immatures in the breeding season
Impacts on birds outside of foraging ranges during the breeding season are not considered for HRA. For example, what are the origins of individuals detected within the footprints of developments that are outwith the foraging range of species in SPAs? Are they breeding birds foraging further offshore than we expect, or are they immatures or non-breeding/sabbatical individuals? These individuals may also visit breeding colonies, i.e. when prospecting, and be counted there as breeding individuals. There is a need to consider this uncertainty in the breeding status and origin of these individuals, especially if the proportion of a population that undertake sabbaticals may vary, i.e. in future with climate change. Can the BDMPS be used to understand the ratio of immatures to adults if there are breeding and non-breeding birds, and how that might vary around the coastline? This could help inform more refined PVA models in the future.

Phase 2 and 3 considerations
There was agreement that a gridded approach to defining BDMPS regions might be beneficial as the underlying data would be at a higher resolution, especially if additional parameters could be included in the clustering, for example, distance to the colony, migration ranges etc. or if colony-specific dispersal and re-aggregation could be modelled.

However, it is important to keep in mind that whether this approach can actually be used for a species will depend on data availability. Ideally, we should try this approach with worked examples for one or two sample species (i.e. a data rich and data poor species) during Phase 2 to determine whether this is feasible, as well as workable for the SNCBs. It was also highlighted that using a gridded approach would be useful to determine where data gaps are, i.e. where should we focus future data collection.

A key point is also whether you can refine the apportioning within the region. For example, is there an approach so that, even for large regions, you do not need to apportion to SPAs equivalently across that region?

Important to recognise that any large changes to how the BDMPS is updated (i.e. using a gridded system at monthly resolution to underpin regions and seasons) will likely need a large overhaul with how the SNCBs deal with displacement. For example, so the process would follow a spatial assessment of how important different areas are for different birds relative to their vulnerability. Consideration would need to be given to how any updates would also mesh with existing assessments and whether they would have to be updated or not.

Considerations around including the Republic of Ireland into BDMPS
How to deal with cross border developments, not just between the UK Member States but also beyond the UK? Is there scope to bring in cross-border impacts as part of the Phase 2 update, specifically for Ireland given that they are starting to expand their offshore wind; particularly when considering developments in Northern Ireland, and in the Irish/Celtic Seas. This has implications for in-combination assessment, with

developments in Irish waters potentially impacting UK SPA populations of species, and vice versa. This relates to the ecologically meaningful biogeographic regional population for a species at different times of year, and how these can be split between the UK and Ireland, or the UK and other European countries if considering the North Sea. However, it is also important to acknowledge that it is hard enough to do assessments cross border within UK Member States, so is it practical to also bring in other countries? It might be possible to obtain seabird data from countries outwith the UK but it is more challenging to obtain wind farm data in terms of the impact assessments which might be carried out using different approaches.

Appendix B: Workshop summary and outcomes

Workshop Report — Workshop on updating the Furness (2015) Biologically Defined Minimum Population Size (BDMPS) report for offshore wind ornithological assessments.

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BTO and Natural England organised this workshop to discuss the scope of requirements associated with a project we are undertaking to update the Biologically Defined Minimum Population Size (BDMPS) report (Furness 2015 — Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS) — NECR164). This work is key to offshore wind ornithological impact assessments as it underpins non-breeding season apportioning to SPAs for HRA and provides population scales for EIA.

The project will deliver a contemporary evaluation of the components of non-breeding season seabird populations in specified sea areas for use in impact assessments. The outputs will help reduce uncertainty in outcomes of these assessments and subsequent consenting decisions. We anticipate the resulting report, and supporting material, will be publicly published and contribute to SNCB guidance and best practice advice.

As part of the initial phase of the project, a half day (3.5 hr) workshop was organised on Wednesday 19 February to provide an opportunity for industry representatives that use the BDMPS report (Furness 2015) to help steer the project at this information-gathering stage. The workshop was attended by 30 representatives from across the sector, including SNCBs, developers, consultants, environmental non-governmental organisations, and universities.

