BTO RESEARCH REPORT NO. 592

Strategic Ornithological Support Services

Project SOSS-05

Assessing the risk of offshore wind farm development to migratory birds designated as features of UK Special Protection Areas (and other Annex 1 species)

Authors

Lucy J. Wright, Viola H. Ross-Smith, Graham E. Austin, Dario Massimino, Daria Dadam, Aonghais S.C.P. Cook, Neil A. Calbrade & Niall H.K. Burton

Report of work carried out by the British Trust for Ornithology
on behalf of The Crown Estate

October 2012

The British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU
Registered Charity No. 216652

ACKNOWLEDGEMENTS

The idea and scope for this project was developed by the Strategic Ornithological Support Services (SOSS) steering group. Work was overseen by a project working group comprising Alastair Mackay (Forewind), Jesper Kyed Larsen (Vattenfall), Richard Caldow (NE) and Sophy Allen (JNCC). We thank the project working group and other members of the SOSS steering group for many useful comments which helped to improve this report. SOSS work is funded by The Crown Estate and coordinated via a secretariat based at the British Trust for Ornithology. More information is available on the SOSS website www.bto.org/soss.

The SOSS steering group includes representatives of regulators, advisory bodies, NGOs and offshore wind developers (or their consultants). All SOSS reports have had contributions from various members of the steering group. However the report is not officially endorsed by any of these organisations and does not constitute guidance from statutory bodies. The following organisations are represented in the SOSS steering group:

SOSS Secretariat Partners:	The Crown Estate
	British Trust for Ornithology
	Bureau Waardenburg
	Centre for Research into Ecological and Environmental Modelling, University of St. Andrews
Regulators:	Marine Management Organisation
	Marine Scotland
Statutory advisory bodies:	Joint Nature Conservation Committee
	Countryside Council for Wales
	Natural England
	Northern Ireland Environment Agency
	Scottish Natural Heritage
Other advisors:	Royal Society for the Protection of Birds
Offshore wind developers:	Centrica (nominated consultant RES)
	Dong Energy
	Eon (nominated consultant Natural Power)
	EdF Energy Renewables
	Eneco (nominated consultant PMSS)
	Forewind
	Mainstream Renewable Power (nominated consultant Pelagica)
	RWE npower renewables (nominated consultant GoBe)
	Scottish Power Renewables
	SeaEnergy/MORL/Repsol (nominated consultant Natural Power)
	SSE Renewables (nominated consultant AMEC or ECON)
	Vattenfall
	Warwick Energy

The authors are also grateful to Ian Newton, Graham Appleton, Jacquie Clark, Nigel Clark, Nick Moran, Mark Rehfisch, Rob Robinson and Chris Wernham who provided valuable advice and expertise on bird migration.

CONTENTS

EXECUTIVE SUMMARY

1. Migratory birds move across seas in large numbers but over a short time period, often at night and sometimes in bad weather, so are not adequately recorded in bird surveys undertaken as part of Environmental Impact Assessments (EIAs) for proposed offshore wind farms. As such, the possible effects of these developments on migratory birds are not well understood.
2. A comprehensive review of the literature on bird migration (particularly around the UK) was undertaken in an attempt to identify gaps in our knowledge and make recommendations for future research. The review focussed on species that are designated features of UK Special Protection Areas (SPAs), and other regularly occurring species listed on Annex 1 of the Birds Directive, as agreed with the SOSS steering group. This does not mean that other migratory bird species should not be considered in impact assessments, but they are not included in the scope of this report.
3. Information was sought on migratory routes and population sizes, along with details of flight altitudes and the frequency of fall events, which were thought likely to influence a species' vulnerability to collision with wind turbines.
4. The review showed that although a large number of species migrate across UK waters, for the majority of them our knowledge of migratory behaviour is limited and does not allow estimation of the proportion of birds migrating at heights where they may encounter wind turbines.
5. Although the migratory destinations on land are quite well understood for many species, details of the routes that they follow when flying over the sea around the UK are rarely known. This means it is difficult to estimate the numbers of birds likely to fly over proposed offshore wind farm sites, particularly for species that use more than one migratory pathway across UK waters.
6. We have provided guidance on methods to assess the potential risk to migratory birds that are features of SPAs from proposed offshore wind farm developments. Whilst this guidance is currently limited to migratory SPA species, this does not preclude the future need for assessment of other species.
7. We have made recommendations for future work to address some of the current gaps in knowledge that pose a potential risk to consenting for offshore wind farm developments. We suggest that future work should initially concentrate on those species that are features of SPAs, and whose entire biogeographic population migrates across UK waters, in particular if initial assessment using the guidance in this report suggests that there is a potential risk to the species in question. The importance of work on other species should also be considered in these terms, such that studies of species for which negligible risk is identified using the methods suggested in this report, and of non-SPA species and/or those species for which only a small proportion of the population is found in UK waters are not prioritised.
8. Where suitable technology exists, studies combining the use of tags with radar could be particularly valuable in informing our understanding of a species' migratory behaviour. Studies combining weather data with radar observation of migrating birds would also be very valuable.

BENEFITS TO CONSENTING

1. This report provides guidance on the assessment of the numbers of migrating birds likely to pass through proposed offshore wind farm developments, feeding these numbers into a collision risk model to calculate mortality estimates, and apportioning this mortality to specific SPA populations. Agreeing this guidance with statutory nature conservation bodies, developers, consultants and other stakeholders will have a significant benefit to consenting as there has previously been no agreement on how to assess likely rates of collision mortality for migrating birds. This lack of agreement previously posed a significant consenting risk. It is important to note that this guidance does not address whether the predicted mortality results in a likely significant effect, and if so, whether the level of additional mortality to an SPA population affects the integrity of the site (assessed against the conservation objectives established for the SPA).

2. There are still many gaps in our understanding of the routes and flight heights of most migratory bird species, and these gaps in knowledge can also pose a risk to consenting if an overly-precautionary stance is adopted. Here we suggest pragmatic solutions to allow an assessment of risk to migrating birds that accounts for these gaps, acknowledges uncertainty, and adopts a reasonable degree of precaution.
3. We have made recommendations for further work that could address some of the remaining gaps in knowledge and further reduce the consenting risk posed by our current lack of understanding of the precise migration routes, timings and flight heights of birds migrating to and from Britain and Ireland. As a first step, it would be beneficial to use the guidance developed in this report to assess the cumulative risk to each bird species from all existing and proposed wind farms around the UK, in order to prioritise and target any further work for risky species, and refine the list of species likely to be of concern in impact assessments.

INTRODUCTION

Offshore wind farms may potentially impact bird populations through four main effects:

(i) displacement due to the disturbance associated with developments,
(ii) the "barrier effect" posed by developments to migrating birds and birds commuting between breeding sites and feeding areas,
(iii) collision mortality,
(iv) Indirectly, due to changes in habitat or prey availability.

In Environmental Impact Assessments (EIAs) and Habitats Regulations Assessments (HRAs) for proposed offshore wind farms, developers are required to assess effects on bird populations that may migrate across the site at certain times of the year. Migration involves very large numbers of birds, but the timing and number of bird surveys conducted as part of the consenting process is inadequate to capture bird migration across sites. Some species will be missed because their migration is routinely at high elevation (Wernham *et al*. 2002) above the range of turbine blades and where they are not seen by surveyors. Notably, this high elevation migration occurs in the weather conditions in which boat or aerial surveys are possible. However the same species may fly lower, and within the range of turbines, when migrating in other conditions such as stormy weather or at night (when boat and aerial surveys are not possible). Other species will be missed because migration occurs in a short time window, often as pulse events of short duration which are missed by the existing level of survey effort. Some bird species migrate mainly or partly at night and are therefore not recorded by daytime surveys. This means that some species that migrate across sites are not recorded at all or are recorded at such low frequency as to make it difficult to obtain realistic quantitative assessments of passage. Furthermore, migration routes and the numbers of birds migrating across sites may vary from year-to-year depending on environmental conditions (Newton 2010), and surveys conducted for only a small number of years will inevitably fail to capture this variation. There have been few studies that attempt to measure the flight heights of migrating birds, and they are likely to vary within and between species (Newton 2010).

There is therefore a need for a better understanding of bird migration routes, the proportion of bird populations that fly at heights at which they might encounter wind turbines, and the weather conditions that might cause them to do so. This will make it simpler to assess the risk to migrants of barrier effects and collision mortality in the EIA and HRA process for proposed wind farm developments and would help inform the consenting process for proposed Round 3, Round 1 and 2 extension and Scottish Territorial Waters (STW) offshore wind developments, and the assessment of other future offshore wind developments. It would also be valuable to improve understanding of the timing of bird migration and the weather conditions that cause birds to fly at low altitudes.

Aims

The aims of this review are as follows:

i. To review available information on bird migration routes in order to identify key migratory bird species for consideration in proposed Round 3, Round 1 and 2 extension and Scottish Territorial Waters offshore wind developments, and the timing of these species' migrations.
ii. To collate any available information on flight heights of migrating birds, and the frequency and timing of "fall" events where migrating birds may come down to lower altitudes and could encounter wind farms, the proportion of bird species' populations that are involved in such events, and the weather conditions that cause them.
iii. To provide recommendations as to how the information gathered should be used in assessing the risk to migrants of barrier effects and collision mortality in the EIA and HRA process for offshore wind farm developments and where (and for which key species) further data collection, would be required to assess these effects.

iv. To identify key gaps in knowledge of important bird migration routes, flight heights, the frequency of “falls” and the effect of weather on migrating birds, and recommend what further work could be conducted to fill these gaps.

METHODS

This review focuses on bird species that are either designated features of UK Special Protection Areas (hereafter referred to as "SPA species"), or other rare or vulnerable species listed in Annex 1 of the EU Birds Directive (hereafter referred to as "Annex 1 species") that regularly migrate across UK waters. Annex 1 bird species that only occasionally migrate across UK waters (e.g. species that occur as "vagrants" in the UK) were excluded from this review. Species that are not SPA species or Annex 1 species are not included within this report, but this does not mean that they should not be included in impact assessments. A small number of SPA or Annex 1 species that are found regularly in the UK were also omitted if none, or only a very small proportion, of the population migrates across UK waters (for example if the population using UK SPAs is sedentary or largely resident). Species that were excluded on these grounds include Capercaillie *Tetrao urogallus*, Little Grebe *Tachybaptus ruficollis*, Red Kite *Milvus milvus*, Golden Eagle *Aquila chrysaetos*, Peregrine *Falco peregrinus*, Crane *Grus grus*, Kingfisher *Alcedo atthis*, Chough *Pyrrhocorax pyrrhocorax*, Scottish Crossbill *Loxia scotica* and the subspecies Fair Isle Wren *Troglodytes troglodytes fridariensis*.

Migration routes and population sizes

In order to obtain the best available information on birds migrating across UK waters, a combination of methods was employed. Literature searches of peer-reviewed published literature and grey literature were carried out but with priority given to information from the former. The Migration Atlas (Wernham *et al*. 2002) was used as a starting point for gathering basic information on the migration routes of each bird species. Other reports have also been used (e.g. Kober *et al.* 2010; Atkinson *et al.* 2006). More recent published peer-reviewed information was obtained both by searching Web of Science and through citations given in other sources used in the literature review. The search aimed to identify articles containing either the terms "bird" and "migration", or the English or scientific name of each species as well as either the term "migration". All peer-reviewed and grey literature was cross-referenced so that any potentially useful references cited by the articles found in the literature review were also obtained and included in the review if they contained appropriate information.

Population size estimates were derived from a range of sources. International population sizes presented are the size of relevant biogeographic or flyway populations of each species or subspecies. For waterbirds, international population estimates were taken from Wetlands International (2012), while for other species international population estimates are from BirdLife International (2004). British population sizes are derived from Musgrove *et al*. (2011) for wintering waterbirds in Great Britain, Crowe *et al*. (2008) for wintering waterbirds in Ireland, and from Baker *et al*. (2006) for other species, unless stated otherwise. Where the UK or GB population forms the entire international population, the UK and international population sizes presented may differ slightly because of different estimation or rounding methods used by the different publications, or differences in the times at which the population sizes were estimated. Information on the number and location of SPAs designated for each species was taken from the SPA Review (Stroud *et al*. 2001) and subsequent updates to the SPA network as detailed on the JNCC website (http://jncc.defra.gov.uk). When the UK or GB population estimate is in breeding pairs and the international population estimate is in individuals (or vice versa), we have converted breeding pairs to individuals (in order to work out the percentage of the population in the UK) by multiplying by two. This is probably accurate for spring migration, but the number of pairs should usually be multiplied by three for autumn migration (following Stroud *et al*. 2004).

Flight heights and fall events

Information on the altitude of flight and the frequency of fall events (or falls) was sought for the same species whose migration routes are detailed below. Fall events are typically defined as the onshore arrival of unusually high numbers of migratory birds in a small space of time and geographical area (Lensink *et al*. 1999), and are often thought to be associated with meteorological activity (Elkins 1983; Lensink *et al*. 1999). For the purposes of this report, falls were thought to potentially increase the likelihood of

interaction with wind turbines, as prior to a fall, migrating birds might fly lower than usual and therefore closer to turbine height. For turbines further offshore this may be less of a problem. Climatic conditions also influence flight altitude. Temperature plays a role, with migrants thought to choose flight heights that minimize energy expenditure and water loss (Bruderer *et al*. 1995; Schmaljohann *et al*. 2008a). Flight height is also significantly reduced on rainy nights compared to clear ones (Hüppop *et al*. 2006), while wind strength and direction are important, with birds selecting heights with favourable tail winds (Erni *et al*. 2005; Dokter *et al*. 2011).

Information on flight heights and falls was again obtained via a detailed search of the literature. Sources included peer reviewed scientific papers, books, grey literature, such as county and observatory bird reports, and online searches, including Web of Knowledge and migration tracking websites (for example, www.trektellen.nl). The terms "flight*", "height*", "fall*" and "migra*" were thoroughly searched along with terms such as "passerine*", "wader*" and songbird*", and "radar", "weather", "wind*" and "turbine*"[1].

[1] The use of an asterisk in Web of Knowledge triggers a search for any word containing the letters preceding the asterisk. For example, a search for "migra*" produces results for literature containing the words "migration", "migrant" and "migratory".

RESULTS

Migration routes/zones

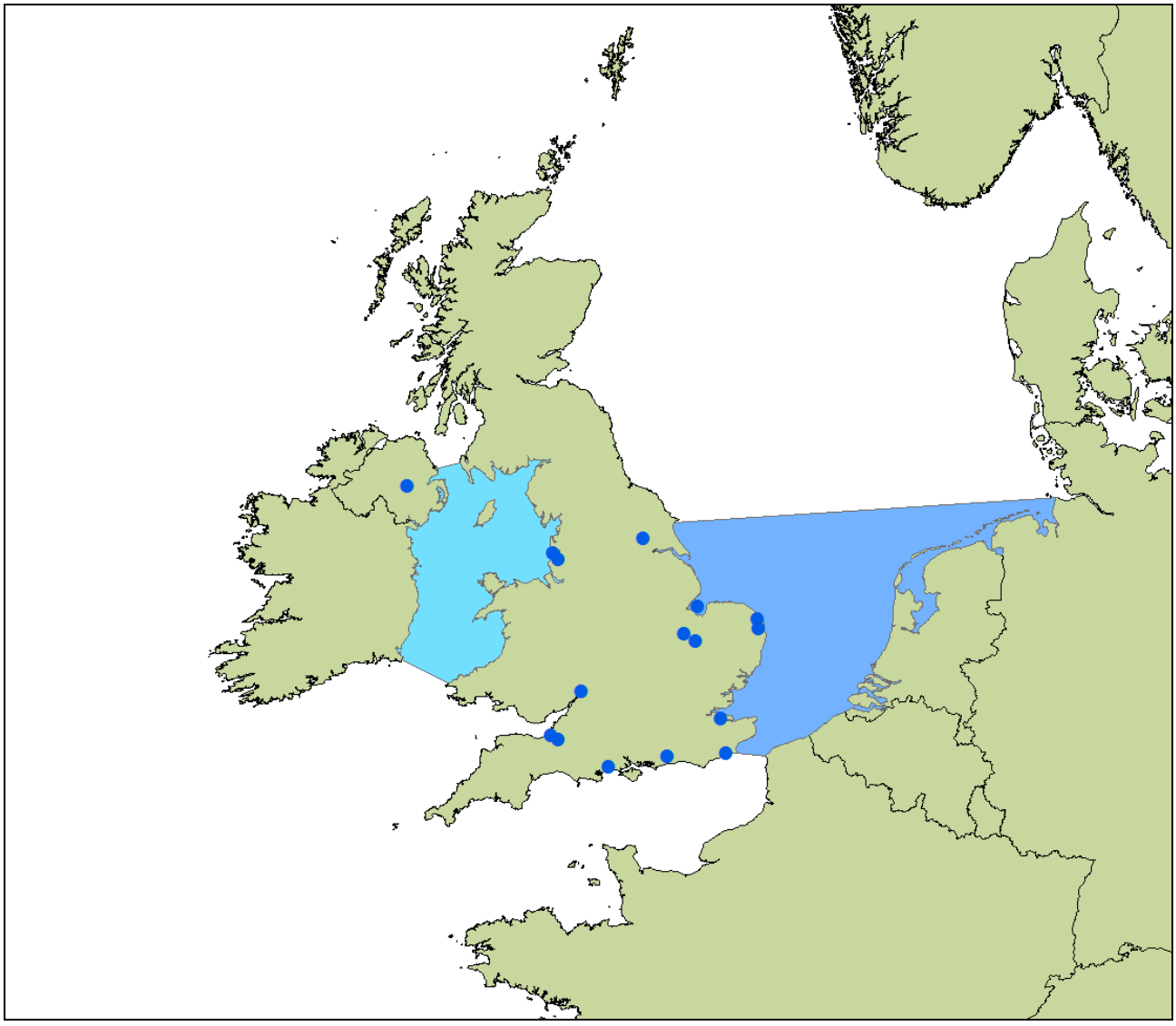
The accounts below give details of the migration routes or migration zones and population sizes of birds of a range of species that are designated features of UK SPAs. The areas highlighted in the maps as migration zones encompass the likely migration corridor rather than specific routes, due to lack of detailed data available. For waterbirds, population sizes given are for Great Britain, and where relevant the All-Ireland population size is also given in the text. For other species population sizes given are for the UK (including Northern Ireland). Note that the number of birds crossing UK waters on migration may be higher or lower than the GB or UK population size given in the table, for example if birds from other populations also move across UK waters, or if only part of the population migrates on particular routes. Where possible, the number likely to cross different parts of UK waters is quantified in the text.

The migration zones shown represent the migration only of individuals from UK SPAs and not for the entire population of each species. The boundaries of zones have largely been defined based on the locations of SPAs, known locations/directions the birds migrate from/to (e.g. from ringing recoveries or knowledge of distributions at other times of year), and for a small number of species information from tracking studies that cover migration seasons (where available) was also used to inform expert judgment on the boundaries of these migration routes. For many species, there will be other individuals from outside UK SPAs that may follow different migration routes across other parts of the sea around the UK; these are not shown here. In addition, as this report is concerned only with how birds migrate across the UK Continental Shelf, the boundaries of migration zones outside this region may be cut off arbitrarily (in particular in the Atlantic).

It is important to note that the information presented in the species accounts below is only intended to be a simplified summary of currently available information to provide a starting point for assessments. With the advent of tracking technologies our understanding of bird migration routes and flight heights is constantly evolving, and therefore we suggest that it would always be wise to conduct a thorough search for up-to-date information regarding migration routes and flight heights of the migratory species to be assessed. This is likely to reduce the risk to consenting posed by the current gaps in knowledge of bird migration, as time passes and our understanding of migration routes and flight heights is refined.