Workshop Aims:

- To share the outcomes of a BTO-led review of the BDMPS approach and recommended methods for the update.
- To provide an opportunity for stakeholders to discuss these outcomes and recommendations.
- Where possible, agree the suggested approach for updating the BDMPS report and any amendments through consensus.
- Promote buy-in for Phase 2 of the project and the use of the outputs in future offshore wind farm impact assessments.
- Help ensure the outputs will be appropriate and easy to use.
- Identify any additional/novel work for future updates.

1. Background

The UK Statutory Nature Conservation Bodies (SNCBs) — the Joint Nature Conservation Committee (JNCC), Natural England (NE), Natural Resources Wales (NRW), NatureScot (NS) and the Northern Ireland Environment Agency (NIEA) — require agreed population estimates for seabird populations in the non-breeding season. The report *Non-breeding season populations of seabirds in UK waters* published in 2015 (Furness 2015) has been a key piece of work that provides information on the origins and sizes of seabird populations that use

UK waters during the non-breeding season, considering their division into appropriate seasons and regions (Biologically Defined Minimum Population Scales (BDMPS)) that underpin non-breeding season apportioning methods for offshore wind related impacts on seabirds in Environmental Impact Assessments (EIAs) and apportioning of impacts in the non-breeding season to Special Protection Areas (SPAs) in Habitats Regulation Assessments (HRAs).

The Furness (2015) report continues to be a key piece of evidence used for apportioning impacts of developments to seabird populations, but it was always anticipated that it would be updated as new data became available, such as that from the recent Seabirds Count census (Burnell et al. 2023), to ensure the continued improvement of the estimates of the seabird population sizes present within different regions in UK waters during the non-breeding period. As such, Natural England (with funding from DEFRA) commissioned the British Trust for Ornithology to carry out a review of the methodology and approach used in Furness (2015) with input from the other SNCBs, technical experts and stakeholders.

Due to time and resource constraints, the project has been split into two phases:

Phase 1 will review the original methods and SNCB evidence needs. BTO will then identify possible refinements and contemporary data sources, create a template Excel workbook, seek input from industry stakeholders and produce two worked species examples.

More specifically, the objectives of this initial review consist of:

1. Understanding the approaches used in the original Furness (2015) report and how outputs were summarised.
2. Understanding the evidence needs of the SNCBs to determine what specific data/information are required for providing guidance and advice for EIAs etc.
3. Providing a specific review of key components of the BDMPS approach and suggest refinements to methods, definitions, parameters and identify appropriate data sources to produce outputs that will meet the evidence needs of the SNCBs.
4. Developing a draft template Excel workbook, with input from the SNCBs, to ensure all required data (where feasible) are accommodated and are easily accessible to users.

Phase 2 will then involve a full update of the BDMPS outputs for all agreed species using the newly refined methods, data, and template developed in Phase 1. For this Phase 2 update we currently recommend following a similar approach to Furness (2015), but identifying new sources of data, updating existing resources used in the report, and refining aspects of the methodology to make data selection clear and replicable using hierarchical approaches. Similarly, a more quantitative approach based on data availability/quality may be used to classify output uncertainty.

However, we are also considering longer-term aspirations of how the BDMPS may be further updated in the future. This includes how additional/novel work that is currently being undertaken may be incorporated into the BDMPS; for example on mapping the distributions of non-breeding populations, better understanding metapopulation dynamics, and the development of tools to apportion breeding seabirds to such approaches to define future recommendations, whilst also considering how these more substantial changes to the current BDMPS will also impact the current approaches of undertaking Environmental Impact Assessments and Habitats Regulations Assessment.

2. Summary of the presentations

The workshop commenced with a brief introduction by Nina O'Hanlon (BTO) describing the background and aims of the project, followed by Andrew Harwood (NE) who described how the original Furness (2015) BDMPS report is currently used and why it was commissioned in the first place.

Following this, Sam Langlois (BTO) and Daniel Johnston (BTO) summarised how key aspects of the methodology used in Furness (2015) work, and potential ways these can be updated to incorporate new data and make the methodology more replicable and future-proof. A more detailed description of these BDMPS components is provided below:

2.1: Apportioning biogeographic populations to BDMPS regions
Quantifying connectivity between both UK breeding populations and overseas populations to UK waters outside of the breeding period is key to define BDMPS. The original Furness (2015) report used extensive literature searches, primarily relying on information obtained from ringing data, to estimate the proportion of birds that used UK waters at some point in the year, as well as to define BDMPS regions.

An update to how the proportion of birds from different populations using BDMPS is estimated could use new modelling techniques of ringing recovery data that account for recovery effort (the primary bias of ringing data). Furthermore, tracking data (GPS and GLS) are now more abundant, and may be used to map the non-breeding distribution of several seabird species, as well as to determine what proportion of individuals use specific wintering areas. If there is not enough ringing or tracking data, a default approach based on literature review and expert opinion can be used as in Furness (2015). This methodology would follow a hierarchical approach based on the quality and availability of data.

2.2. Age composition of populations
Seabird population estimates are generally only available for breeding adults, however the number of immature birds must also be considered in BDMPS and impact assessments as these can form large proportions of populations. Furness (2015) used simple population models (Leslie matrices) to estimate the proportion of immatures in populations, building the models with demographic data from BTO BirdsFacts. A precautionary approach was taken and all populations were modelled as stable since increasing populations have higher numbers of immatures. However, this approach did not consider observed trends in seabird populations. Therefore, an alternative approach could use new sources of demographic data (Horswill & Robinson 2015, and an update due in 2025) to populate population models that reflect observed trends in seabird populations as reported in the recent census (Burnell et al. 2023). This approach would provide a more realistic scenario, matching modelled populations to empirical data.

2.3. Defining biogeographic regions
Regions are used to refine the large spatial scales of biogeographic populations. Stroud et al. 2001 was used to define the overall biogeographic populations, while ringing (Wernham et al. 2002) and tracking data were used to refine the regions. Breaking up a biogeographic population has been introduced as cumulative assessment of a development across all projects in the biogeographic population may be impractical. Currently the report uses the biogeographic population with connectivity to UK waters, excluding birds that never visit the UK. For most species two main BDMPS regions are defined comprising the North Sea and western waters (Fulmar, Great Skua, Manx Shearwater, tern species, auk species). These regions may be further broken by north and south distinctions if relevant for some species (including Red-throated Diver, Shag, Cormorant). Species that exhibit little movement during the winter were allocated smaller regions. Smaller scale regions reflective of movements across space and time and between age classes were previously difficult to define and may potentially be unsuitable for current EIAs.

An update to the methodology for assigning regions would aim to assign regions through spatial analysis using a combination ring recovery and tracking data. We would take a hierarchical approach to this analysis by first considering the available tracking data, followed by ring recovery data, and in absence of tracking or ringing data, regions will be informed by the available literature. While this hierarchical approach will weigh regional definitions to highest resolution data, all knowledge (including tracking, ringing and literature) will be considered in combination.

2.4. Defining seasons
Defining the start and end of the breeding season, wintering and migration periods is a key aspect provided in Furness (2015). These periods were defined according to phenological data extracted from a wide range of resources such the *Eurasian African Migration Atlas*, *Birds of Scotland*, *Birds of Shetland*, annual bird reports, the Gibraltar migration watch website and Trektellen. Following our review of this methodology, the aim would be to identify more recent sources of phenological data, whilst implementing a hierarchical approach that classifies phenological data quality used to define year-round seasons, to improve repeatability in the future. For example, a hierarchical approach of data availability may run from standardised migration data through to expert opinion in the following way: Trektellen data > BirdTrack data > bird reports data > expert opinion.

The number of seasons varies between species in Furness (2015), and these are generally defined as a set of months. Through talks with Natural England and SNCBs, it has been highlighted that defining appropriate seasons is highly important. A possible update would present outputs at a monthly resolution, whilst also providing species-specific seasons, allowing stakeholders to tweak the provided seasons if necessary using monthly data as building blocks, as for example there may be phenological differences between different regions or the UK, or species may have different life histories (e.g. catastrophic moult period in auks). Presenting outputs at a monthly resolution would also align with other aspects of assessments such as seabird surveys at sea and collision risk modelling.

2.5. Defining uncertainty in outputs

The confidence in the outputs presented in Furness (2015) was categorised in terms of uncertainty based on expert opinion, which considered the extent of the available literature, population trends, and available sample sizes. A possible update to categorise uncertainty in an updated version could consider the hierarchical approach used to apportion populations to UK waters, and the data used to define regions and seasons, to allocate a quality score to the outputs depending on the quality of the data that were used for the above components, whilst presenting uncertainty with a similar traffic light system as used in Furness (2015).