Bewick's Swan *Cygnus columbianus bewickii*

Bewick's Swan *Cygnus columbianus bewickii*	
SPA Species?	Yes (non-breeding population)
SPA Sites	15 sites in England and Northern Ireland
Population Size (GB)	7,000
Populations Size (Ireland)	380
Population Size (International)	21,500 (Arctic Russia breeding, NW Europe non-breeding)
Percentage of international population in GB & Ireland	34%



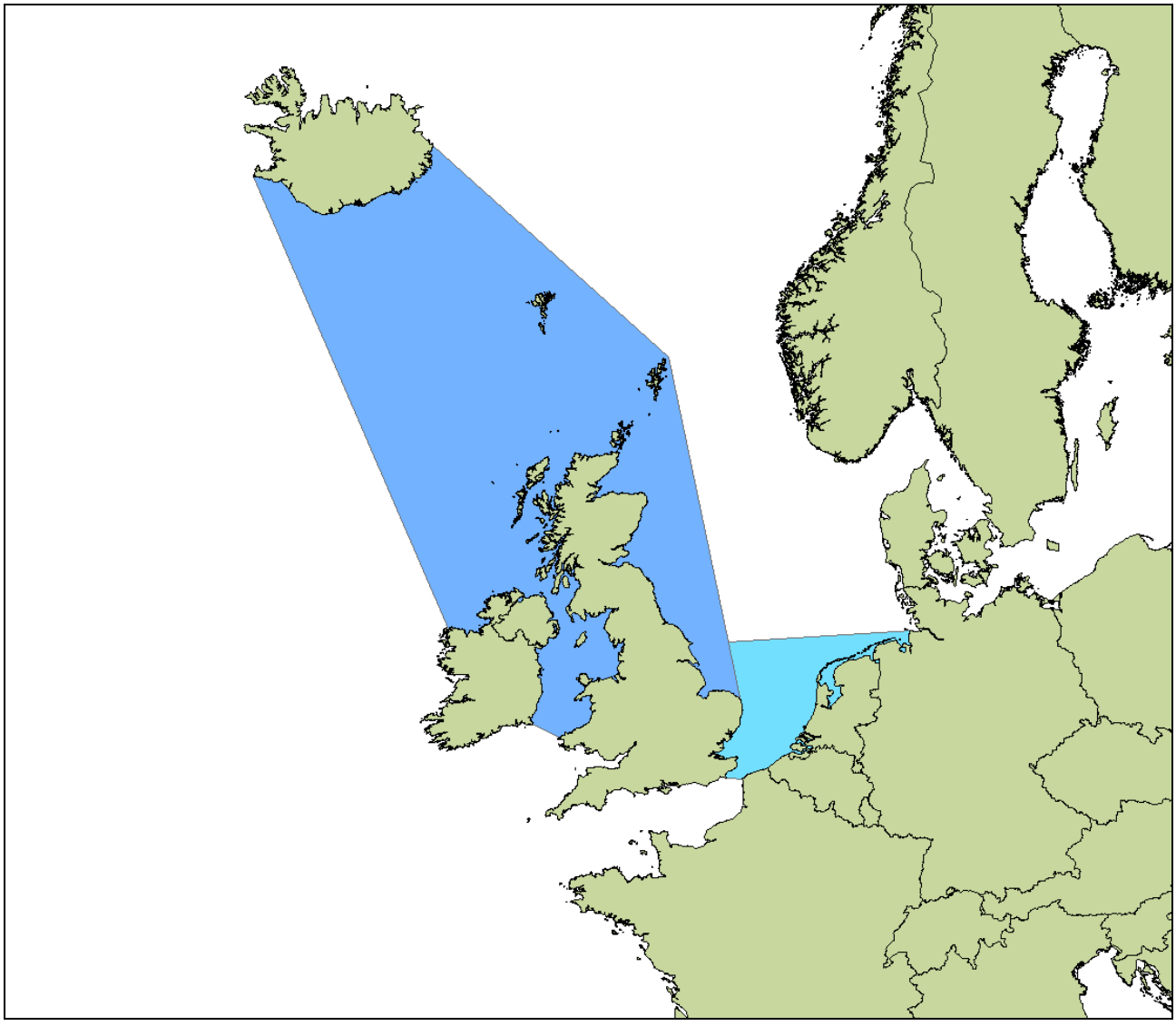
The darker blue shading on this map shows the main migration zone predicted to be crossed by all Bewick's Swans wintering in Britain and Ireland, while the pale blue shows the route crossed only by those wintering in Ireland. Dark blue dots show the SPA wintering sites for this species.

Bewick's Swans breed on the Russian tundra and migrate to a relatively small number of wintering sites in the Netherlands, Britain and Ireland. Birds are extremely site-faithful in winter, returning to the same traditional sites annually. In addition to the 7,000 birds that winter in Britain, an estimated 380 winter in Ireland (Crowe *et al*. 2008). Bewick's Swans migrate to Britain across the North Sea from staging sites in the Netherlands, arriving in autumn from mid to late October, but with arrivals continuing through November and into midwinter (December-January). Return migration during February and March is again across the North Sea, to staging sites in the Netherlands or northern Germany (Wernham *et al*. 2002). The distribution

of staging and wintering sites suggests that all of the 7,380 birds that winter in Britain and Ireland probably cross the southern part of the North Sea in both autumn and spring, with a small number (380) continuing across the Irish Sea. Satellite tracking studies have been carried out on this species, but mainly on birds wintering in continental Europe (Beekman *et al*. 1996, 2002). Further satellite tracking of British-wintering Bewick's Swans would improve understanding of the precise migration routes taken by these birds across the southern North Sea, and whether they are likely to pass across existing or planned wind farm development sites. This further research is a high priority, particularly in relation to proposed wind farm development sites in the southern North Sea. The Wildfowl and Wetlands Trust are currently undertaking a project to fit GPS loggers to Bewick's Swans that winter in the UK, and expect to get the first results in winter 2011/12. These data will be of use in advising on the location of turbines within round 3 zones near to the coast of East Anglia, and it would be beneficial for developers of wind farms in this region to consider consulting WWT regarding these results to get improved information regarding migration routes of this species.

Whooper Swan *Cygnus cygnus*

Whooper Swan *Cygnus cygnus*	
SPA Species?	Yes (non-breeding population)
SPA Sites	20 sites in coastal and inland areas of Scotland, Northern Ireland, northwest and eastern England
Population Size (GB)	11,000
Population Size (Ireland)	12,730
Population Size (International)	26,500 (Iceland breeding) 59,000 (N mainland Europe breeding)
Percentage of international population in GB & Ireland	Almost 100% of Iceland population (a few remain in Iceland) 0.3% of mainland Europe population



The darker blue colour on this map shows the main migration zone predicted to be crossed by almost all Whooper Swans wintering in Britain and Ireland that come from the Icelandic breeding population, while the pale blue shows the route predicted to be crossed by a small number from mainland Europe. It is thought that a small number (approximately 200 birds) may cross the zone shown in pale blue

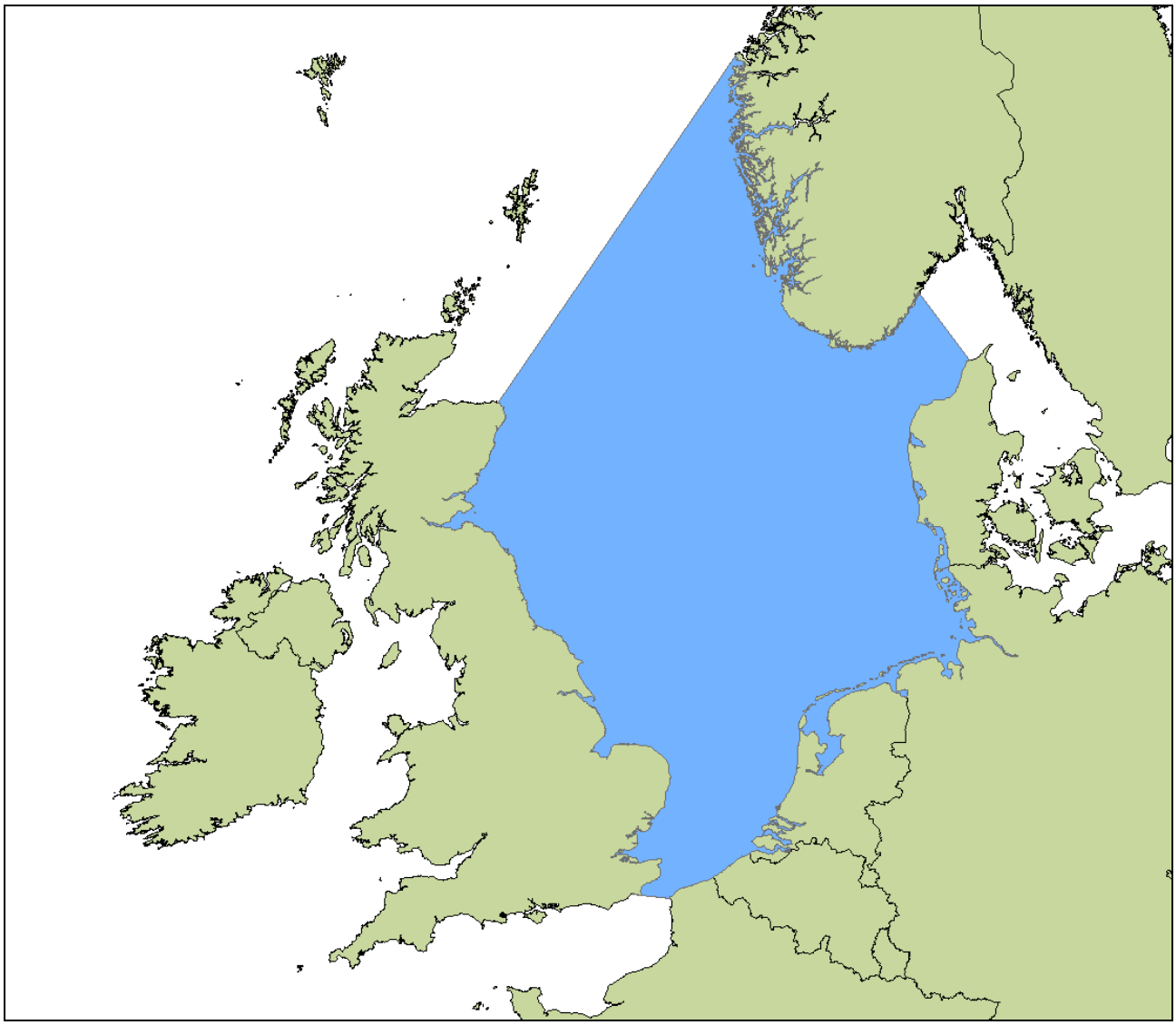
Most of the birds that winter in the UK are from the Icelandic breeding population, but a small number (approximately 200) of birds breeding in Scandinavia and North European Russia apparently also occur here (Laubek *et al*. 1998, Musgrove *et al*. 2011). The majority of the Icelandic-breeding population of Whooper

Swans migrates to Britain and Ireland in the winter, with an estimated 12,730 in Ireland (Crowe *et al*. 2008) in addition to the 11,000 in Britain, but a small proportion remains in Iceland. Satellite tracking of Whooper Swans that winter at three key sites, Welney, Martin Mere and Caelaverock (Griffin *et al*. 2010a, b), demonstrates that in spring birds migrate along both the east and west coasts of Britain, depending largely on their wintering sites, and potentially overlapping with existing or planned offshore wind farm developments in the east Irish Sea, Hebrides, and in the North Sea. Spring migration occurs mainly during March or the first few days of April. In autumn, migration appears to be across a broader front with some birds migrating via Ireland to Britain. Assessments for offshore wind farm developments to in UK waters north of Wales and Norfolk should refer to the report on this tracking work (Griffin *et al*. 2010a) when considering potential effects to migrating Whooper Swans. Further work to improve understanding of the likely numbers passing across potential wind farm sites, and to understand the likelihood of collision, would be extremely valuable and is a high priority given the internationally important nature of British populations of this species, and the large proportion of the Icelandic population that passes across UK waters. Work combining satellite tracking of individual birds with radar studies could achieve this.

In addition to the main migration, there may also be movements across the Irish Sea between Britain and Ireland during the winter.

Bean Goose *Anser fabalis*

Bean Goose *Anser fabalis*	
SPA Species?	Yes (non-breeding population)
SPA Sites	2 sites (Broadland, Norfolk and Slammanan Plateau, Scotland)
Population Size (GB)	Taiga Bean Goose 410 Tundra Bean Goose 320
Population Size (International)	Taiga Bean Goose 40,000-45,000 (NW Europe non-breeding) Tundra Bean Goose 550,000
Percentage of international population in GB	1% of Taiga NW Europe population 0.06% of Tundra population



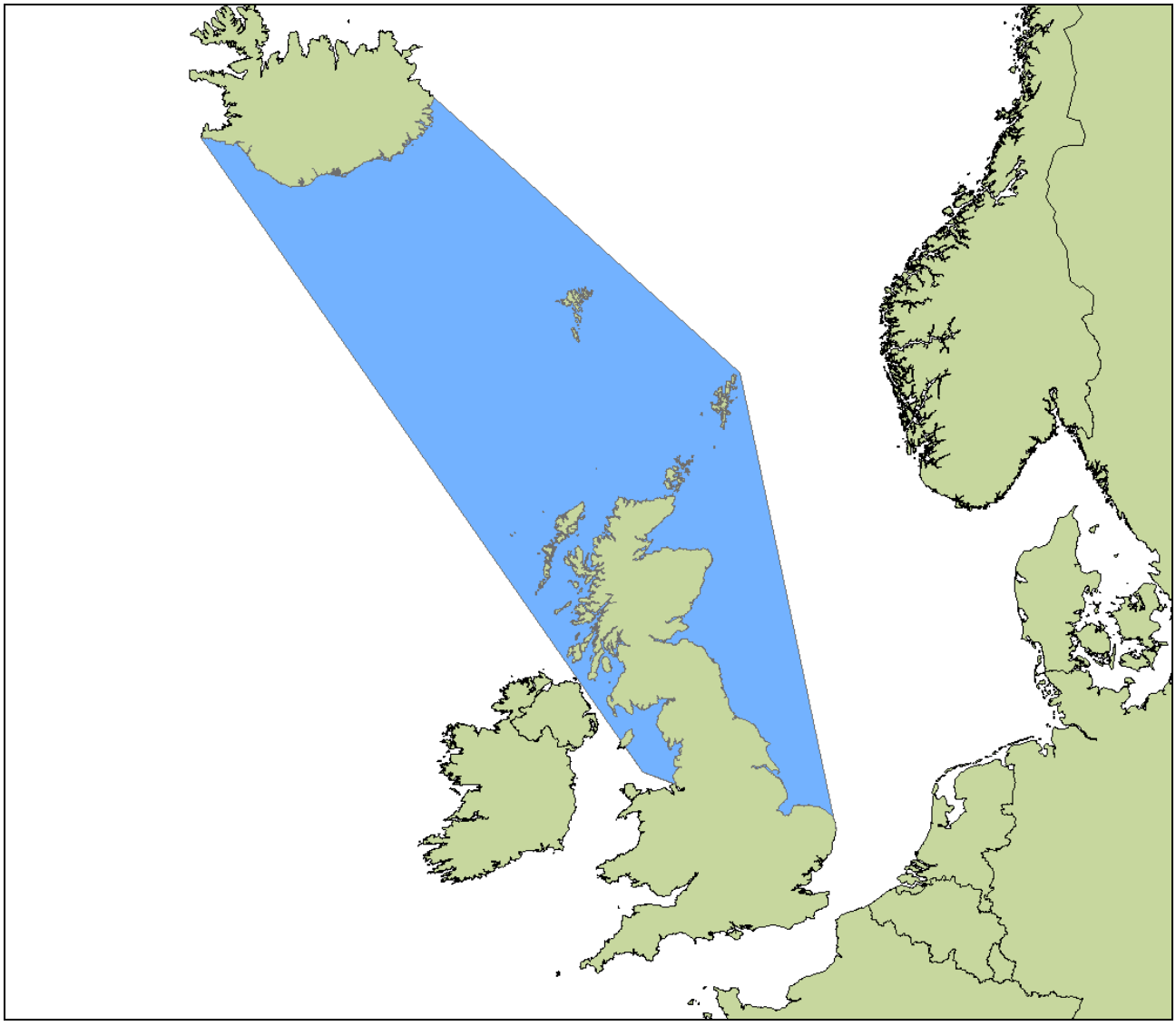
The blue area on this map shows the main migration zone predicted to be crossed by all Bean Geese wintering in Britain.

Both Taiga Bean Goose (subspecies *fabalis*) and Tundra Bean Goose (subspecies *rossicus*) occur regularly but in fairly small numbers in Britain in winter, with Taiga Bean Goose being the more numerous. It is an SPA species because its British populations are thought important in maintaining the species' wintering

range, as they are at the south western edge of it. Bean Geese stay in Britain for a relatively short amount of time in winter; birds migrate to Britain, probably across the central or southern North Sea, from November, and arrivals continue through the winter months, sometimes with influxes during periods of cold weather, and leave between mid-February and early March (Wernham *et al*. 2002). Bean Goose migration should be considered in assessments for offshore wind farms in the central and southern North Sea.

Pink-footed Goose *Anser brachyrhynchus*

Pink-footed Goose *Anser brachyrhynchus*	
SPA Species?	Yes (non-breeding population)
SPA Sites	24 sites in coastal and inland areas of east and south Scotland, NW England and Norfolk
Population Size (GB)	360,000
Population Size (International)	350,000 (Greenland and Iceland breeding)
Percentage of international population in GB	100%



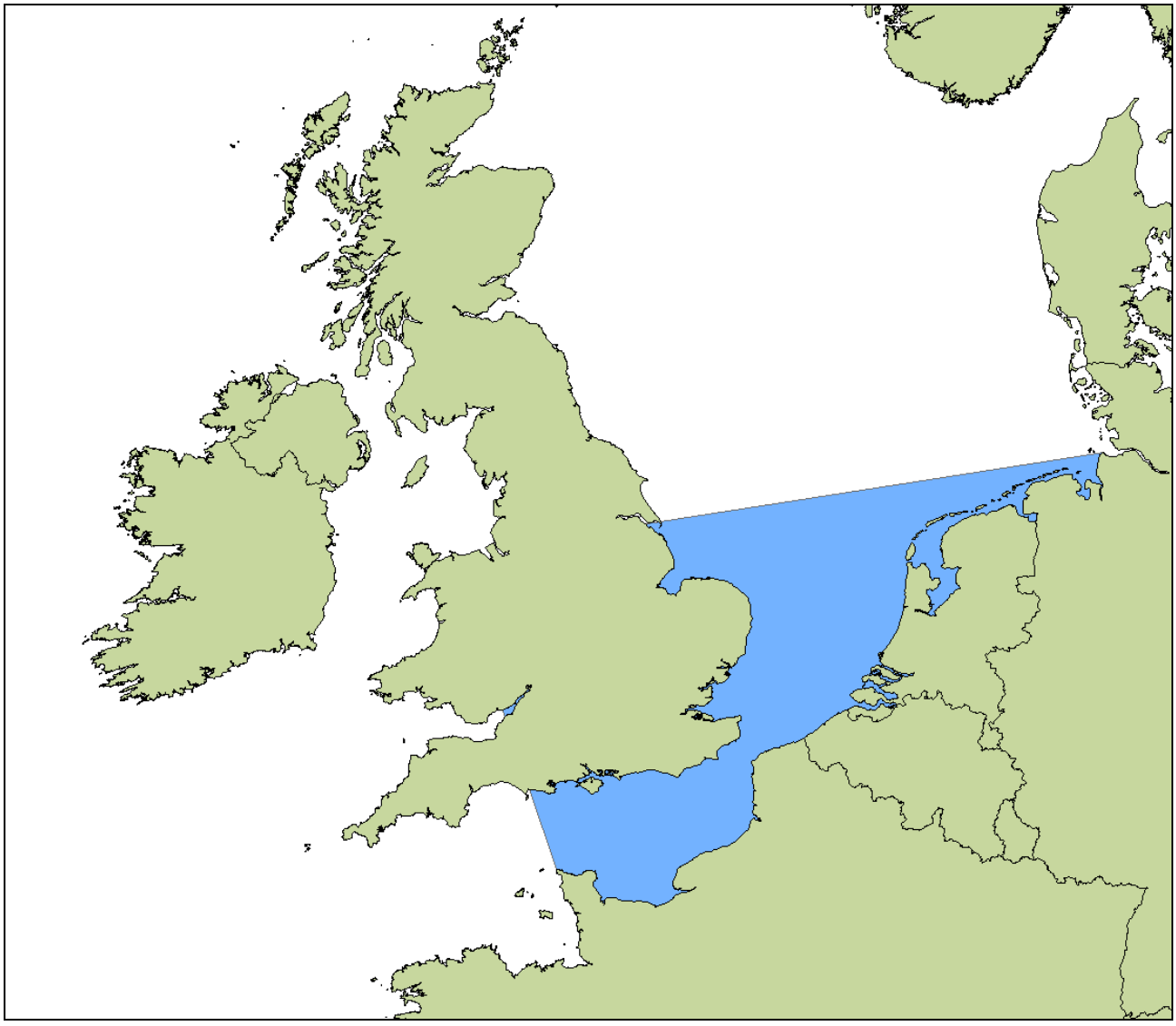
The blue area on this map shows the main migration zone predicted to be crossed by all Pink-footed Geese wintering in Britain.

Pink-footed Goose numbers have increased in recent years (Musgrove *et al*. 2011), hence the latest British population estimate is higher than the international population estimate which pre-dates it. It is thought that the entire Greenland and Iceland breeding population spends the winter in Britain, where it is found in northern and eastern parts of England and Scotland. In addition to spring and autumn migrations, diurnal movements of Pink-footed Geese between roosting and feeding sites may be important at some offshore wind farm sites, and some studies have been conducted using radar to monitor such movements. Furthermore, there is considerable redistribution of Pink-footed Geese within Britain during the winter. Autumn migration sees birds arriving in Scotland from mid-September to mid-October, but birds then

redistribute to sites further south with southward movement continuing until January. Northward movements can begin in February with the main migration to Iceland from mid-April to early May (Wernham *et al*. 2002). Further research would be valuable to improve understanding of the migratory movements of Pink-footed Geese around the UK during winter, and this is a very high priority given that the entire Greenland and Iceland breeding populations of this species winter in Britain and thus migrate across UK waters. Migratory movements of this species should be considered in assessments for offshore wind farm developments throughout northern and eastern parts of Britain (within or north of their wintering range).

European White-fronted Goose *Anser albifrons albifrons*

European White-fronted Goose *Anser albifrons albifrons*	
SPA Species?	Yes (non-breeding population)
SPA Sites	8 sites, all but the Severn Estuary are in eastern England.
Population Size (GB)	2,400
Population Size (International)	1,200,000 (North-west Europe)
Percentage of international population in GB	0.20%

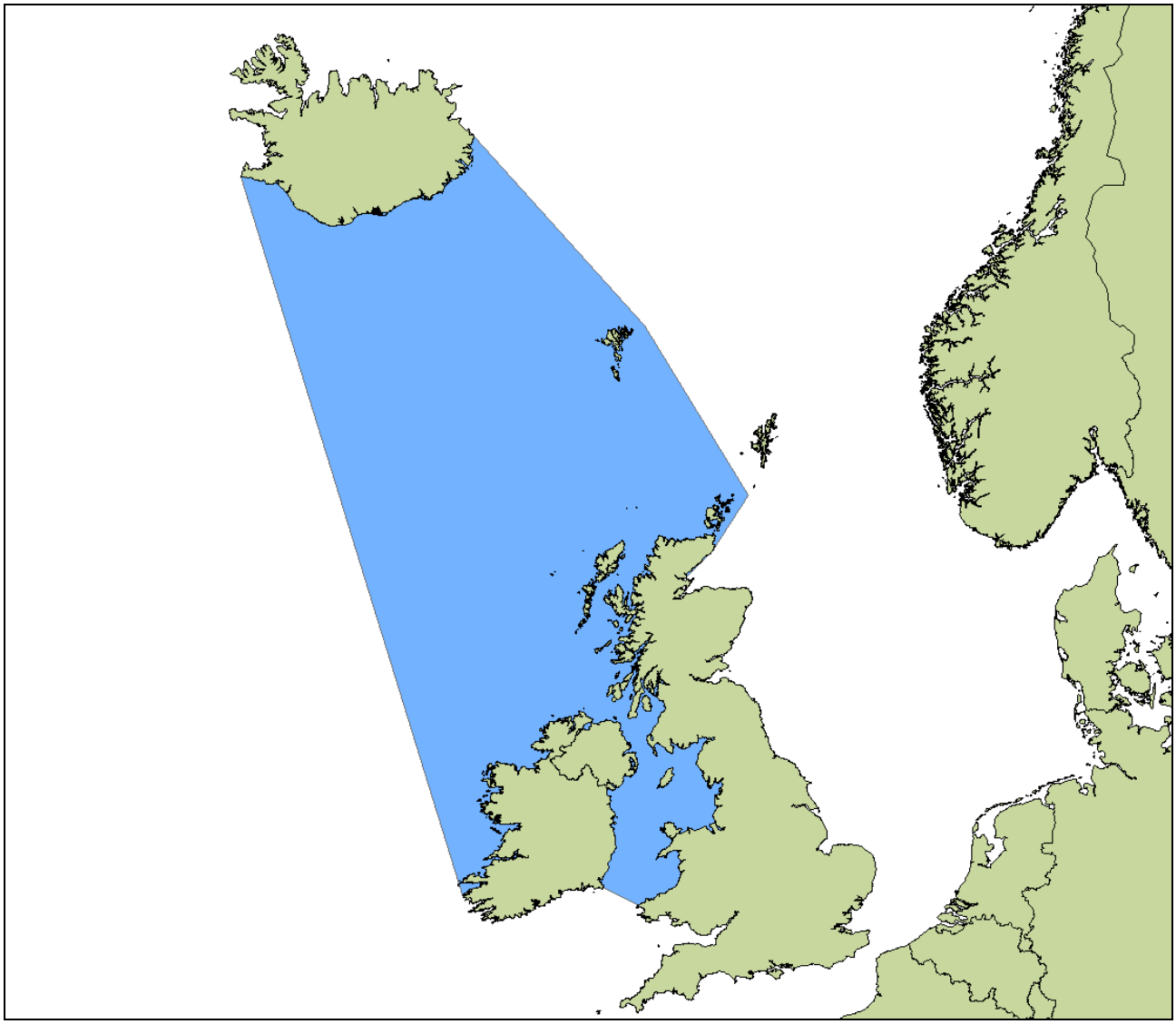


The blue area on this map shows the main migration zone predicted to be crossed by all European White-fronted Geese wintering in Britain.

Britain forms the western edge of the wintering range of the European White-fronted Goose. Their migration route to Britain is across the southern North Sea between the Netherlands and eastern England, arriving between late November and early February and returning to staging sites in the Netherlands in March. Migrating birds of this race of White-fronted Goose should be considered in assessments for offshore wind farm developments in the southern North Sea. Further research on this species is only a moderate priority, as the migration route between the Netherlands and Britain is concentrated in a reasonably well-defined area, and because only a small proportion of the international population crosses UK waters.

Greenland White-fronted Goose *Anser albifrons flavirostris*

Greenland White-fronted Goose *Anser albifrons flavirostris*	
SPA Species?	Yes (non-breeding population)
SPA Sites	12 sites in northern and western Scotland and islands, and west Wales.
Population Size (GB)	13,000
Population Size (Ireland)	11,340
Population Size (International)	24,000
Percentage of international population in GB & Ireland	100%



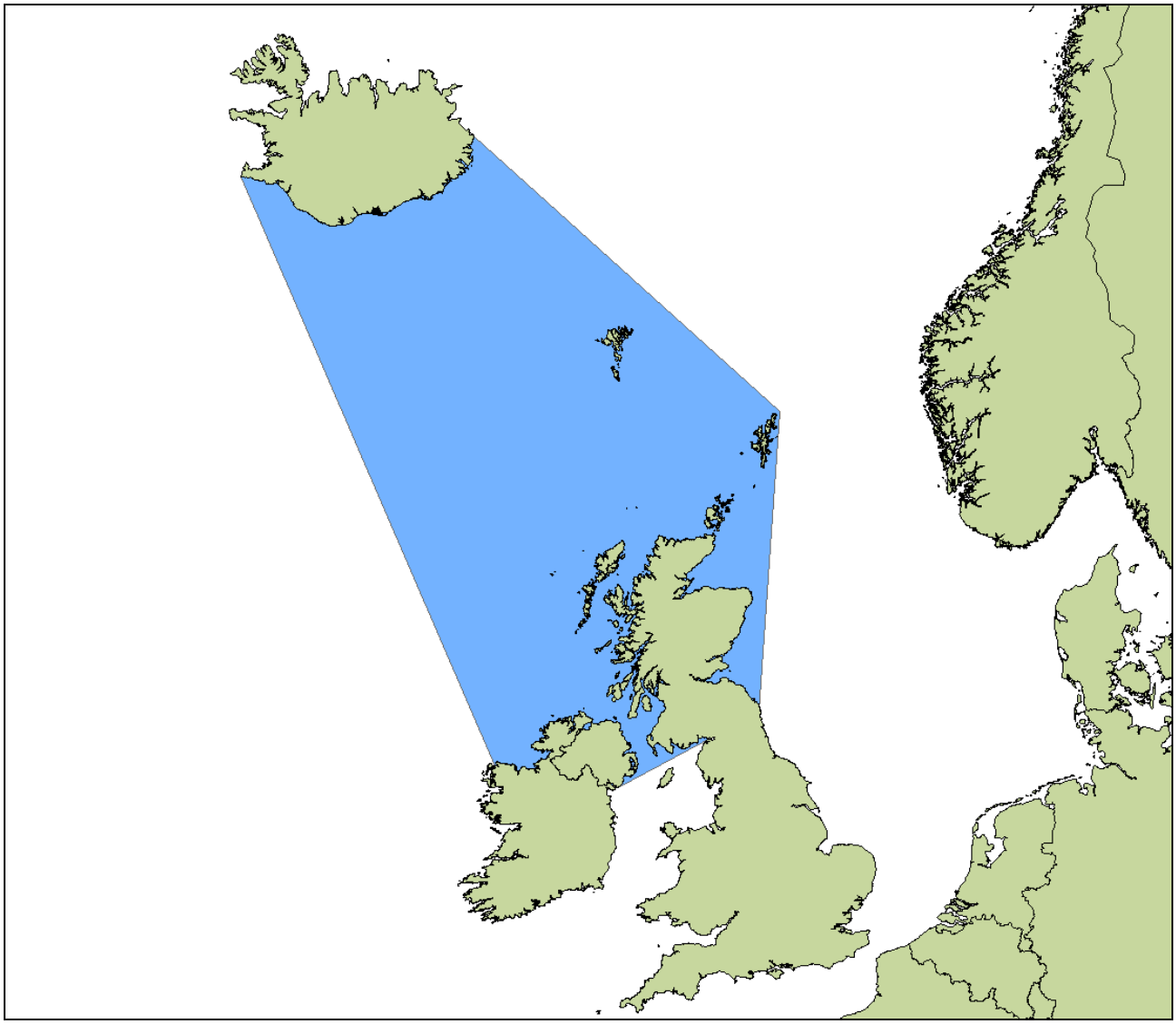
The blue area on this map shows the main migration zone predicted to be crossed by all Greenland White-fronted Geese wintering in Britain and Ireland.

The entire population of Greenland White-fronted Goose winters in Britain and Ireland, where they are restricted to northern and western areas. They are extremely site-faithful with individuals returning to the same sites annually, though a small proportion of birds move between wintering sites. They migrate via staging sites in Iceland, and arrive in Britain and Ireland between late September and November (Wernham *et al*. 2002). Return migration sees birds leaving Britain and Ireland during the second and third weeks of April. A small number of birds have been satellite tracked by the Wildfowl and Wetlands Trust, and this

technique may be useful in improving understanding of migration routes where there is concern that they could cross proposed or existing offshore wind farms.

Icelandic Greylag Goose *Anser anser*

Icelandic Greylag Goose *Anser anser*	
SPA Species?	Yes (non-breeding population)
SPA Sites	22 sites in eastern and southern Scotland, and Northern Ireland
Population Size (GB)	85,000
Population Size (Ireland)	5,030
Population Size (International)	98,000
Percentage of international population in GB & Ireland	100%



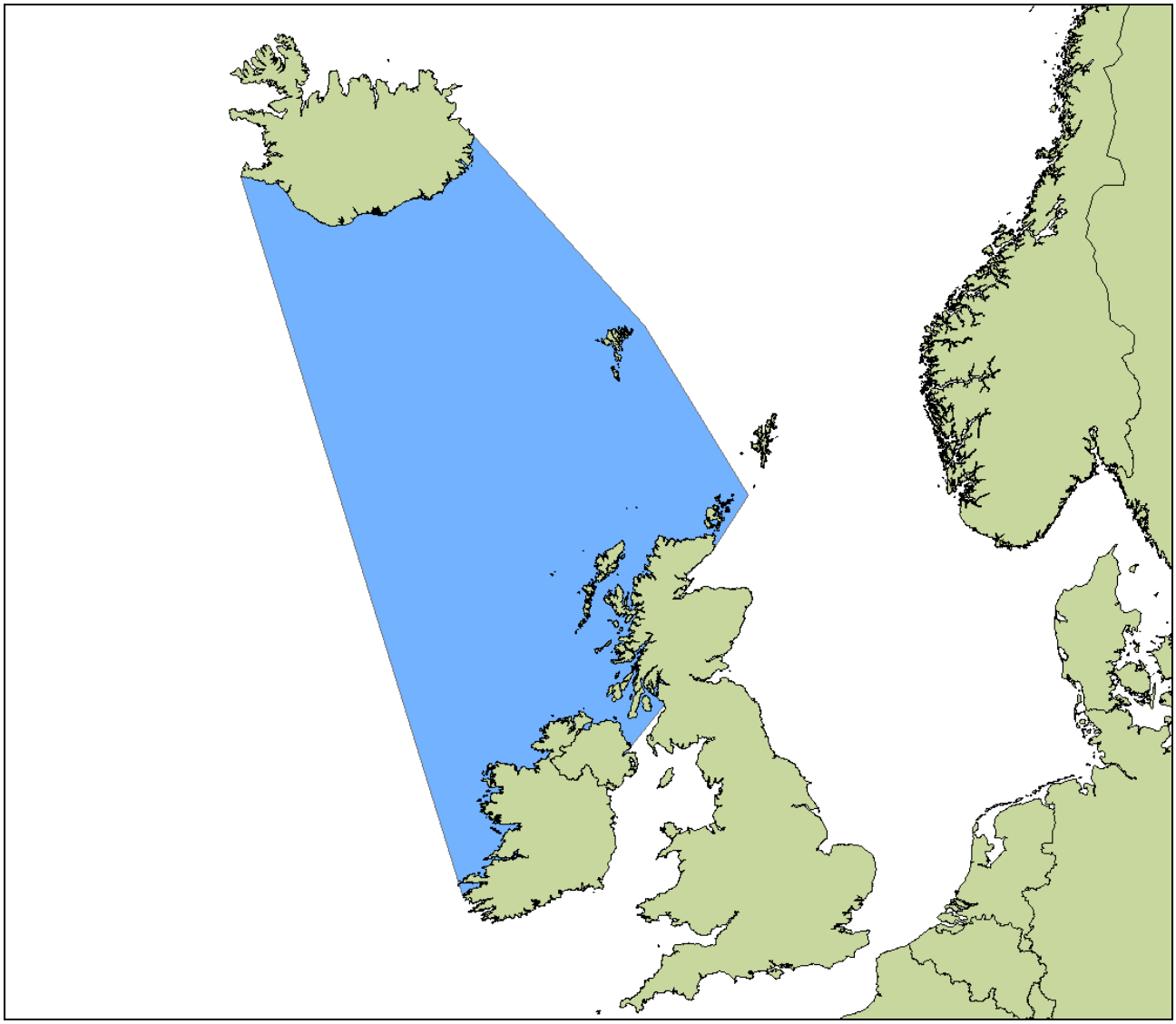
The blue area on this map shows the main migration zone predicted to be crossed by all Icelandic Greylag Geese wintering in Britain and Ireland.

Icelandic-breeding Greylag Geese winter almost exclusively in Scotland, with the majority of birds in northern and eastern Scotland, though smaller numbers occur elsewhere in the country and in Ireland. Autumn migration occurs between late September and early November, with spring migration between mid-March and late April (Wernham *et al*. 2002). Studies using plastic collars and leg rings to allow resightings of individual birds have given a reasonably good understanding of the movements of this species (Wernham *et al*. 2002), and these data may be of value when investigating potential effects of

offshore wind farms within the range of this population. The movements of this population of Greylag Geese should be considered in assessments for offshore wind farms around Scotland.

Greenland Barnacle Goose *Branta leucopsis*

Greenland Barnacle Goose *Branta leucopsis*	
SPA Species?	Yes (non-breeding population)
SPA Sites	11 sites in north and west Scotland and islands
Population Size (GB)	58,000
Population Size (Ireland)	9,035
Population Size (International)	70,500
Percentage of international population in GB & Ireland	100%

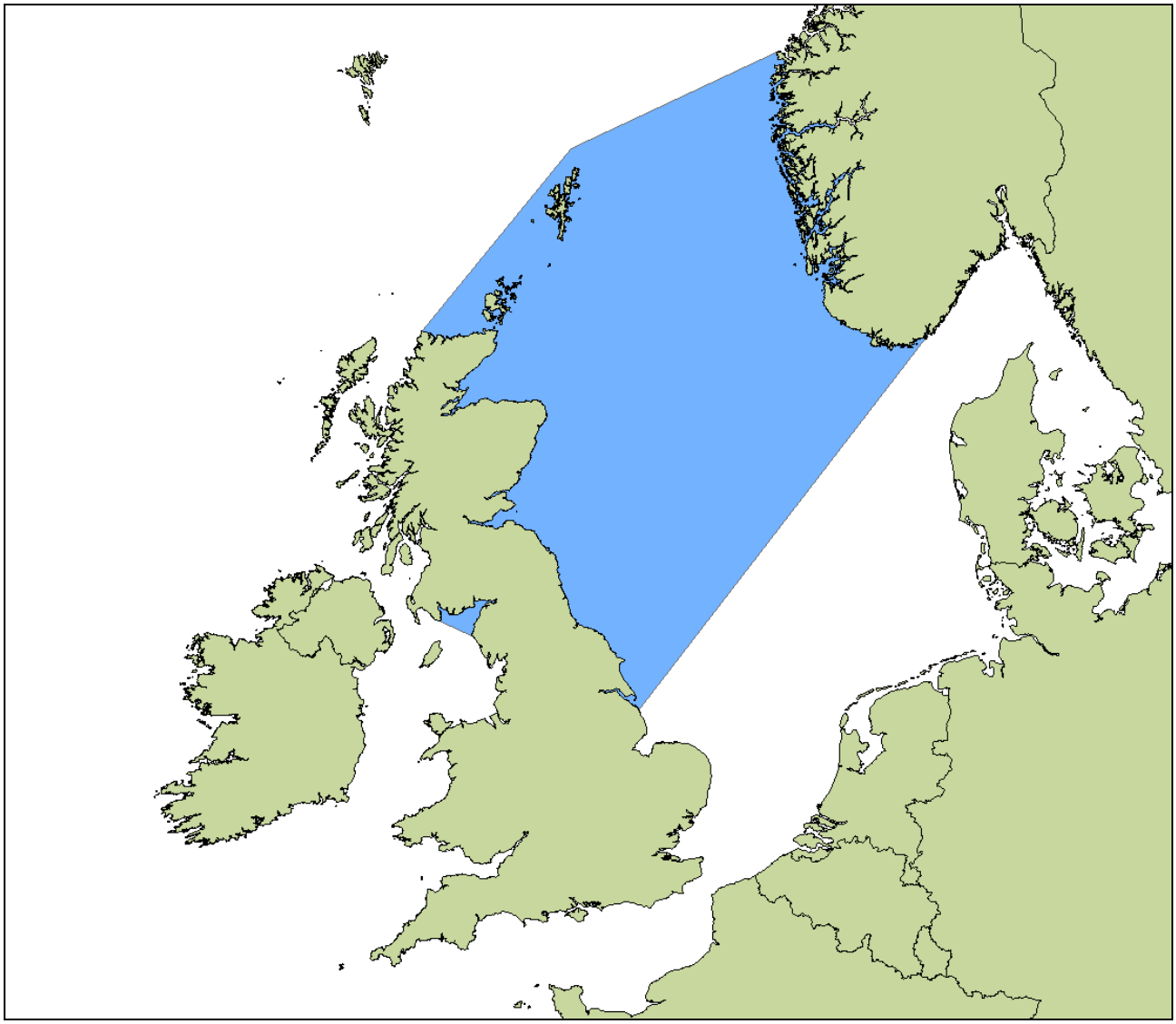


The blue area on this map shows the main migration zone predicted to be crossed by all Greenland Barnacle Geese wintering in Britain and Ireland.