2.6. Presenting report outputs with two example case study species

In the original Furness (2015) report, all outputs are provided as tables either in the main text or appendix. A recommended update would be to create an Excel spreadsheet which contains all required outputs and from which the desired information can be easily extracted. To demonstrate how the updated data outputs would be presented in the Excel spreadsheet, two case study species were suggested: Guillemot (as a data rich species) and Great Black-backed Gull (as a more data limited species). Guillemot was selected as there is a need to assess new data since Furness (2015) to establish 1) if four seasons is more suitable than the current two, in line with Razorbills and 2) whether a moult season should be incorporated. Great Black-backed Gull was selected as this is a less data rich species (i.e. in terms of available tracking data) but that is still an important species with regards to impact assessments, especially in terms of collision risk.

At the end of this session the participants had also had a short presentation about the research currently being undertaken by Vance Mak, a PhD researcher at the University of Exeter, who is using geolocator tracking data to improve our ability to identify how different seabird colonies (from across the North Atlantic) are using UK waters during the non-breeding season, using the Kittiwake as an example. The results from this work can provide spatial and temporal information on where individuals are spending their time across the annual cycle which can then be used to inform apportioning of impacts, for example, from offshore renewable developments (which will be considered during Phase 3 of the proposed BDMPS update).

2.7. Initial points made in the Q&A following the presentations that need to be considered when updating the BDMPS

1. Seasons are not discrete for all populations/individuals of a species so how to account for seasonal overlap?
2. When considering a hierarchical approach:
    1. Different sources of data i.e. from tracking and ringing may be equivalent in importance as they can provide information on different components of a population (i.e. tracking of breeding adults, ringing of chicks).
    2. The availability of different data sources will differ by species so need to consider how a hierarchical approach can be used consistently across multiple species, and how multiple data sources can be combined for any given species.

3. Breakout room summaries

The following questions were discussed across the breakout rooms:

1. Would changing the seasons to a monthly resolution benefit or cause issues to how you currently use the BDMPS?
2. What would be the best/preferable option regarding seasonal definitions moving forward?

3. Would modifying the regions benefit or cause issues to how you currently use the BDMPS?
4. What alternative options are there to the current BDMPS regions?
5. What would be the best/preferable option moving forward regarding regional definitions?
6. How do we estimate proportions of individuals within each region and month/season?
7. Are there alternatives to the use of ringing data and tracking data that have not been discussed?

A summary of the main outcomes from the discussions is presented below:

3.1. Breakout room 1 – Nina O'Hanlon and Andrew Harwood

3.1.1. Defining seasons for BDMPS

The group was generally supportive of the monthly resolution of data, where there is sufficient evidence. The project team made it clear that it would currently underpin the information for seasons. There are concerns about how different seasons can be applied in different areas, and this probably needs to be addressed by SNCBs in interpretation of evidence and guidance. There is a need to balance biologically meaningful data and simple approaches to assessments.

Having data at a monthly resolution would be good, but there is a need to retain seasons which should be reviewed and spatial variation considered. Phase 3 may provide options for converting to full monthly resolution for apportioning.

Specific points

Concern about how moving to a monthly approach might have knock on effects on displacement assessments that are currently underpinned by seasons. It would be useful to have monthly estimates of displacement eventually so noted that there might be a need to revisit displacement assessments.

Given there are differences in how seasons are defined between different SNCBs it is important to think about what drives differences in seasonal distributions (i.e. phenology) and how this is complicated by natural history, spatial variation in prey availability.

Need to consider that if data is used from different months in a dataset to define seasonal apportioning, could you end up double counting aspects of the population?

Offshore Wind Farm data often feed into assessments and could provide really useful information on seasonal distribution/abundance of birds – therefore can survey data (i.e. at sea-survey data) from individual offshore wind farms be used to help define season?

3.1.2. Defining BDMPS regions

Regarding the current regions, it was made clear that any updates or changes should depend on the strength of evidence. It might be useful to reduce the size of the region, but only if there were sufficient data.