Greenland Barnacle Geese winter across many islands and coastal areas in north and west Scotland and north-west Ireland, with the entire flyway population wintering in this area. Their migration routes should be considered in relation to offshore wind farm developments to the north and west of Scotland (or Ireland). Birds migrate to Britain and Ireland via staging sites in Iceland, and arrive between September and November, returning in mid-April. Many birds have been followed using engraved plastic rings that are readable in the field, and data from these studies may be valuable when considering the movements of this species in relation to offshore wind farm sites.

Svalbard Barnacle Goose *Branta leucopsis*

Svalbard Barnacle Goose *Branta leucopsis*	
SPA Species?	Yes (non-breeding population)
SPA Sites	2 sites in Scotland (Loch of Strathbeg and Upper Solway Flats and Marshes)
Population Size (GB)	33,000
Population Size (International)	30,000
Percentage of international population in GB	100%



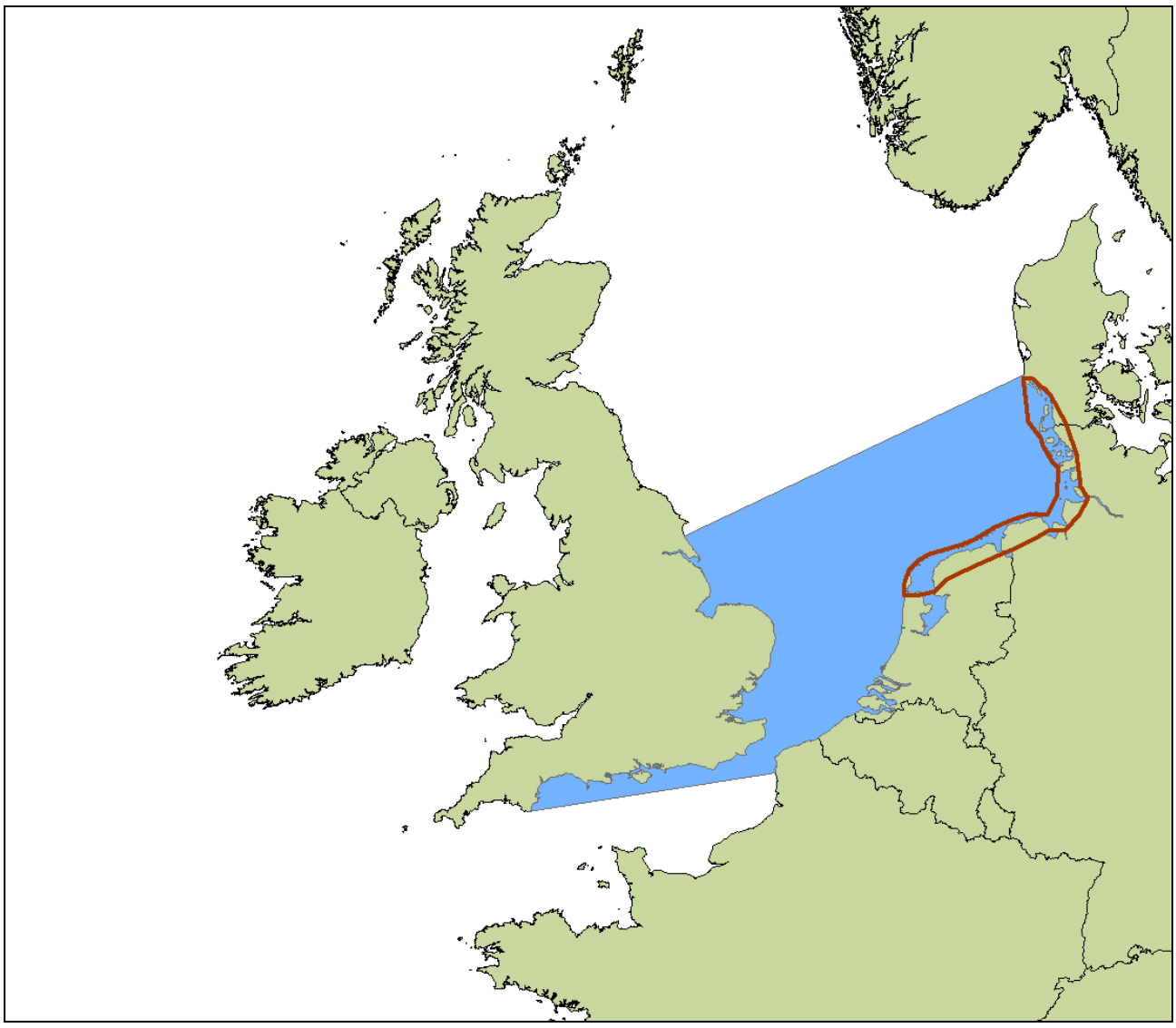
The blue area on this map shows the main migration zone predicted to be crossed by the entire Svalbard Barnacle Goose population. The blue dot shows the main wintering site on the Solway Firth.

Almost all Svalbard Barnacle Geese winter on the Solway Firth, though small numbers occur at other sites in north-east England and eastern Scotland (Musgrove *et al*. 2011). Birds arrive on the east coast of Britain in September and October on a broad front from the Northern Isles to Yorkshire, having crossed northern parts of the North Sea from the south-western coast of Norway. Return migration occurs between mid-April and mid-May. The Wildfowl and Wetlands Trust has satellite-tracked a number of these birds over several years and examination of the data from these studies would be of value when assessing potential effects of proposed offshore wind farm developments off the east coast of Scotland and northern England

(Griffin *et al.* 2011). Further work combining radar studies with satellite tracking could improve understanding of the numbers of birds migrating along particular routes, and would be extremely valuable.

Dark-bellied Brent Goose *Branta bernicla bernicla*

Dark-bellied Brent Goose *Branta bernicla bernicla*	
SPA Species?	Yes (non-breeding population)
SPA Sites	19 coastal sites in southern and eastern England
Population Size (GB)	91,000
Population Size (International)	200,000 – 280,000
Percentage of international population in GB	33-46%

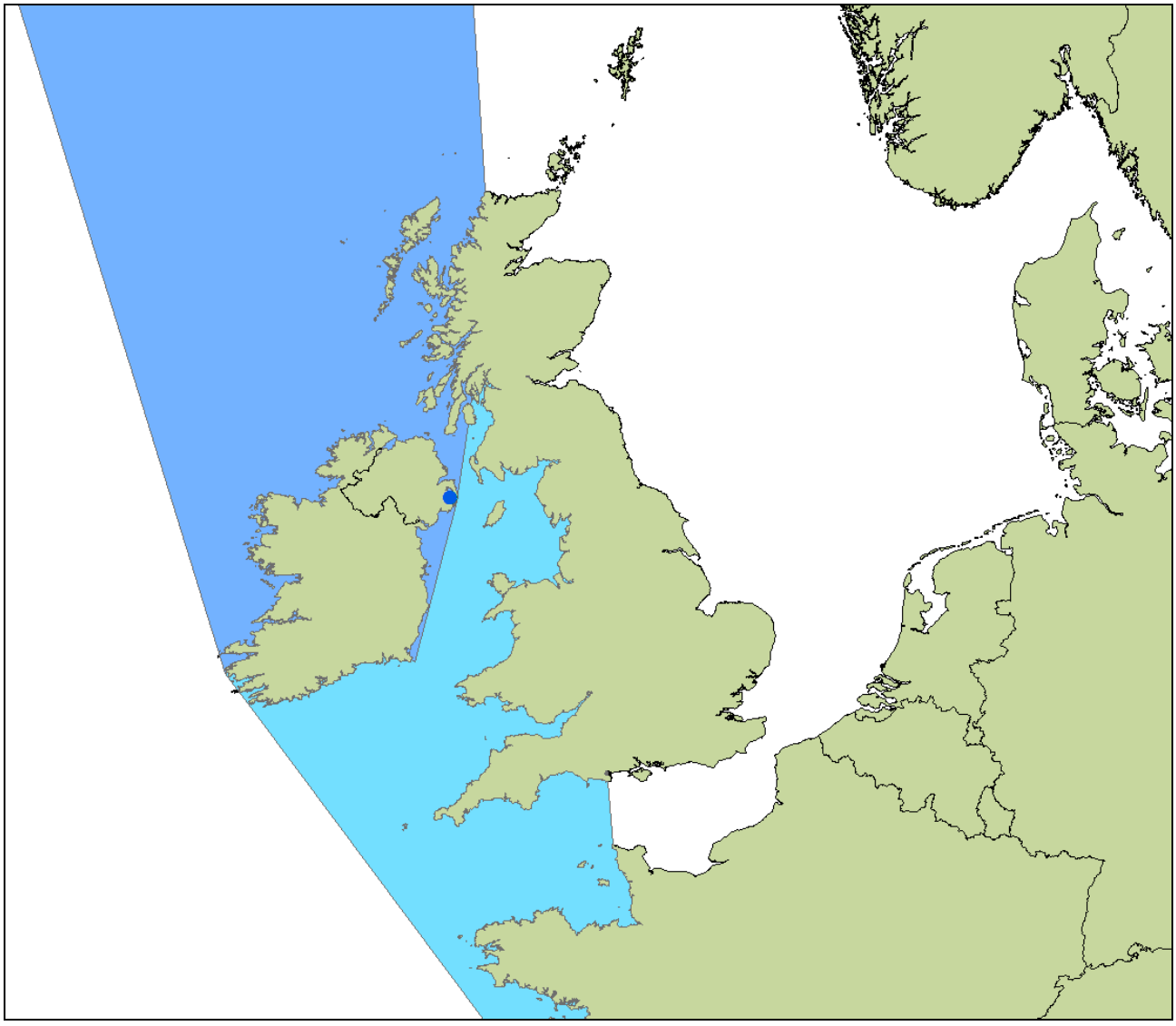


The blue area on this map shows the main migration zone predicted to be crossed by all Dark-bellied Brent Geese wintering in Britain. The brown outline shows key staging areas for this species.

This population of Brent Geese spends the winter in southern and south-eastern parts of Britain, and migrates from breeding sites in arctic Russia, via staging sites in the Wadden Sea during both autumn and spring migrations. This means that the majority of migrants visiting Britain probably pass across the central or southern parts of the North Sea and so should be considered in relation to offshore wind farms in this area. British wintering birds account for almost half of the entire flyway population. Autumn migration occurs between late September and November, with return migration in spring between late February and May. This species is a high priority for further research to improve understanding of the precise timings, locations and flight heights of movements of this species across the North Sea.

Canadian Light-bellied Brent Goose *Branta bernicla hrota*

Canadian Light-bellied Brent Goose *Branta bernicla hrota*	
SPA Species?	Yes (non-breeding population)
SPA Sites	6 sites in Northern Ireland
Population Size (GB)	710
Population Size (Ireland)	21,750
Population Size (International)	40,000
Percentage of international population in GB & Ireland	100%



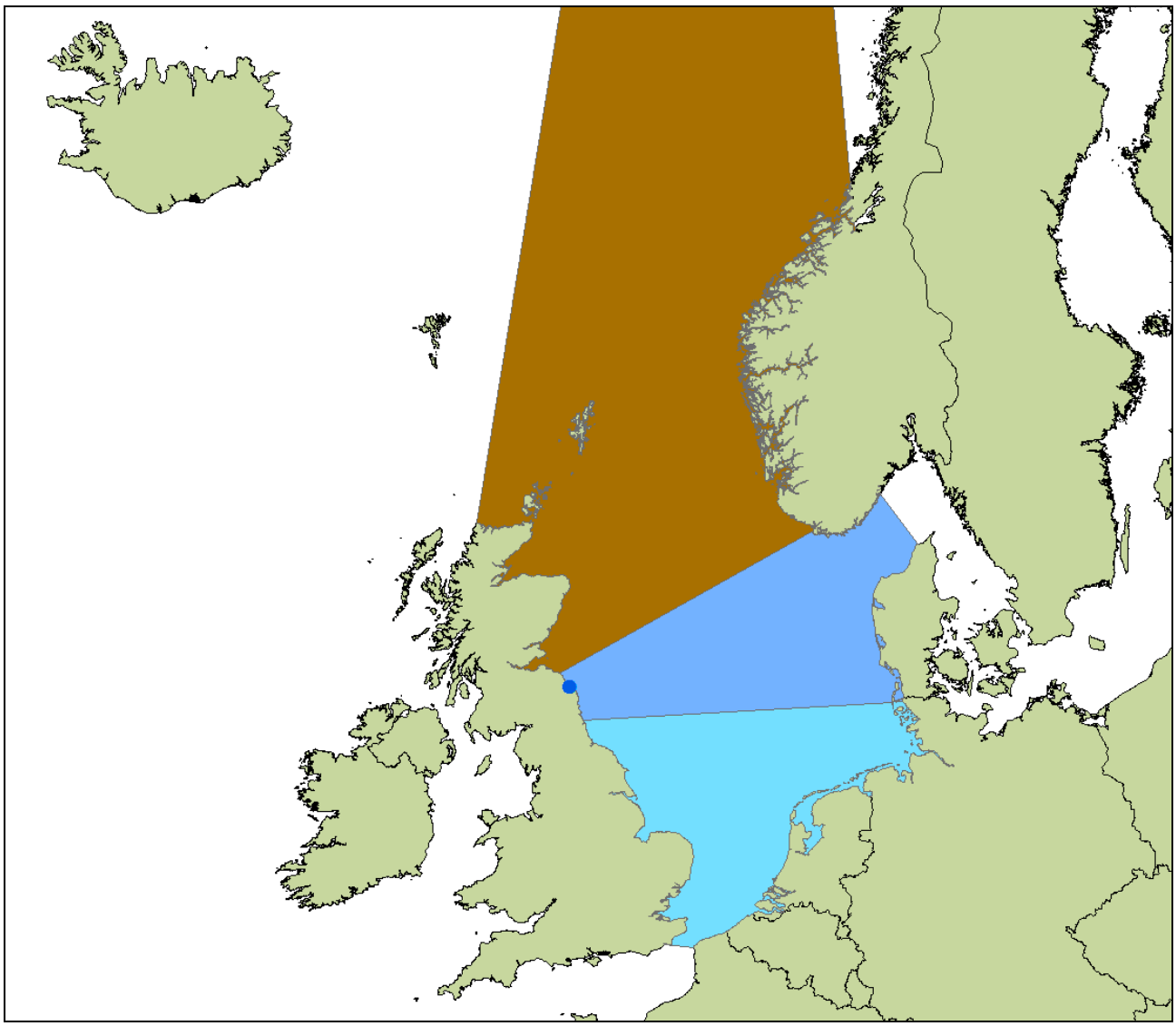
The blue area on this map shows the main migration zone predicted to be crossed by the entire population of Canadian Light-bellied Geese, while the pale blue shows the zone predicted to be crossed by a few hundred that cross to Britain or elsewhere after staging in Ireland. The blue dot shows a key staging site at Strangford Lough.

Brent Geese from this population winter mainly in Ireland, but a small number of birds cross to Britain, where they occur mainly on the west coast with concentrations around Anglesey, but smaller numbers can be found anywhere on the west coast of Britain, as well as in the Channel Islands and the Atlantic costs of France and Spain, often crossing to these areas from Ireland during the winter (Holt *et al*. 2012). In autumn, birds arrive into Northern Ireland where the majority stage at Strangford Lough between late September and November, before dispersing to sites elsewhere, thus it is likely that migration across the Irish Sea (of

those birds that winter in Britain) occurs from November. Birds return to their breeding grounds, via Iceland, in April and May (Wernham *et al*. 2002). The Wildfowl and Wetlands Trust has conducted satellite tracking studies on a small number of Canadian Light-bellied Brent Geese, and the data from these studies may be valuable in determining more precise migration routes offshore. Satellite tracking work could be extended to incorporate birds that winter in Britain, in order to clarify the location and timings of movements across the Irish Sea. This species is, however, only a moderate priority for further research to determine migration routes in relation to UK offshore wind farms, as it is likely that the majority of the population (those that stay in Ireland to winter) do not pass across UK waters where offshore wind farms are planned.

Svalbard Light-bellied Brent Goose *Branta bernicla hrota*

Svalbard Light-bellied Brent Goose *Branta bernicla hrota*	
SPA Species?	Yes (non-breeding population)
SPA Sites	1 site (Lindisfarne)
Population Size (GB)	3,400
Population Size (International)	7,600
Percentage of international population in GB	45%



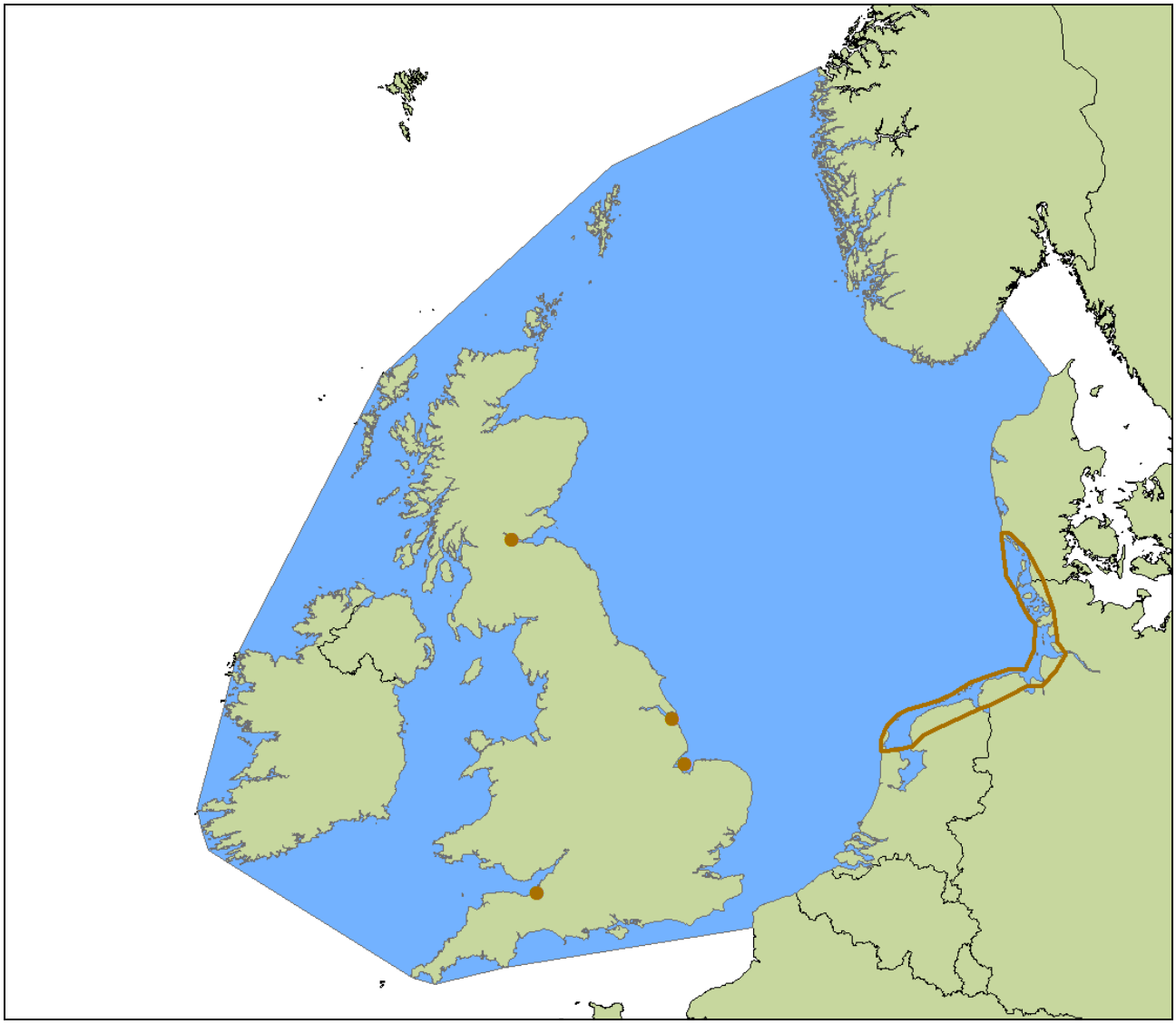
The dark blue area on this map shows the main migration zone predicted to be crossed by the majority of Svalbard Light-bellied Brent Geese wintering in Britain and Ireland. However a small number of birds may also cross direct from Svalbard (brown area) or via the Wadden Sea (pale blue area). The blue dot shows the key wintering site at Lindisfarne.

Brent Geese from this population winter mainly at Lindisfarne, with very small numbers occurring elsewhere on the east coast. Around half of the entire international population winters at Lindisfarne, with the remainder wintering at a small number of sites in Denmark and the Netherlands (Denny *et al*. 2004). Birds arrive at Lindisfarne after crossing the North Sea in late September and October. In the past, the majority of birds migrated to Lindisfarne via stopover sites in Denmark, but there is increasing evidence that some birds now migrate directly to Lindisfarne from Svalbard (Clausen *et al*. 1998, Wernham *et al*. 2002), and some birds migrate via stopover sites in the Wadden Sea. Small flocks of Light-bellied Brent

Geese are frequently recorded along the east coast of Britain in early autumn. These are assumed to be birds making landfall before filtering along the coast to Lindisfarne (Denny *et al*. 2004). In spring, birds probably migrate from Lindisfarne to staging sites in northwest Jutland, Denmark, where the entire population is thought to congregate in early March before continuing northwards to the breeding grounds (Denny *et al*. 2004). The migration routes of this species should be considered in assessments for offshore wind farms in the North Sea, and further research using satellite tracking would be valuable to improve understanding of the routes, flight heights and timings of migration across the North Sea. In the meantime, we suggest that assessments for wind farms planned in the dark blue area of the map should make the precautionary assumption that the entire British-wintering population passes across the dark blue area, while those within the pale blue or brown areas should make the precautionary assumption that up to 1,000 individuals might cross each of these areas (see guidance section below for next steps in calculations).

Shelduck *Tadorna tadorna*

Shelduck *Tadorna tadorna*	
SPA Species?	Yes (non-breeding)
SPA Sites	32 sites in widespread coastal areas in all parts of the UK and on large inland loughs in Northern Ireland
Population Size (GB)	10,600 pairs (breeding) 61,000 individuals (non-breeding)
Population Size (Ireland)	14,610 individuals (non-breeding)
Population Size (International)	300,000 (NW Europe)
Percentage of international population in GB & Ireland	25%

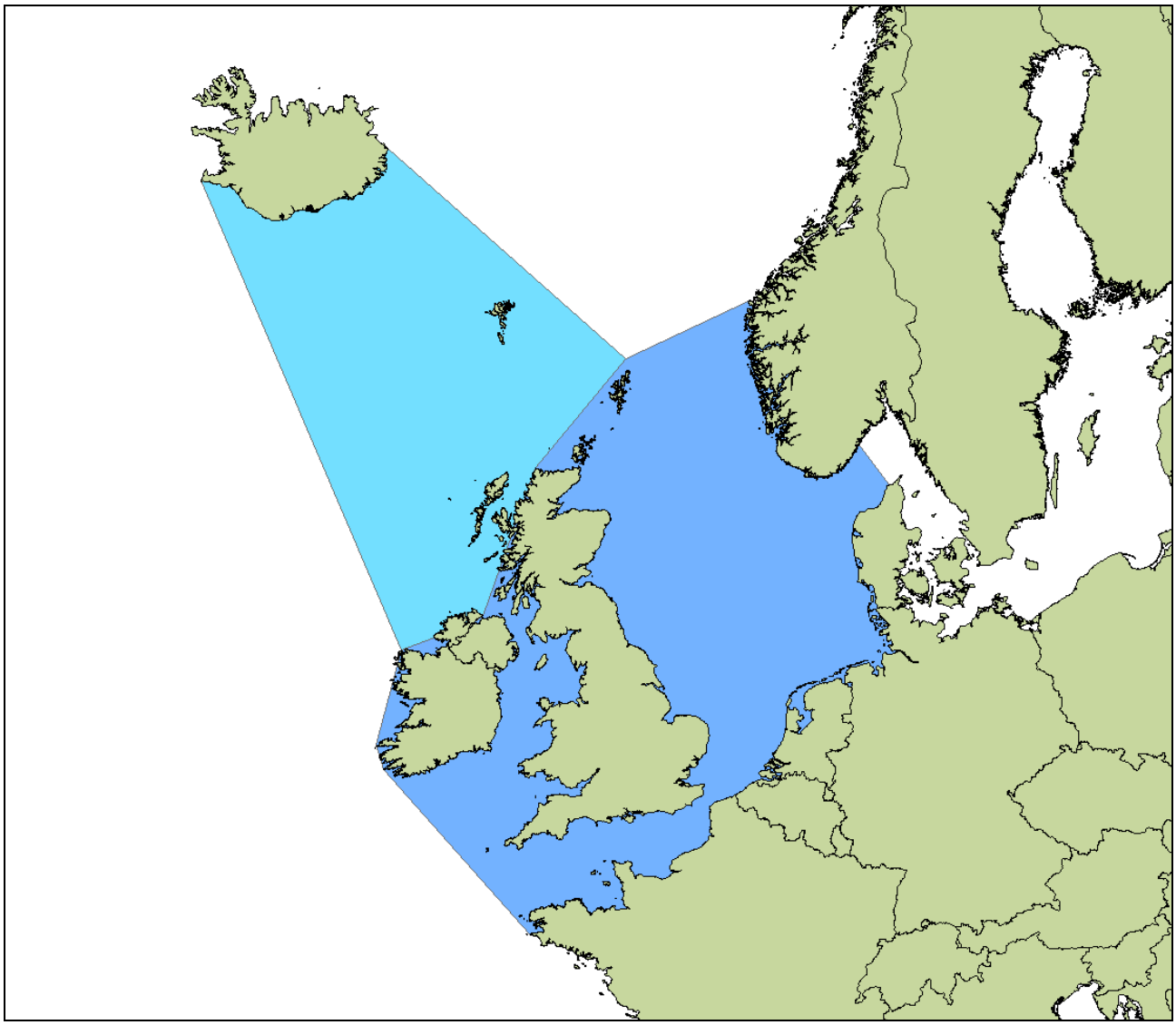


The blue area on this map shows the predicted migration zone travelled by the majority of Shelducks that either breed or winter in Britain. Many British breeding Shelducks make a moult migration to and from the Helgoland Bight, outlined in brown on this map, or to the other moulting sites outlined (see account below for further details). At least 40,000 additional birds cross into Britain and Ireland during winter (assuming that around 21,200 individuals (2x the number of breeding pairs) of the wintering population are birds that breed in Britain (with no emigration), at least the remaining 40,000 wintering birds must come from elsewhere, quite likely more as there may be some emigration of British breeders).

The main movements of British and Irish breeding Shelduck involve a moult migration across the North Sea to moulting sites in the Helgoland Bight in the Wadden Sea. However a smaller number remain in Britain, moulting on a few large estuaries including Bridgwater Bay in the Severn, and the Forth, Humber and Wash on the east coast. The majority of birds complete their journey to moulting sites between mid-June and July, with some in August. The timing of return migration is less well defined, but it appears that birds gradually return to Britain during the first half of the winter, with many arriving first in the south east and then gradually dispersing around the coast back to breeding sites, stopping at several large estuaries en route where large concentrations occur as birds move through (Wernham *et al*. 2002). These birds are also joined in winter by migrants from breeding populations in Scandinavia and the Baltic, but the timing and routes of their crossings of the North Sea is uncertain (Wernham *et al*. 2002). Clearly the migration routes of Shelducks across UK waters must be concentrated in the North Sea, but as birds move around the coast of Britain on return migration smaller numbers probably migrate over most parts of UK waters. There are an estimated 14,610 Shelducks in Ireland and these birds must also cross the Irish Sea on their moult migration. Other concentrations of migrating Shelducks will occur close to British moulting sites, notably around the Bristol Channel and on the east coast.

Wigeon *Anas penelope*

Wigeon *Anas Penelope*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 2 sites in northern Scotland Non-breeding 38 sites in widespread coastal and inland areas around the UK
Population Size (GB)	300-500 pairs (breeding) 440,000 individuals (non-breeding)
Population Size (Ireland)	82,370 individuals (non-breeding)
Population Size (International)	1,500,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	0.06% (breeding) 35% (non-breeding)



The dark blue area on this map shows the main migration zone predicted to be crossed by the majority of Wigeon wintering in Britain and Ireland. The pale blue shows the area encompassing the predicted migration route taken by a smaller number of birds that migrate from Iceland.

Although a small number of Wigeon breed in the UK, a far greater number visit the country during the winter, migrating from breeding areas in Scandinavia and northern Russia, with some also coming from Iceland. In addition to the British population, a further 82,370 birds are estimated to spend the winter in

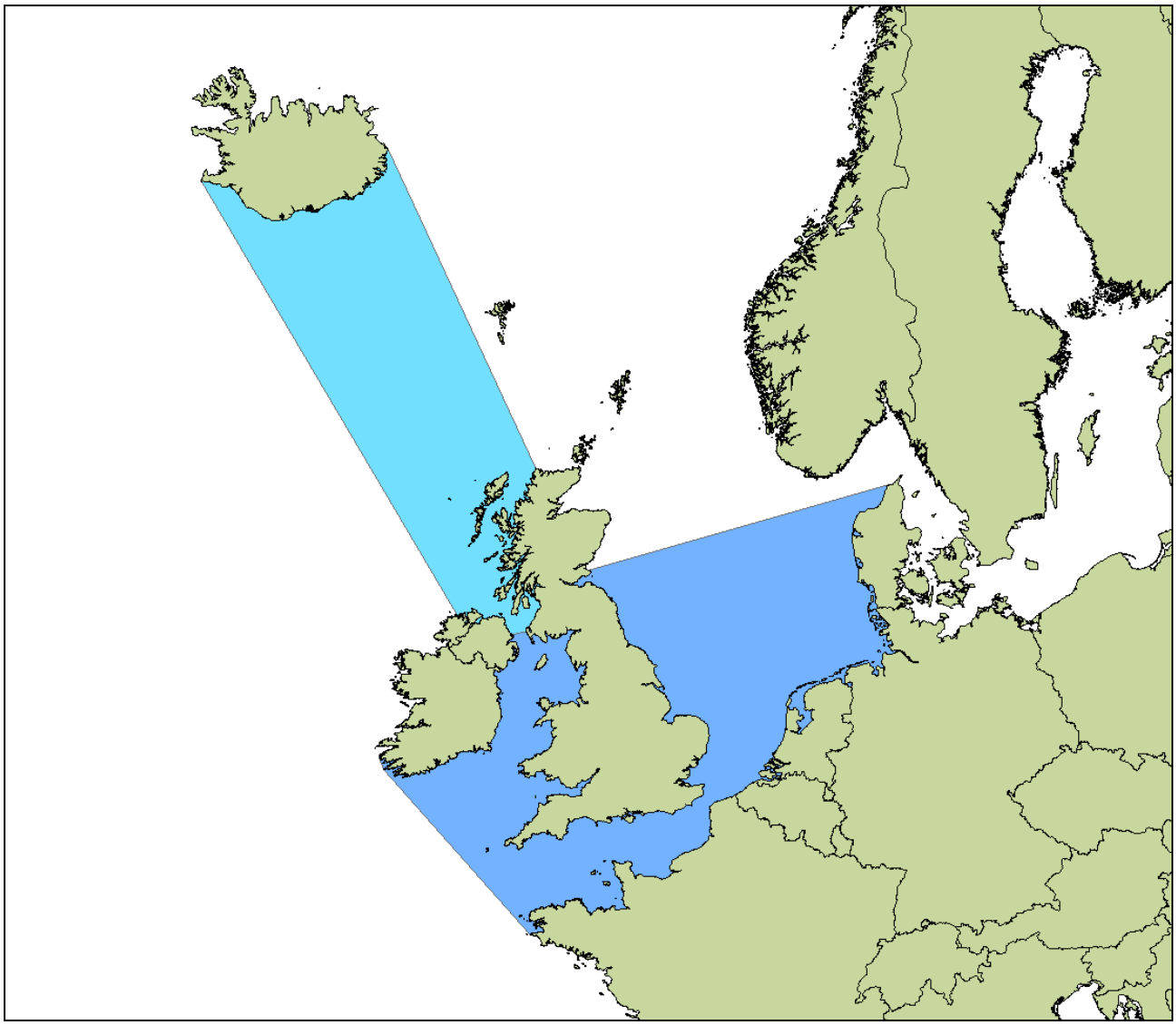
Ireland (Crowe *et al*. 2008), with most of these also crossing UK waters during migration. Autumn migration takes place between August and November, and birds depart on spring migration in late March and April (Wernham *et al*. 2002). In addition to the main migration periods, there are substantial movements of Wigeon within Britain and Ireland throughout the winter, and further influxes from Europe occur during period of cold weather. Precise migration routes of Wigeon over the seas around the UK are not known, but as they are widespread around Britain and Ireland in winter, their migration routes probably take birds across most parts of UK waters, though with the highest concentrations of migrating birds in the North Sea, which the majority of British and Irish wintering populations (except those migrating from Iceland) must cross. Further research to improve understanding of Wigeon migration routes (especially across the North Sea) would be valuable.

The numbers/proportions coming from each direction (Iceland vs. continental Europe) are not known, making it difficult to estimate the number following each route. In order to be precautionary, we suggest that assessments for wind farms in the North Sea should assume that the entire British and Irish wintering population of 522,370 birds could potentially cross the North Sea. Assessments for wind farms in the Irish Sea should assume that the entire Irish wintering population of 82,370 birds could potentially cross the Irish Sea.

It is more difficult to come up with a precautionary assumption for assessments for proposed wind farms in the pale blue area of the map above (birds migrating from Iceland). We were unable to find an estimate of the number of breeding Wigeon in Iceland, however, if this were available then it would be straightforward to make a precautionary assumption that this number of birds could potentially follow the migration route shown in pale blue on the map above (this is precautionary as some birds also stay in Iceland). However we do not have a population estimate for Icelandic-breeding Wigeon so the number of birds following this route must be based on the GB and Ireland wintering population size. A precautionary assumption would be to presume that half of the birds wintering in Britain and Ireland (i.e. 261,185 birds) could follow the migration route from Iceland shown in pale blue on the map (this is precautionary because it is thought that far more Wigeon come from continental Europe than from Iceland).

Gadwall *Anas strepera*

Gadwall *Anas strepera*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 1 site (Ouse Washes) Non-breeding 18 sites in widespread coastal and inland areas but with most in SE England
Population Size (UK/GB)	790 pairs in UK (breeding) 25,000 individuals in GB (non-breeding)
Population Size (Ireland)	630 individuals
Population Size (International)	60,000 (NW Europe)
Percentage of international population in UK/ GB & Ireland	3% (breeding) 43% (non-breeding)



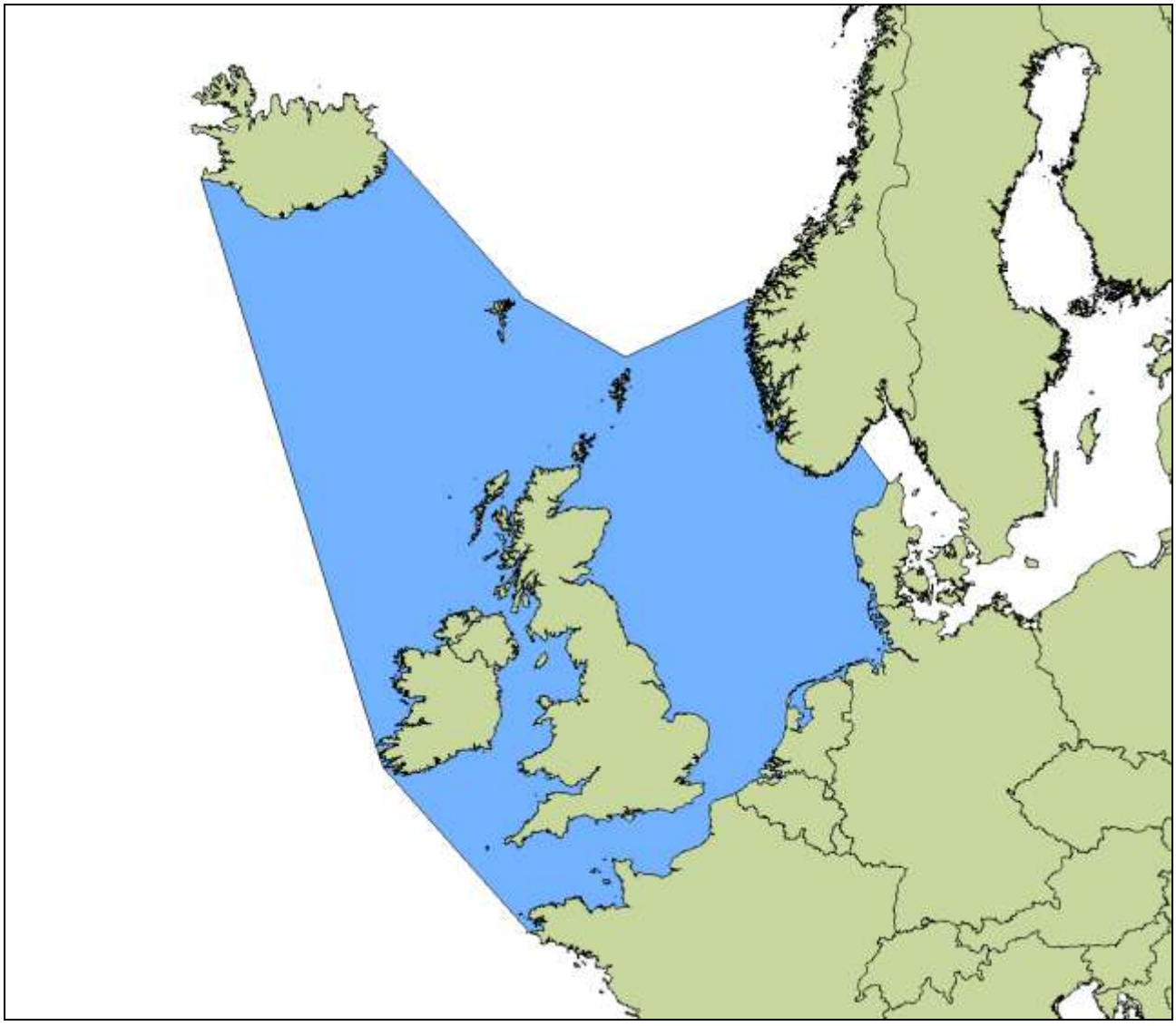
The dark blue area on this map shows the main migration zone predicted to be crossed by the majority of Gadwall wintering in Britain and Ireland. The pale blue area shows the area encompassing the predicted route taken by a small number of birds that migrate from Iceland.

Ringing recoveries suggest that some of the Gadwall that breed in Britain and Ireland move south to France or Iberia in winter while others are more sedentary. However in winter a much larger number of birds migrate to this country from northern and eastern Europe, with many subsequently moving south to France

and Spain later in the winter (Wernham *et al*. 2002). Precise migration routes and timings of sea crossings are not well understood as ringing data are limited. However, as the distribution of Gadwall is concentrated in the south and east it is likely that migration routes are also concentrated in this area. Further research would be useful.