We touched on the use of BDMPS for EIA and everyone acknowledged this was a tricky issue. We noted that whilst understanding of metapopulations may be helpful, the use of BDMPS might be more appropriate for EIA given the complexities of variable impacts across the metapopulation. Everyone agreed that, whilst it is important to consider biological reality, it is best to keep things as simple as possible.

3.1.3. Additional points

Issue of age structure

Need to consider how to deal with having limited information on the numbers and distribution of immatures. Determining age structures of populations is tricky especially as it can be challenging to identify immatures, particularly of older age-classes, from adults.

The current approach for determining age structure in the BDMPS is a simplification, but this could be addressed where there is suitable evidence. There may be options to compare spatial data from different sources to provide information on the distribution of age classes at different times of the year. For example, comparing tracking data from breeding adults with at-sea survey data of all age-classes. Issues around sabbaticals/non-breeding adults also raised, but not really taken further.

Inclusion of the Republic of Ireland
In general, the group appeared supportive of the inclusion of the Republic of Ireland in the update, it was noted that there had been previous attempts during recent projects but that there was no straightforward way to extend. The project team highlighted that it was our intention to scope Ireland into the Phase 2 update, but that we would want further input on this prior to implementation, given the additional work required.

Case Study Species
Case study species were suggested, with no issues being raised with the two suggestions which include Guillemot and Great Black-backed Gull.

3.2. Breakout room 2 – Daniel Johnston and Sophy Allen

3.2.1. Defining BDMPS regions
The current region sizes were highlighted as being potentially too large for some species masking population level effects of some developments, alternatively smaller regions may increase the perceived impacts within Habitat Regulations Assessments (HRAs). There was discussion on the feasibility of using grid cells, with clarifications that the current phase would include immediate step updating existing regions and considering the use of grid cells in future. By practitioners which carry out assessments it was emphasised the importance of defining ecologically meaningful regions. Those with past experience with spatial distribution modelling emphasised the need for an updated, adaptive BDMPS process that integrates environmental variables to predict bird locations. It was stressed that assessments must consider the SPA network scale and be species-specific, graded by data quality and values of confidence intervals to represent uncertainty within estimates. It was noted that a shift toward spatial models and smaller grid scales, could accumulate uncertainty in a more meaningful way while remaining adaptable to new data. There was general agreement that ecologically meaningful assessments need to disentangle the scientific process from the assessment process. It was emphasised that there is a need to separate seabird ecology from assessment methodology, advocating for a streamlined approach that integrates ecological understanding into assessments effectively.

The dialogue around non-breeding season assessments questioned whether the current approach remains fit for purpose and whether assessments should be SPA-specific or network-wide. Potentially useful new tools were highlighted, such as AppSaS (improving methods for apportioning seabirds seen at sea in the breeding season and non-breeding season, ORJIP), which could provide a useful template for expanding assessments to include additional data and species.

3.2.2. Defining seasons for BDMPS
The discussion explored whether shifting BDMPS seasons to a monthly resolution would be beneficial or problematic. There was discussion on whether finer temporal and spatial scales truly enhance assessments, with suggestions that a broadly ecologically meaningful approach might be more effective. A potential compromise was proposed leveraging fine-scale understanding to inform broader-scale assessments. A participant, who works with increasingly complex models, highlighted disparities in displacement impact assessments when different numbers of seasons are used (e.g. Razorbill vs. Guillemot). The use of a new tool to integrate fine-scale data into streamlined, practical assessments designed to support practitioners was highlighted. It was indicated that seasonal impacts can vary, but for static impacts from offshore wind farms, resolving to seasonal scales may not always be necessary – unlike in fisheries, where fish stocks are more dynamic. An environmental consultant highlighted the challenge of conducting cumulative and in-combination assessments in the non-breeding season due to the project-by-project approach, questioning whether there were ongoing discussions within SNCBs to address this or if a plan-level assessment would be more effective. They also asked whether updates should align with a specific leasing round. An environmental consultant concluded by stressing that any changes must remain compatible with past assessments, as cumulative and in-combination assessments are a key concern. Finally, it was noted that the timeframe for guidance and an updated BDMPS method could be aligned with the start date of an upcoming leasing round.