Teal *Anas crecca*

Teal *Anas crecca*	
SPA Species?	Yes (non-breeding population)
SPA Sites	30 sites in widespread coastal and inland areas
Population Size (GB)	210,000
Population Size (Ireland)	45,010
Population Size (International)	500,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	51%



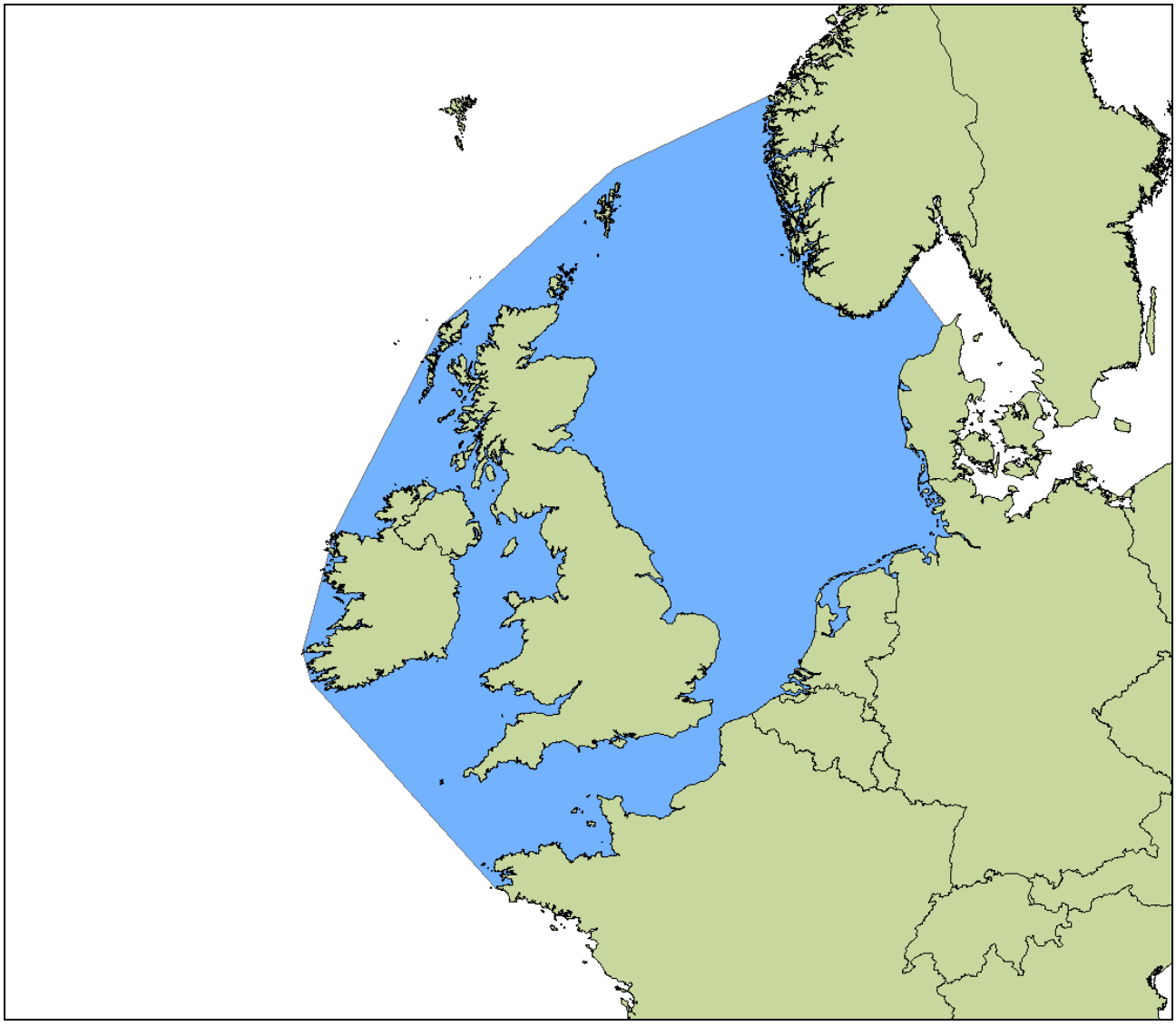
The blue area on this map shows the migration zone predicted to be crossed by Teal wintering in Britain and Ireland.

Small numbers of Teal breed in Britain and Ireland, but the area is of international importance for its wintering populations. An estimated 45,000 birds spend the winter in Ireland (Crowe *et al*.) such that the British and Irish wintering populations combined comprise more than half of the international flyway population. Some birds also migrate via the UK on passage towards wintering sites further south in Europe. Teal migrate to Britain and Ireland from Iceland and from northern Europe (especially around the Baltic) and Russia. Autumn migration occurs over a long period from late June until at least November, and the progression of migration varies according to weather conditions. In periods of cold weather there may be further influxes to Britain from the north and east, and birds may move south from Britain to France or

Spain. Spring migration also occurs over a long periods, with birds departing from Britain and Ireland between late February and May. Ringing recoveries suggest that Teal migrate over almost all parts of UK waters. While further research would be valuable to improve our understanding of the movements of this species, its wide distribution in winter, and the wide variety of movement patterns, means that methods such as tracking studies are unlikely to provide a representative picture of the movements of this species over UK waters unless very large numbers of birds are tracked from all parts of the country, which would be extremely difficult to do.

Mallard *Anas platyrhynchos*

Mallard *Anas platyrhynchos*	
SPA Species?	Yes (non-breeding population)
SPA Sites	14 sites in widespread coastal and inland areas
Population Size (GB)	680,000
Population Size (Ireland)	38,250
Population Size (International)	4,500,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	16%

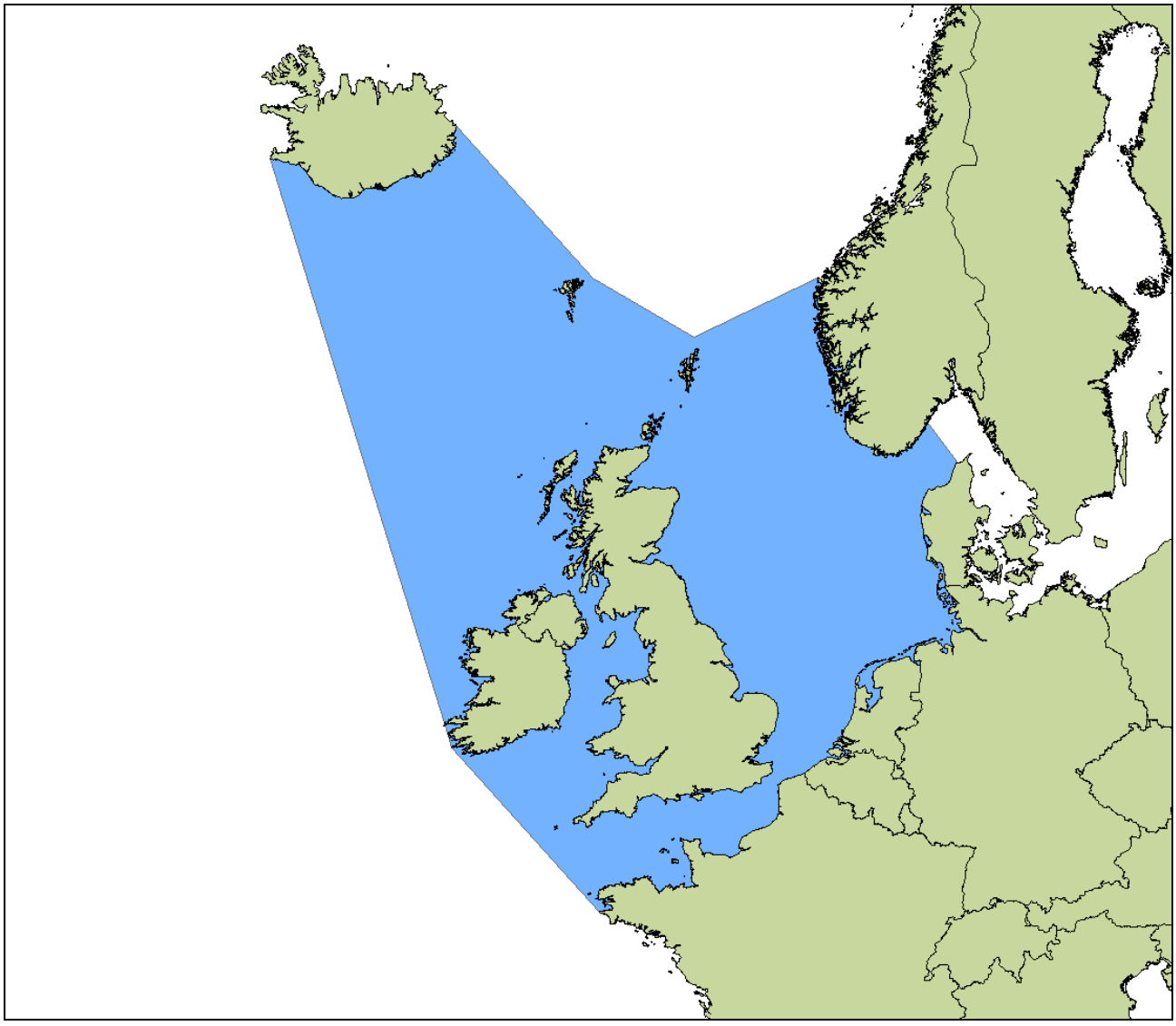


The blue area on this map shows the migration zone predicted to be crossed by Mallards breeding or wintering in Britain and Ireland.

Ringing recoveries suggest that the majority of Mallards that breed in Britain are fairly sedentary, but some move to the near-continent (especially France and the Netherlands) in winter, migrating across the English Channel or southern North Sea. In addition, a large number of Mallards migrate to Britain and Ireland during the non-breeding season from breeding areas in northern and eastern Europe, especially the near-continent and around the Baltic (Wernham *et al*. 2002). These birds are thought to arrive in Britain gradually through the autumn, when most probably cross the central and southern North Sea or eastern English Channel, though this is uncertain.

Pintail *Anas acuta*

Pintail *Anas acuta*	
SPA Species?	Yes (non-breeding population)
SPA Sites	25 sites in widespread coastal and inland areas
Population Size (GB)	29,000
Population Size (Ireland)	1,235
Population Size (International)	60,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	50%



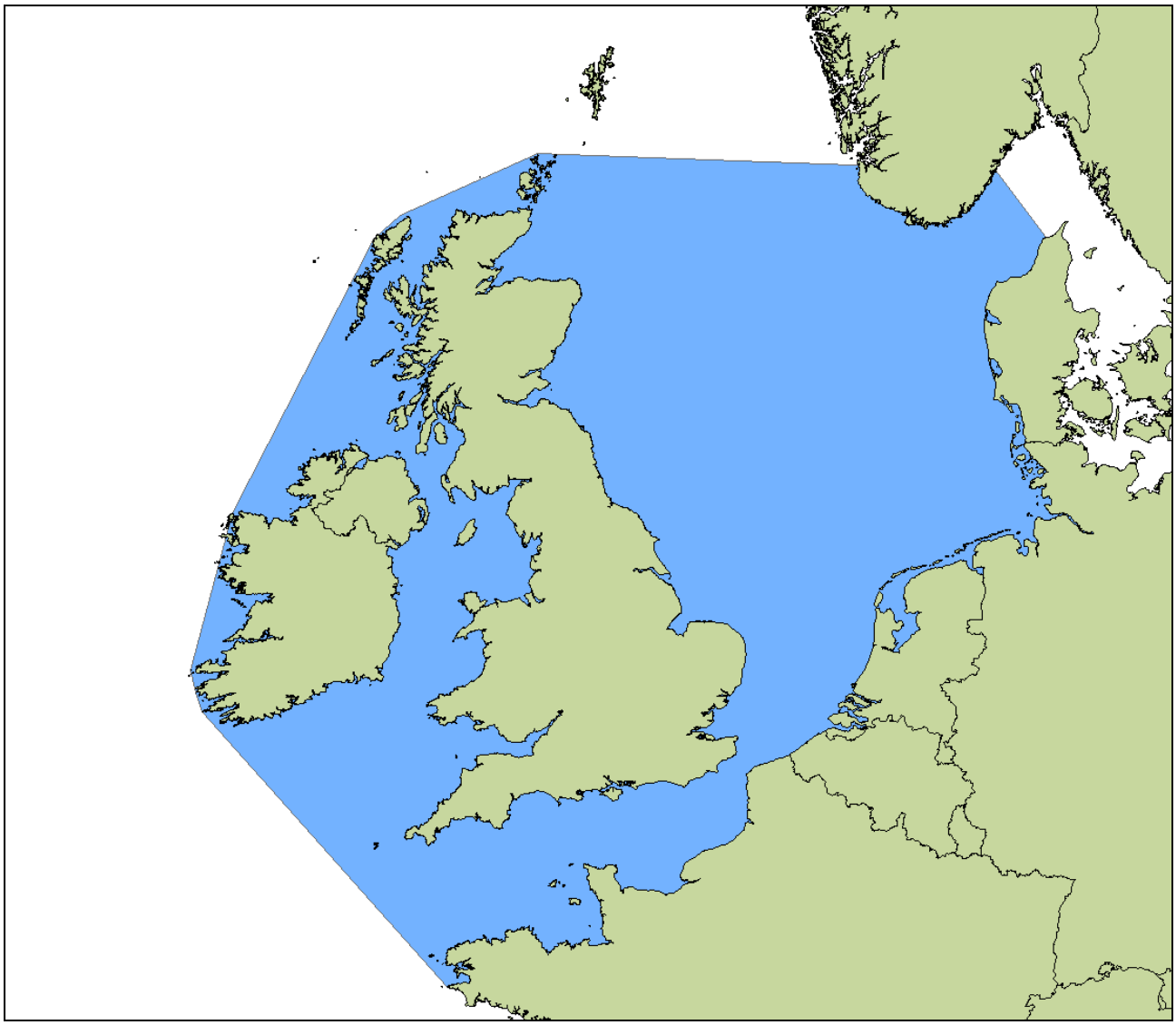
The blue area on this map shows the migration zone predicted to be crossed by Pintail wintering in Britain and Ireland.

Britain and Ireland together support around half of the northwest European wintering population of this species, with an estimated 1235 in Ireland (Crowe *et al*. 2008) in addition to those in Britain. Additionally, birds of this species travel over UK waters on passage migration in spring and autumn. These birds come from breeding grounds in Iceland, Scandinavia, the Baltic States and Russia. Autumn migration sees birds arriving in the UK between late August and December with spring migration between February and April (Wernham *et al*. 2002). Migration routes are not known precisely, but recoveries of birds ringed in the UK are widespread in all directions, suggesting that at least some birds migrate across most parts of UK waters.

Further research would be useful to improve understanding of precise migration routes and to ascertain whether migration occurs across a broad front or is concentrated in particular areas.

Shoveler *Anas clypeata*

Shoveler *Anas clypeata*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 1 site (Ouse Washes) Non-breeding 26 inland and coastal sites around the UK but most in southern England
Population Size (GB)	1,000-1,500 pairs in UK (breeding) 18,000 individuals in GB (non-breeding
Population Size (Ireland)	2,545
Population Size (International)	40,000 (NW & central Europe non-breeding)
Percentage of international population in GB & Ireland	6% (breeding) 51% (non-breeding)



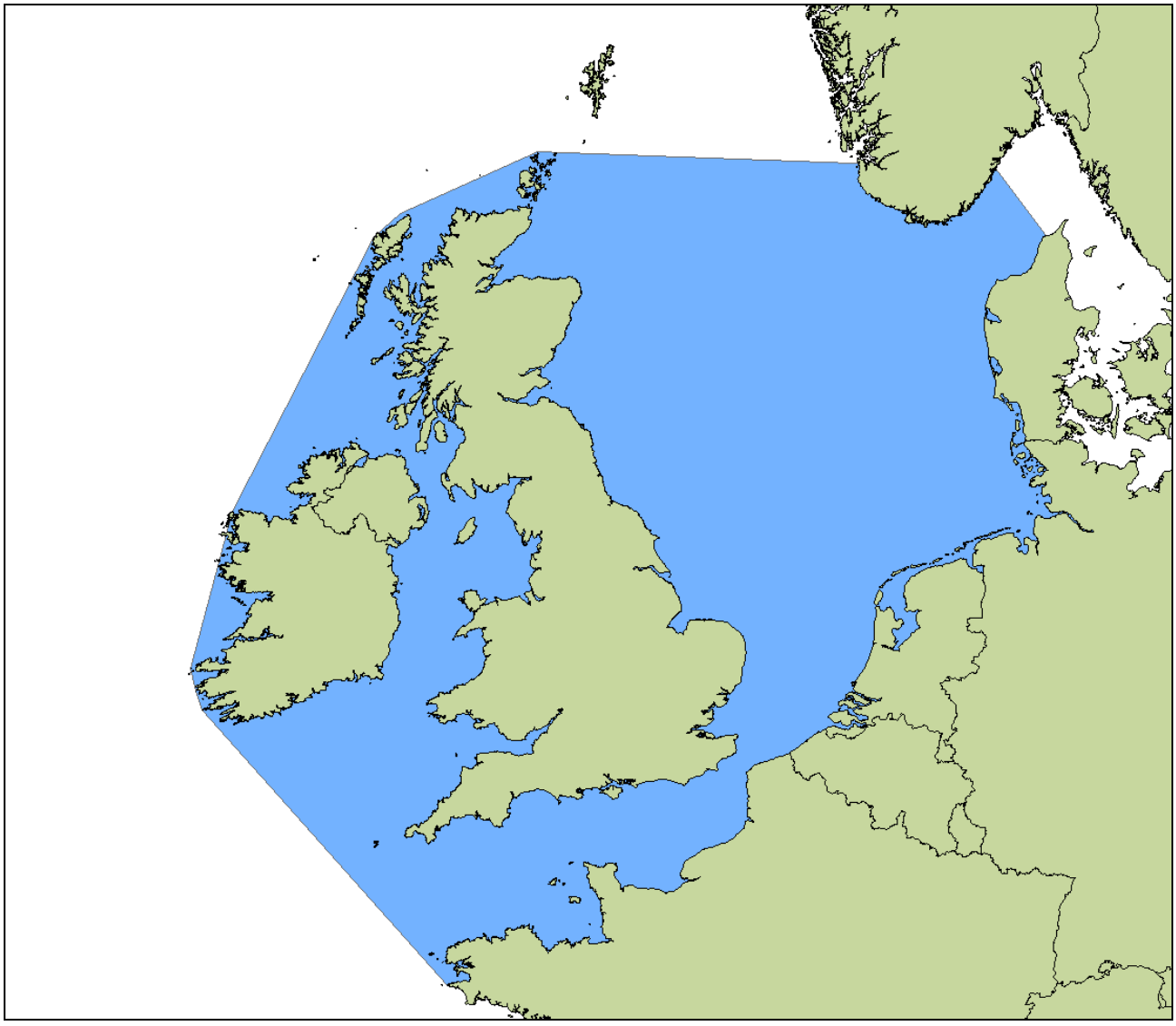
The blue area on this map shows the migration zone predicted to be crossed by Shoveler wintering in Britain and Ireland.

Although over 1000 pairs of Shoveler breed in the UK, far greater numbers occur in the winter. Birds from northern parts of Europe migrate to Britain in the autumn, presumably across the North Sea, and subsequently a large proportion of these birds will continue on south into France, Spain and southern Europe, probably crossing the English Channel. Around 2500 winter in Ireland (Crowe *et al*. 2008) and these

birds presumably cross the Irish Sea on migration. Shovelers are known to move southwards out of the UK during periods of severe weather (Wernham *et al*. 2002). Further research would be useful to improve understanding of precise migration routes and to ascertain whether migration occurs across a broad front or is concentrated in particular areas.