3.2.3. Summary
It was agreed that a framework is required to effectively utilise the new high-resolution spatial and temporal

data while ensuring it remains transferable to ecologically meaningful assessments. It was noted that current in-combination assessments involve an overwhelming number of calculations, often resulting in lengthy and inaccessible reports spanning hundreds of pages. Concern was raised that the increased complexity of Environmental Impact Assessments due to higher resolution data also raises the potential for errors. Therefore, a structured method is needed to bridge high-resolution data into a user-friendly, broad-scale, and ecologically meaningful format. This challenge presents a contrast between two approaches: one that focuses on producing estimates at a high-resolution scale and another that emphasises ecologically meaningful estimates suitable for planning applications. A balanced approach could involve using a spatial distribution model based on high-resolution data, which is then scaled to an ecologically relevant level, allowing for uncertainty quantification. At a minimum, an interface for extracting and utilising this data needs to be developed. Additionally, the assessment process should evolve in line with any changes to BDMPS, ensuring that the current approach remains fit for purpose.

3.3. Breakout Room 3 – Sam Langlois and Liz Humphreys

3.3.1. Defining seasons for BDMPS

There was general agreement that presenting the number of birds per region at a monthly resolution would be a good way forward, whilst also providing seasonal definitions using months as building blocks. This approach would match other aspects of the EIA and HRA process such as surveys at sea, and collision risk modelling, which are also carried out at monthly intervals; ensuring consistency with the Cumulative Effects Framework tool for Scottish assessments is also key. A monthly approach provides better foundations to define seasons as required depending on location (within UK or internationally) or different life histories (e.g. moult in auks) and is more future-proof if the BDMPS methodology changes in the future.

There may be a lack of data to allow for a monthly resolution for some species. However, the existing approach (Furness 2015) can still be used to provide data at a monthly resolution, and this can be updated as new data become available. Additionally, this approach would better highlight where knowledge gaps are and which are priority species.

3.3.2. Defining BDMPS regions

Any changes made to the original regional definitions (Furness 2015) made in Phases 1 and 2 would not result in big changes in the assessment process. A grid system (similar to a species distribution model) was described as a possible future option (Phase 3).

A future grid system where each cell contains information on the number of birds at any month of the year (rather than having large regions as is currently the case), and the origin of those birds was briefly discussed (though discussion about this was mostly had in the second breakout session). Differences between using square and hexagonal cells in a grid system were mentioned. Hexagonal cells are an option because they potentially account for geolocator error better than square cells. Such an approach will likely only be possible for a small number of data-rich species.

Using ringing recoveries is one of the best methods available to define BDMPS regions as data is from all age classes (not only from adults as is the case with most tracking data). However, there are numerous biases with using ringing recoveries, for example, where birds are found dead may not necessarily be areas they actively use. Furthermore, ringing data are generally biased due to uneven recovery effort among regions (though modelling approaches can now account for this).

At-sea data from the POSEIDON (Planning Offshore Wind Strategic Environmental Impact Decisions) project (funded by The Crown Estate through the Offshore Wind Evidence and Change programme) can help validate bird distributions against other methods such as ring recoveries and tracking data.

Seabird distributions are defined by prey availability. The timing of Herring spawning, especially for the west coast, was highlighted as a potentially important driver of seabird distributions during non-breeding. Similarly, there is likely interannual variation in seabird distributions due to environmental conditions and prey availability.

It was acknowledged that data availability is very different between species and regions. A species-specific approach is likely better for defining seasons and regions.

In the current approach where regions are defined through hard, straight boundaries projecting from land, there are issues around how to apportion impacts if developments sit on the edge of two boundaries, or very near the edge of one. There can be unrealistic apportioning values where this takes place. Alternative approaches that can account for, or remove such hard boundaries, would be preferable.

3.3.3. Biogeographic populations

Estimating the proportion of birds from a population that use regions of UK waters during non-breeding is key for defining BDMPS. Modelling ringing data whilst accounting for recovery effort bias is a possible approach to obtain these estimates as accurately as possible. There is expertise within BTO on how this can be carried out, but it is data dependent, and it will not be possible for all species.

Many tracking studies have been published since Furness (2015). GLS data will be a good source to estimate the proportion of birds from different populations using UK waters, as well as to define regions. However, tracking data are typically only available from breeding adults, excluding juveniles and immatures which can form large proportions of populations. Combining data from different sources could therefore be beneficial. Previous studies where ringing and tracking data are compared were highlighted (i.e. Matthiopoulos et al. 2022), which will be good sources when defining new methodology for BDMPS.

A combined approach will likely be needed where there are species with knowledge gaps. It is common from immatures to have different strategies to breeding adults, often wintering further south and not returning to breeding grounds until later in life.

4. The future of BDMPS

This session was used to primarily discuss what the BDMPS could look like in the future. For example, using a more complex approach based on a species distribution model, informed by a range of data to generate a grid system that contains information on the abundance of seabirds and associated variables required to produce impact assessments.

4.1. Breakout rooms summary

A summary of participants' views on how the BDMPS may be updated in future, across all breakout groups, is provided below.

There were concerns that such an approach would make an already complex assessment process even more complex. However, it was discussed that we should not shy away from developing a complex analysis framework if the outputs are more robust and accurate, whilst maintaining a simple way of presenting outputs that can be used in assessments.

Another concern was how quickly an approach using modelled species distributions may become outdated. For example, due to changes in a species behaviour or distribution in response to environmental change and food resources. There may be an option to look at predicted modelled species distributions using available climate models to see what changes may occur in future.

A grid system had general support as a way forward, however there would have to be a clear plan for how the outputs are presented. A Shiny app is an option but there are concerns about legacy and maintenance costs, especially if updates or additional functionality are required. Additionally, Shiny apps can take a long time to develop, can be difficult to use and not easy to understand, as they appear as black boxes to most end users. Therefore, resources may be better spent producing required outputs in a simpler form.

If such a big change occurred in how BDMPS are produced the effects on the assessment process would first need to be trialled, with SNCBs consulted throughout the whole process to ensure the method is appropriate.

Whatever new methodology is used, it needs to be flexible so that changes can be incorporated as new data become available, particularly in the context of environmental change and potentially rapid shifts in seabird distributions.

Additional discussions included:

Novel work that can be applied to the BDMPS updates during Phase 2 and 3.

- Recent colony count data from the Republic of Ireland could be used. This was proposed alongside discussion on the need for a BDMPS framework for the Republic of Ireland.
- The use of developer owned data from pre/post construction surveys. This is currently blocked by contracts which do not stipulate that data become publicly available after a period of time. Therefore, a mechanism within contracts is needed to make data available and accessible through platforms such as ESAS.
- Projects which can contribute to an updated BDMPS include GLS data undertaken as part of Aukestra, and auk and Kittiwake tracking being conducted in Aberdeenshire coast.
- At-sea stable isotope analysis being trialled on Dogger Bank by Royal Haskoning could be useful.
- Data poor species requiring further consideration include Great Black-backed Gull and the storm petrels.

Final points made following the future of BDMPS breakout sessions.

- How often should future updates to the BDMPS be made? With the focus of these being on updating the underlying data/evidence. The point was made that an Excel spreadsheet is likely easier to update than a Shiny app based on species' distribution models.
- An argument was made for Kittiwake to also be included as a case study species given that they are more widely distributed across the annual cycle (compared to Guillemot) and that there are no differences between SNCBs in how they currently treat this species.

5. Conclusion

The intention to update the Furness (2015) BDMPS report was welcomed by all workshop attendees, highlighting that it is a very important resource and that it is widely used in the context of EIAs and HRAs for renewable energy developments in the UK. More data and resources are now available that will be key to updating the BDMPS methodology and outputs, whilst making some parts of the methodology more robust and reliant on quantitative approaches rather than expert opinion. It was also acknowledged that the EIA and HRA processes are already complex and time consuming, and that significant changes to how BDMPS are estimated and presented can have consequences for these processes. Consequently, it is important that stakeholders are consulted throughout the update to ensure BDMPS outputs are easily accessible and usable.

Thank you to everyone that attended the workshop for sharing their thoughts and ideas. All contributions to this workshop will be considered when outlining our recommendations for updating the Furness (2015) BDMPS in the Phase 1 report, and when undertaking the update of the BDMPS during Phase 2 of this project.