Pochard *Aythya ferina*

Pochard *Aythya ferina*	
SPA Species?	Yes (non-breeding population)
SPA Sites	12 coastal and inland sites around the UK
Population Size (GB)	38,000
Population Size (Ireland)	37,780
Population Size (International)	300,000 (NE & NW Europe non-breeding)
Percentage of international population in GB & Ireland	25%



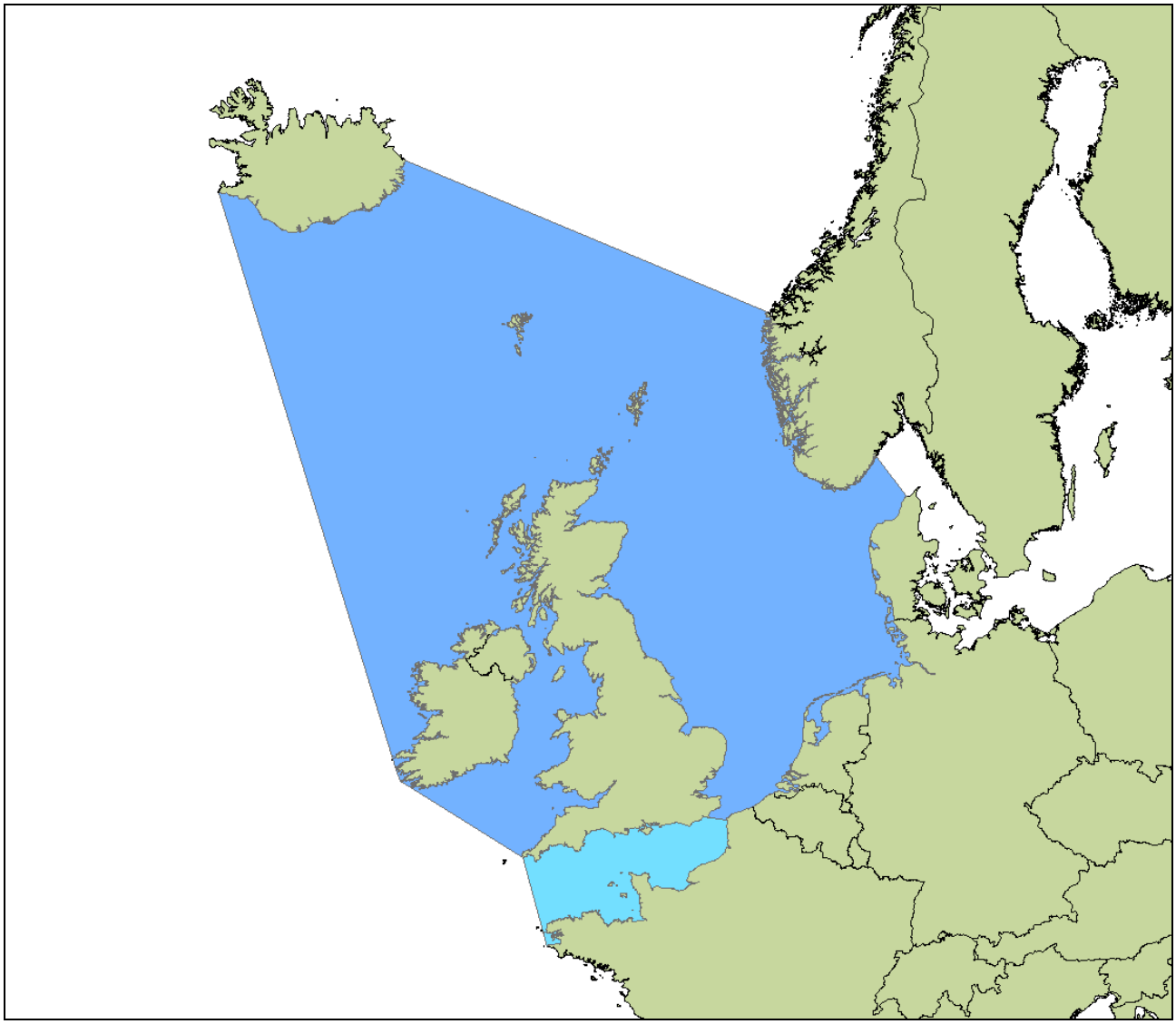
The blue area on this map shows the migration zone predicted to be crossed by Pochard wintering in Britain and Ireland.

The Pochard occurs in the UK in small numbers in the breeding season, but Britain and Ireland are far more important as a wintering site for the species. Approximately the same number of Pochard winter in Ireland as in Britain (Crowe *et al*. 2008). Ringing recoveries suggest that these birds migrate from breeding sites across central and northern Europe (though not the far north), the Baltic and into Asia. Birds migrate into Britain and Ireland mainly in October and November, and return in spring between February and early April, with most departing during March (Wernham *et al*. 2002). Migration routes are not well known but the majority of the 76,000 birds wintering in Britain and Ireland probably cross central and southern parts of the North Sea with smaller numbers crossing the English Channel. Birds wintering in Ireland must also

cross the Irish Sea. For the purposes of assessment it should be assumed that 76,000 birds cross the North Sea and 37,780 cross the Irish Sea during each migration season. Further research would be useful to improve understanding of precise migration routes and to ascertain whether migration occurs across a broad front or is concentrated in particular areas.

Tufted Duck *Aythya fuligula*

Tufted Duck *Aythya fuligula*	
SPA Species?	Yes (non-breeding population)
SPA Sites	7 coastal and inland sites around the UK
Population Size (GB)	110,000
Population Size (Ireland)	36,610
Population Size (International)	1,200,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	12%



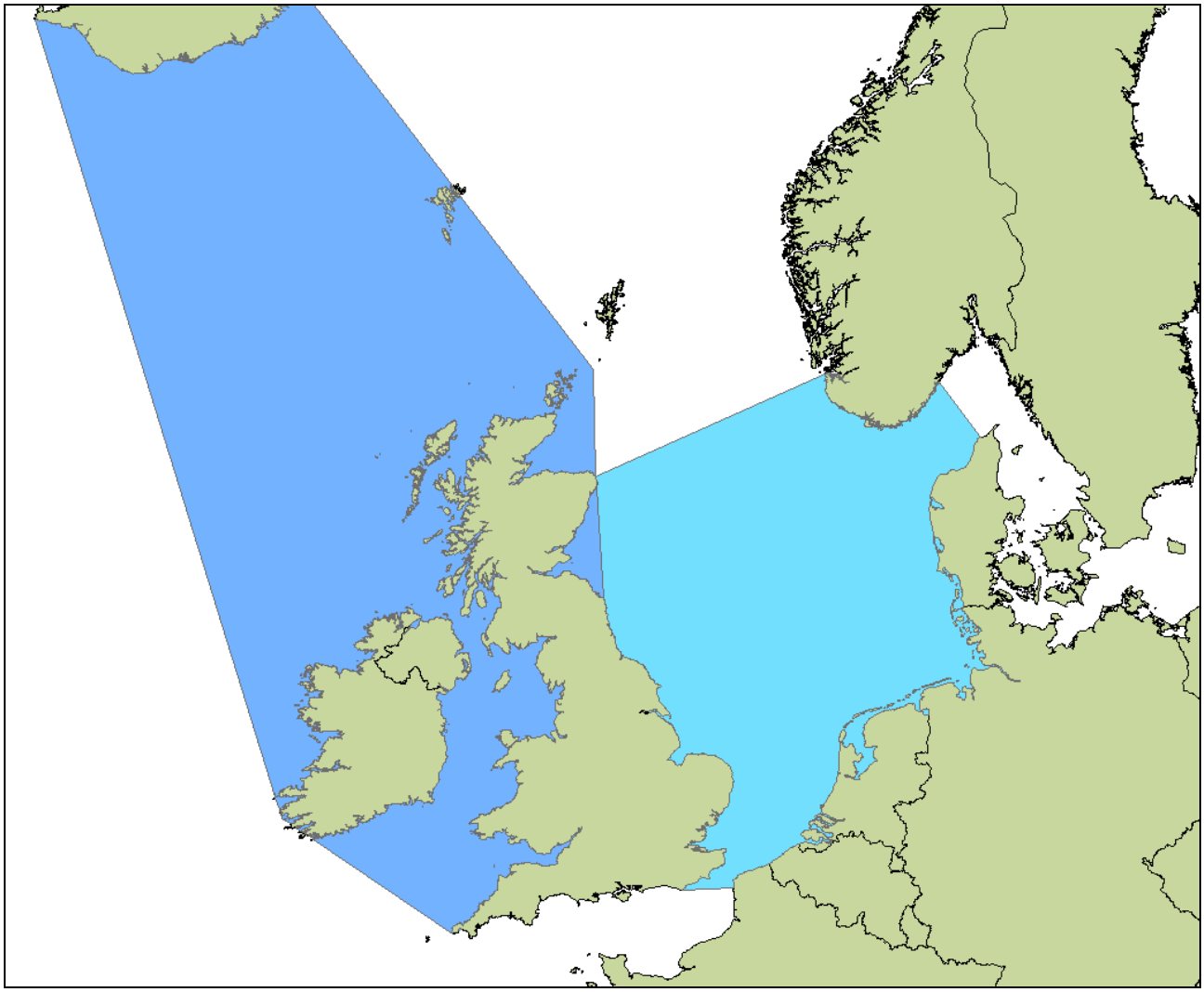
The dark blue area on this map shows the migration zone predicted to be crossed by the majority of Tufted Duck wintering in Britain and Ireland. Some birds also cross the English Channel, in the zone shown in pale blue.

Several thousand pairs of Tufted Duck breed in Britain and Ireland, but the area is far more important as a wintering destination for migrant Tufted Ducks that winter in the UK. These birds come from breeding sites in Iceland, Scandinavia and Russia (Wernham *et al*. 2002). These birds arrive in the autumn from October onwards, with arrivals continuing into December and January. Spring migration may start as early as February, but the majority of birds leave Britain and Ireland in April and May. Most of the 146,610 birds wintering in Britain and Ireland probably migrate across the North Sea, but there is also a significant migration to Iceland (a similar assumption to that described in the Wigeon account could be followed in

assessments for proposed wind farms on this route) and some movements across the English Channel (Wernham *et al.* 2002). The majority of the 36,610 birds that winter in Ireland (Crowe *et al*. 2008) probably migrate either across the Irish Sea or in a northerly direction to Iceland. Further research would be useful to improve understanding of precise migration routes and to ascertain whether migration occurs across a broad front or is concentrated in particular areas.

Scaup *Aythya marila*

Scaup *Aythya marila*	
SPA Species?	Yes (non-breeding population)
SPA Sites	6 sites in Scotland and Northern Ireland
Population Size (GB)	5,200
Population Size (Ireland)	4,430
Population Size (International)	310,000 (W Europe non-breeding)
Percentage of international population in GB & Ireland	3%



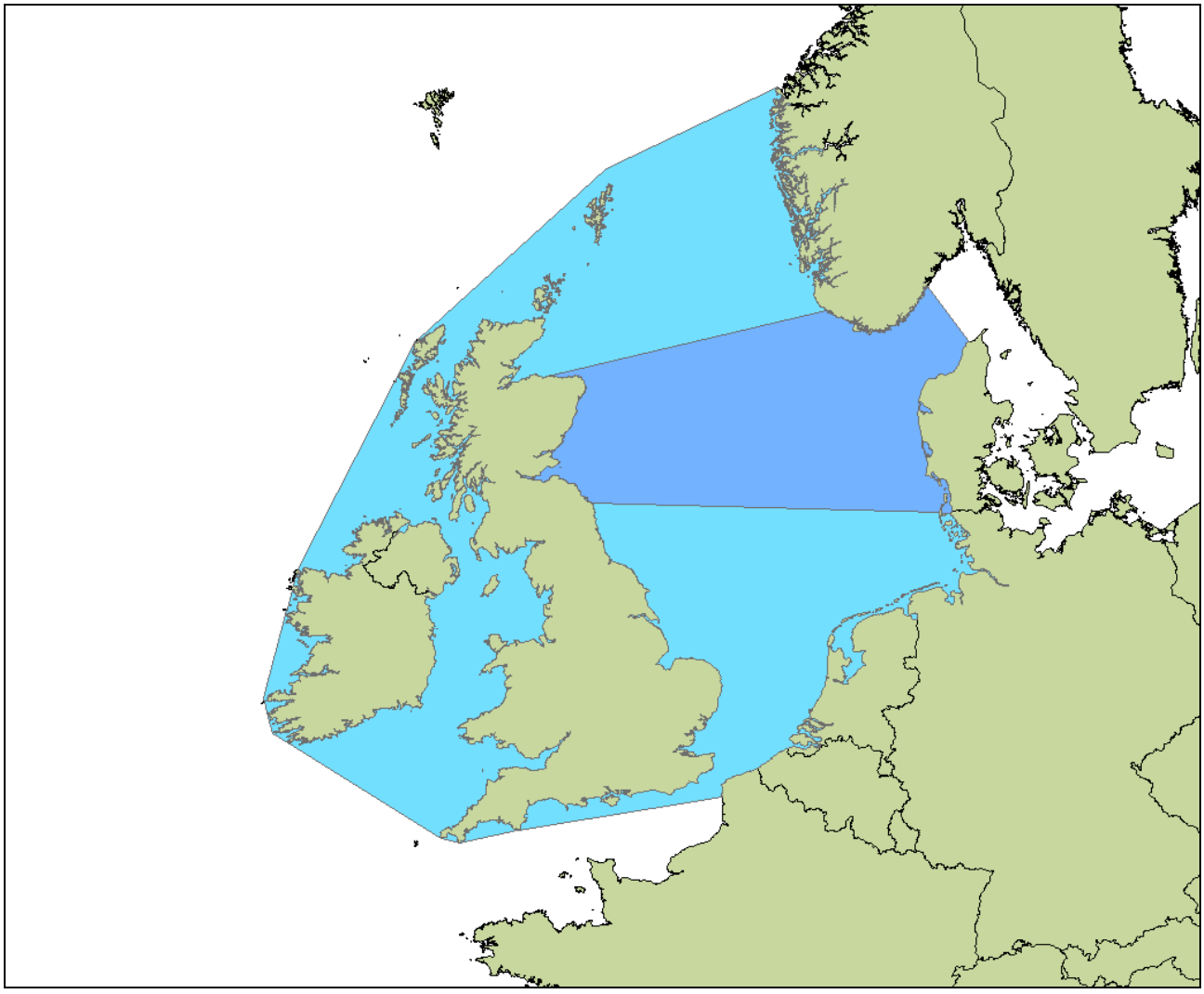
The dark blue area on this map shows the migration zone predicted to be crossed by the majority of Scaup wintering in Britain and Ireland that come from Iceland. The route followed by birds from elsewhere in the breeding range is shown in pale blue.

Scaup has a circumpolar breeding distribution and ringing recoveries demonstrate that birds wintering in Britain and Ireland come from all parts of the breeding range (Wernham *et al*. 2002), but with the majority coming from Iceland. Migration routes across UK waters and the precise timing of migration are not well understood, but Wetland Bird Survey data indicate that the majority of birds arrive at UK wintering sites between September and December, with departures between February and April (Holt *et al*. 2012). Within Britain, wintering Scaup are concentrated in northern areas, and largely in coastal areas (though some also occur on freshwater sites inland). Almost as many Scaup winter in Ireland as in Britain (Crowe *et al*. 2008), especially at Loughs Neagh and Beg (Holt *et al*. 2012). The northerly distribution of Scaup in Britain and

Ireland, and the fact that most migrate to Iceland, suggests that migration routes over UK waters are likely to be concentrated in northerly areas around the coasts of Scotland and Ireland.

Eider *Somateria mollissima*

Eider *Somateria mollissima*	
SPA Species?	Yes (non-breeding)
SPA Sites	8 sites in Scotland, Northern Ireland & N England
Population Size (GB)	55,000 (*mollissima*) 5,500 (*faeroeensis*)
Population Size (Ireland)	2,890
Population Size (International)	57,800 – 57,900 (*mollissima* Britain & Ireland) 6,000 – 12,000 (*faeroeensis*)
Percentage of international population in GB & Ireland	100% (*mollissima* Britain & Ireland) 46-92% (*faeroeensis*)

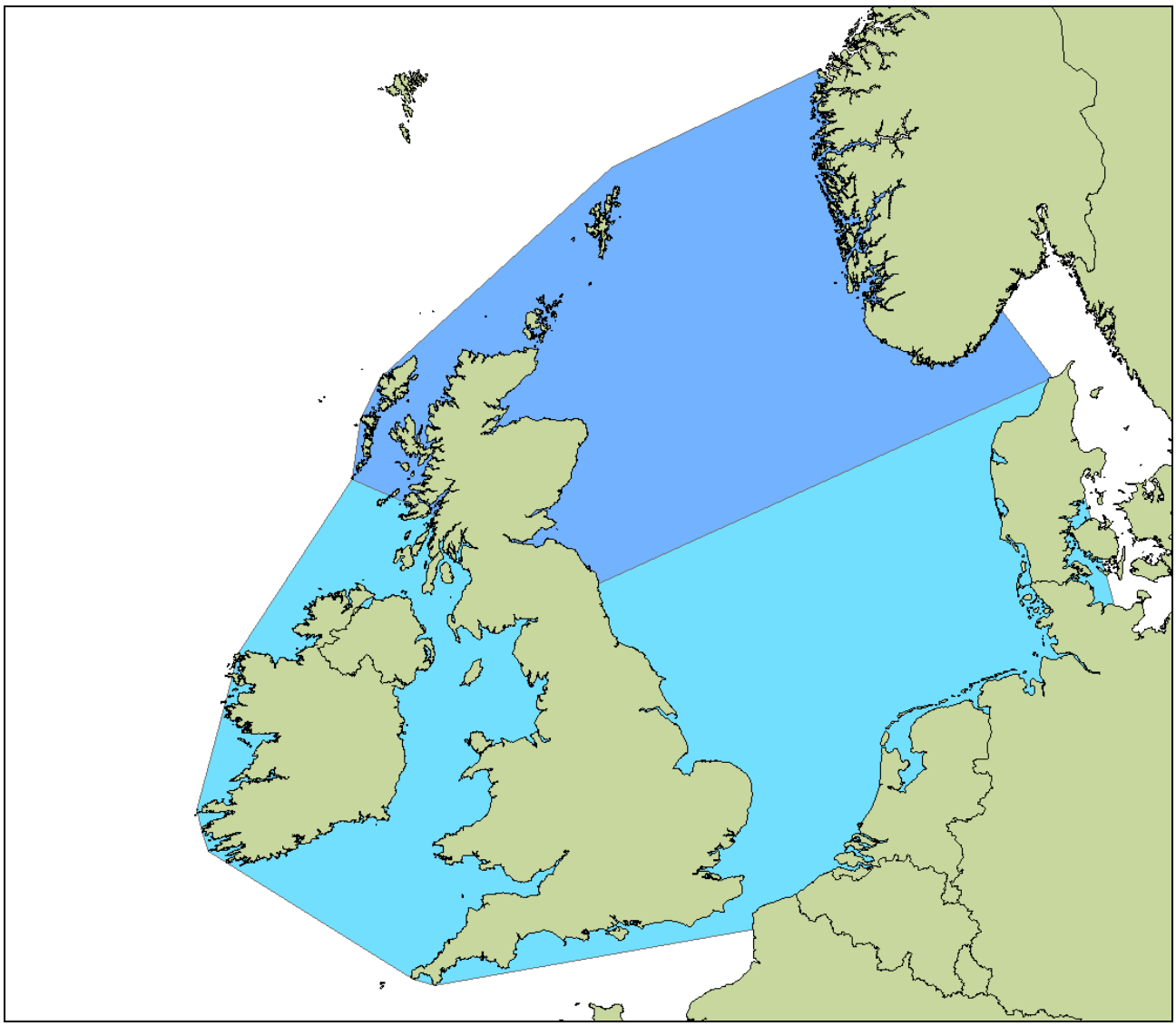


The pale blue area on this map shows the migration zone predicted to be crossed by Eider in Britain and Ireland. The darker blue area highlights where there is a higher concentration of birds moving between key sites such as the Firth of Tay and Scandinavia, as highlighted by Wernham *et al*. (2002).

British-breeding Eiders are largely sedentary, but they are joined in winter by continental birds particularly on the east coast, and east coast Scottish breeders aggregate in the Firth of Tay in winter. A small number of these continental migrants may cross as far as Ireland but this is thought to be exceptional. This species is far more likely to be an issue where wind farms overlap with its marine feeding areas (which occur in many parts of the UK's waters, especially further north), as migrating birds make up a relatively small proportion of its population. Further study of eider migratory behaviour is therefore a low priority.