6. References

Burnell, D., Perkins, A.., Newton, S.F., Bolton, M., Tierney, D. & Dunn, T.E. 2023. *Seabirds Count, A census of breeding seabirds in Britain and Ireland (2015–2021).* Lynx Nature Books, Barcelona.

Furness, R.W. 2015. Non-breeding season populations of seabirds in UK waters: population sizes for biologically defined minimum population scales (BDMPS). *Natural England Commissioned Reports* **164**. Natural England, Peteborough.

Horswill, C. & Robinson, R.A. 2015. Review of seabird demographic rates and density dependence. *JNCC Report* No: **552**, JNCC, Peterborough.

Matthiopoulos, J., Trinder. M. & Furness, B. 2022. Study to Develop Best Practice Recommendations for Combining Seabird Study Data Collected from Different Platforms. Marine Scotland Science Report.

Stroud, D.A., Mudge, G.P. & Pienkowski, M.W., 1990. Protecting internationally important bird sites: a review of the EEC Special Protection Area network in Great Britain.

Wernham, C. V, Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R., 2002. *The Migration Atlas. Movements of the Birds of Britain and Ireland.* T. & A.D. Poyser, London.

Workshop structure/agenda

09:30–09:35 Welcome

09:35–10:30 Presentations

1. Introduction to the BDMPS update
2. How BDMPS is currently used in case work
3. Overview of the BDMPS approach by BTO
4. Biogeographic populations – apportioning and age structure
5. Regions
6. Seasons
7. New Excel template to summarise report outputs and case study species

Q+A session – for clarification

10:30–11:15 Breakout room discussions

Group 1 – Nina O'Hanlon (Chair) and Andrew Harwood (scribe)

Group 2 – Daniel Johnston (Chair) and Sophy Allen (scribe)

Group 3 – Sam Langlois (Chair) and Liz Humphreys (scribe)

1. Seasons:
   Would changing the seasons to a monthly resolution benefit or cause issues to how you currently use the BDMPS?
   What would be the best/preferable option moving forward?
2. Regions:
   Would changing the regions benefit or cause issues to how you currently use the BDMPS?
   What alternative options are there to the current BDMPS regions?
   What would be the best/preferable option moving forward?
3. Biogeographic populations:
   How do we estimate proportions of individuals within each region and month/season?
4. Are there are any specific issues you are encountering with using the BDMPS data or specific updates you would like us to consider

11:15–11:30 BREAK 15 minutes

11:30–11:45 Brief summary of breakout room discussions

11:45–12:45 The future use of the BDMPS and apportioning

Discussion around the identification of any additional/novel work that could be incorporated to future updates to the BDMPS (including breakout discussions)

12:45–13:00 Wrap-up and summary of next steps

Appendix C: Excel workbook with case studies (Guillemot and Great Black-backed Gull)

Appendix C: can be downloaded from the report webpage **via this link**

Cover images, Great Black-backed Gulls, by Sam Langlois Lopez / BTO

A review of the Biologically Defined Minimum Population Scale (BDMPS) approach and methodology to apportioning non-breeding season impacts on seabirds arising from offshore wind farms

UK Statutory Nature Conservation Bodies require estimates of seabird populations during the non-breeding season to apportion impacts of offshore wind farm developments to Special Protected Areas. Furness (2015) formed the Biologically Defined Minimum Population Scales (BDMPS) method, the primary tool in apportioning impacts of offshore wind farms to SPAs for Habitats Regulation Assessments (HRAs) during the non-breeding season. The outputs of the report have also been used to inform reference population values for Environmental Impact Assessments (EIA) and seasonal definitions for assessments.

This review aims to evaluate the methods used within the original report (Furness 2015) and highlights potential refinements to the current BDMPS approach, including methods, definitions, and data resources, to improve future ease of use and accuracy of estimates. The review included workshops to consult SNCBs and industry stakeholders to discuss refinements to populations, seasons, and regional designations within the BDMPS framework.

Suggested citation: Johnston, D., Langlois Lopez, S., Humphreys, E. & O'Hanlon, N. 2025. A review of the Biologically Defined Minimum Population Scale (BDMPS) approach and methodology to apportioning non-breeding season impacts on seabirds arising from offshore wind farms. *BTO Research Report* **791**, BTO, Thetford, UK.

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