Long-tailed Duck *Clangula hyemalis*

Long-tailed Duck *Clangula hyemalis*	
SPA Species?	Yes (non-breeding)
SPA Sites	Three sites on the east coast of Scotland
Population Size (GB)	11,000
Population Size (International)	1,600,000 (W Siberia, N Europe)
Percentage of international population in GB	0.7%

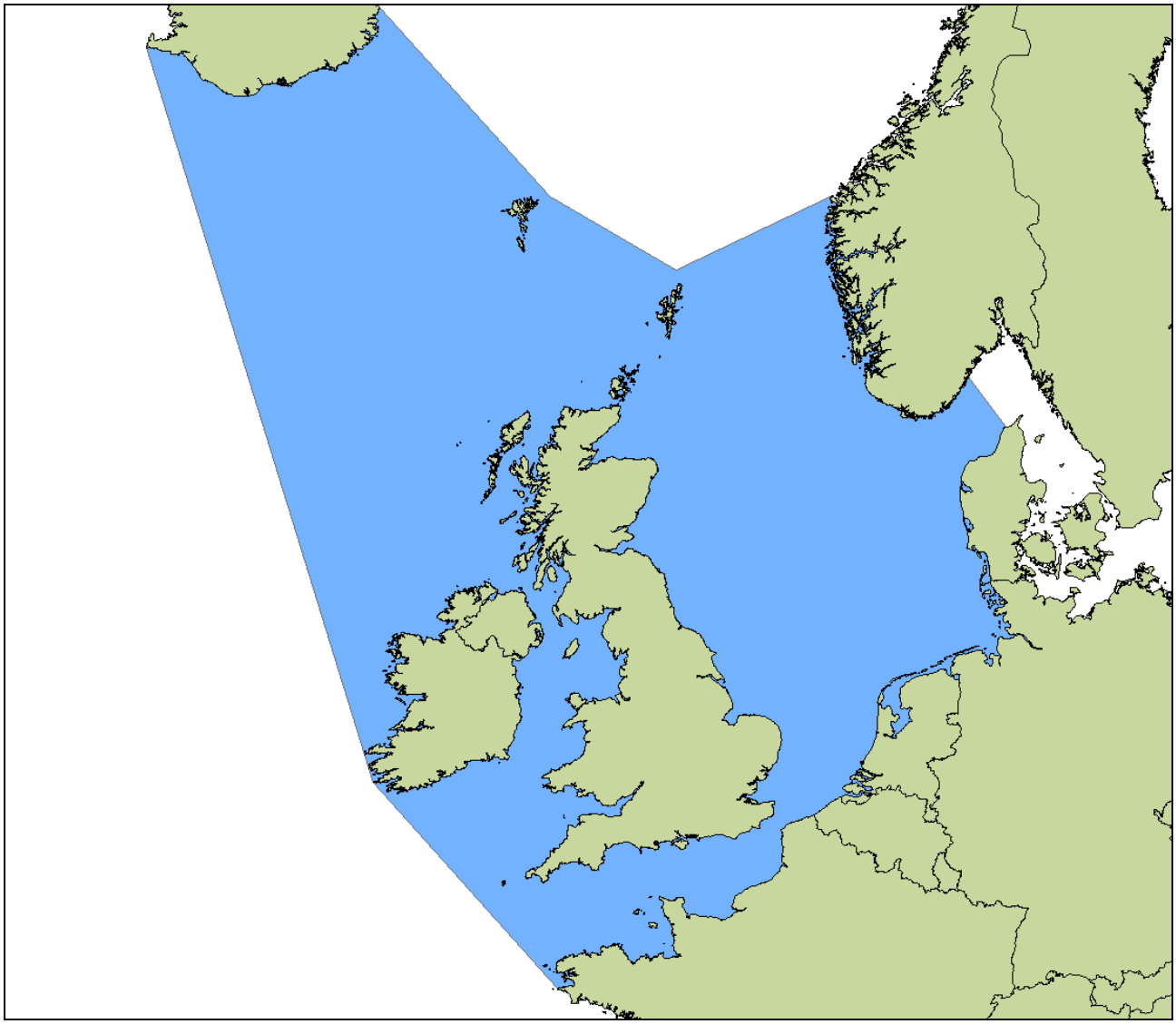


The blue area on this map shows the migration zone predicted to be used by most Long-tailed Duck wintering in Britain and Ireland, while a smaller number might use the pale blue area.

There is little understanding of the origins and migration routes of Long-tailed Ducks wintering around the coasts of Britain and Ireland. It is thought that the majority breed in northern Fennoscandia and northwest Russia, but there is almost no evidence for this as there has only been one ringing recovery. They arrive around UK coasts from October to December or January, and remain around Scottish coasts until mid-February.

Common Scoter *Melanitta nigra*

Common Scoter *Melanitta nigra*	
SPA Species?	Yes (breeding and non-breeding)
SPA Sites	2 sites in Scotland (breeding)
	7 coastal sites (non-breeding)
Population Size (GB)	100,000 (non-breeding)
Population Size (Ireland)	23,190
Population Size (International)	550,000 (*nigra*)
Percentage of international population in GB	22%

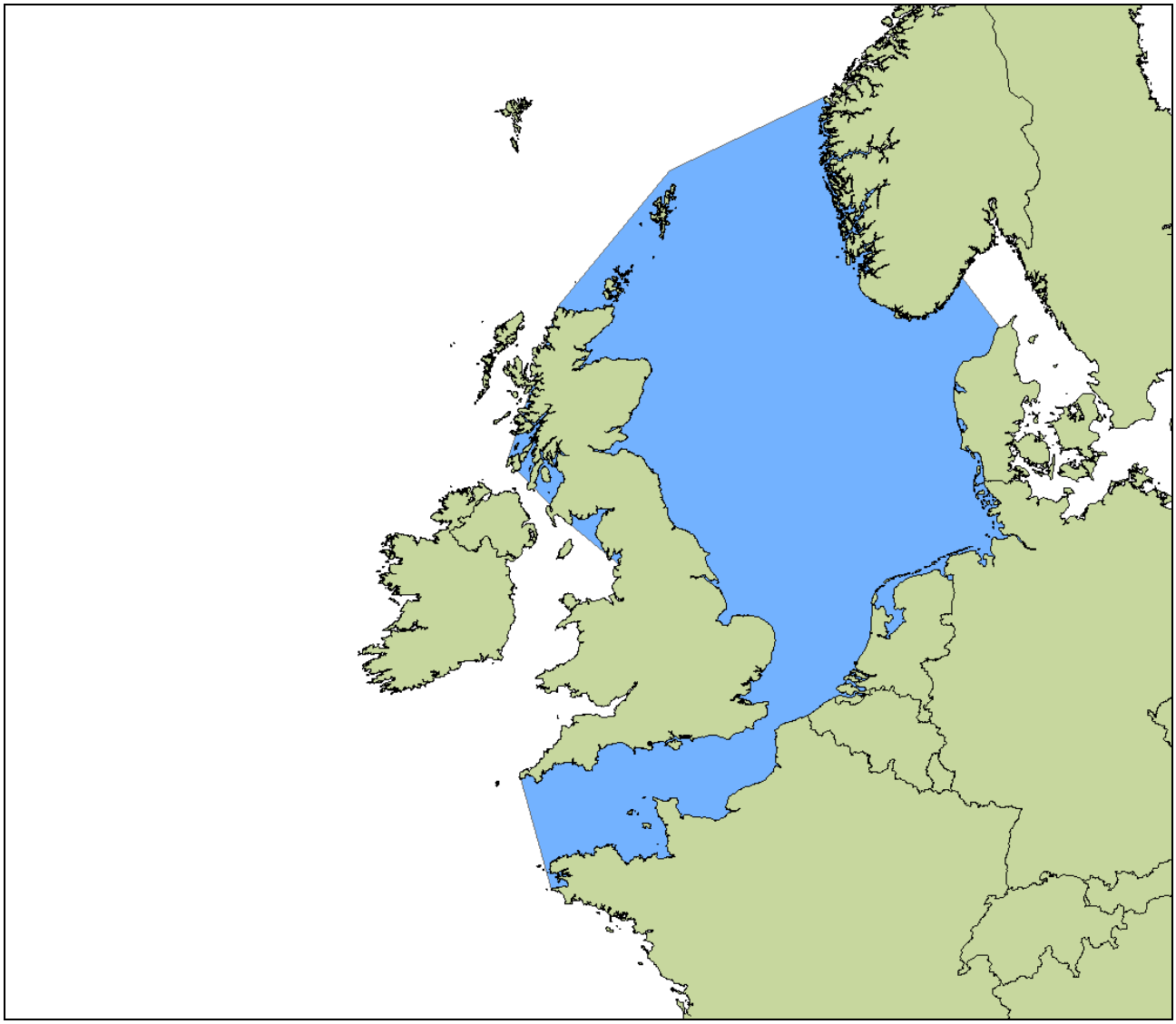


The blue area on this map shows the migration zone predicted to be crossed by Common Scoters in Britain and Ireland.

There are two SPAs for breeding common scoters in the UK, but it is thought that these breeding birds are likely to also winter around our shores (large number of wintering birds found at Carmarthen Bay SPA, for example), and migration routes are not understood. In addition there are 6 SPAs for wintering Common Scoters. These comprise both British breeders and those that breed elsewhere, and it is thought that many of these birds might migrate across the North Sea from moulting sites in the Baltic or the eastern North Sea. Birds from these populations are also known to migrate south-west through the English Channel in autumn after moulting, returning in spring.

Velvet Scoter *Melanitta fusca*

Velvet Scoter *Melanitta fusca*	
SPA Species?	Yes (non-breeding)
SPA Sites	4 sites on the east coast of the UK
Population Size (GB)	2,500
Population Size (International)	450,000 (NW Europe non-breeding)
Percentage of international population in GB	0.6%

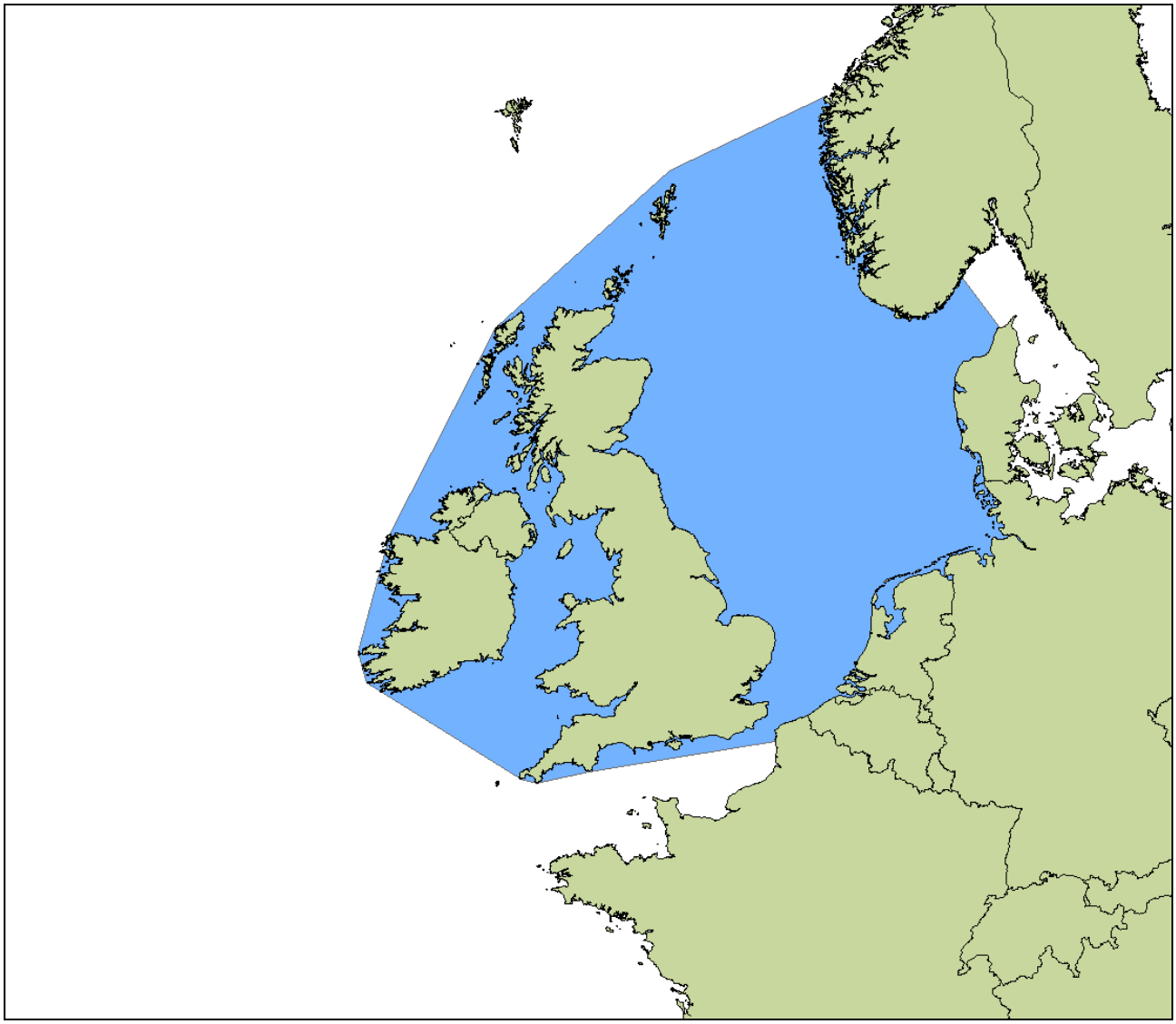


The blue area on this map shows the migration zone predicted to be crossed by Velvet Scoters wintering in Britain.

Velvet Scoter is part of the waterbird assemblage on four SPAs on the east coast, but the species is most numerous in north-east Scotland especially around the Moray Firth. These sea ducks come from breeding populations in Scandinavia or northern Russia, arriving around the UK in late summer, presumably crossing the North Sea. Return migration occurs between March and early May. Precise migration routes are not well understood, but only a small proportion of the international population is likely to winter in UK waters.

Goldeneye *Bucephala clangula*

Goldeneye *Bucephala clangula*	
SPA Species?	Yes (non-breeding population)
SPA Sites	15 widespread coastal and inland sites in England, Scotland and Northern Ireland
Population Size (GB)	20,000
Population Size (Ireland)	9,665
Population Size (International)	1,000,000-1,300,000 (NW & central Europe non-breeding)
Percentage of international population in GB & Ireland	3%



The blue area on this map shows the migration zone predicted to be crossed by Goldeneye wintering in Britain and Ireland.

A small number of Goldeneye breed in Scotland but the species is far more common in Britain during the non-breeding season. Additionally, almost 10,000 birds are also thought to spend the winter in Ireland (Crowe *et al*. 2008). Migration routes across UK waters and the precise timing of migration are not well understood, but Wetland Bird Survey data indicate that the majority of birds arrive at UK wintering sites between October and December, with departures between March and May (Holt *et al*. 2012). Ringing recoveries suggest that these birds come exclusively from the Scandinavian breeding population, thus the main migration route for the 30,000 birds wintering in Britain and Ireland is across the North Sea, with

10,000 Irish-wintering birds also crossing the Irish Sea. Further research would be useful to improve understanding of precise migration routes and to ascertain whether migration occurs across a broad front or is concentrated in particular areas.

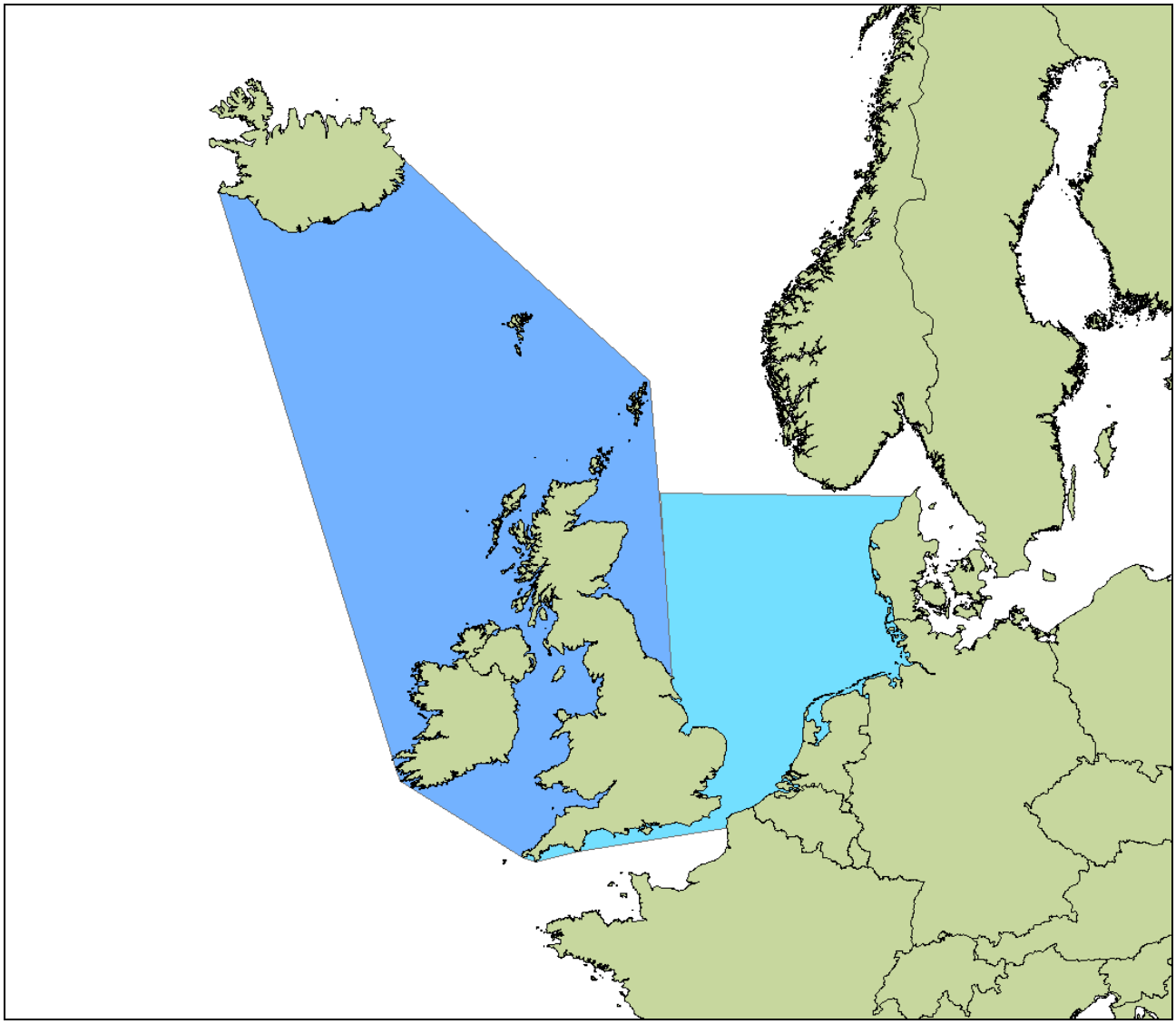
Smew *Mergus albellus*

Smew *Mergus albellus*	
SPA Species?	No – but is Annex 1
Population Size (GB)	180
Population Size (International)	40,000 (NW & central Europe non-breeding)
Percentage of international population in GB	0.5%

A small number of Smew migrate to Britain, mainly south and south-east England, though smaller numbers may occur in any part of Britain and Ireland, in winter. These birds are thought to migrate largely across the southern North Sea from populations wintering in the Netherlands, especially in response to cold weather on the continent, and peak numbers arrive in Britain in January. As only small numbers migrate across UK waters this species is not a priority for further research and is likely to be of lower concern in assessments for proposed offshore wind farms than most other migratory waterbirds. No map has been presented for this species as only small numbers of birds move to the UK in winter making it difficult to assess likely migration routes, and unlikely that the species will be of concern in relation to offshore wind farm consenting.

Red-breasted Merganser *Mergus serrator*

Red-breasted Merganser *Mergus serrator*	
SPA Species?	Yes (non-breeding population)
SPA Sites	15 widespread coastal sites in England, Scotland and Northern Ireland
Population Size (GB)	8,400
Population Size (Ireland)	3,390
Population Size (International)	170,000 (NW & central Europe non-breeding)
Percentage of international population in GB & Ireland	7%

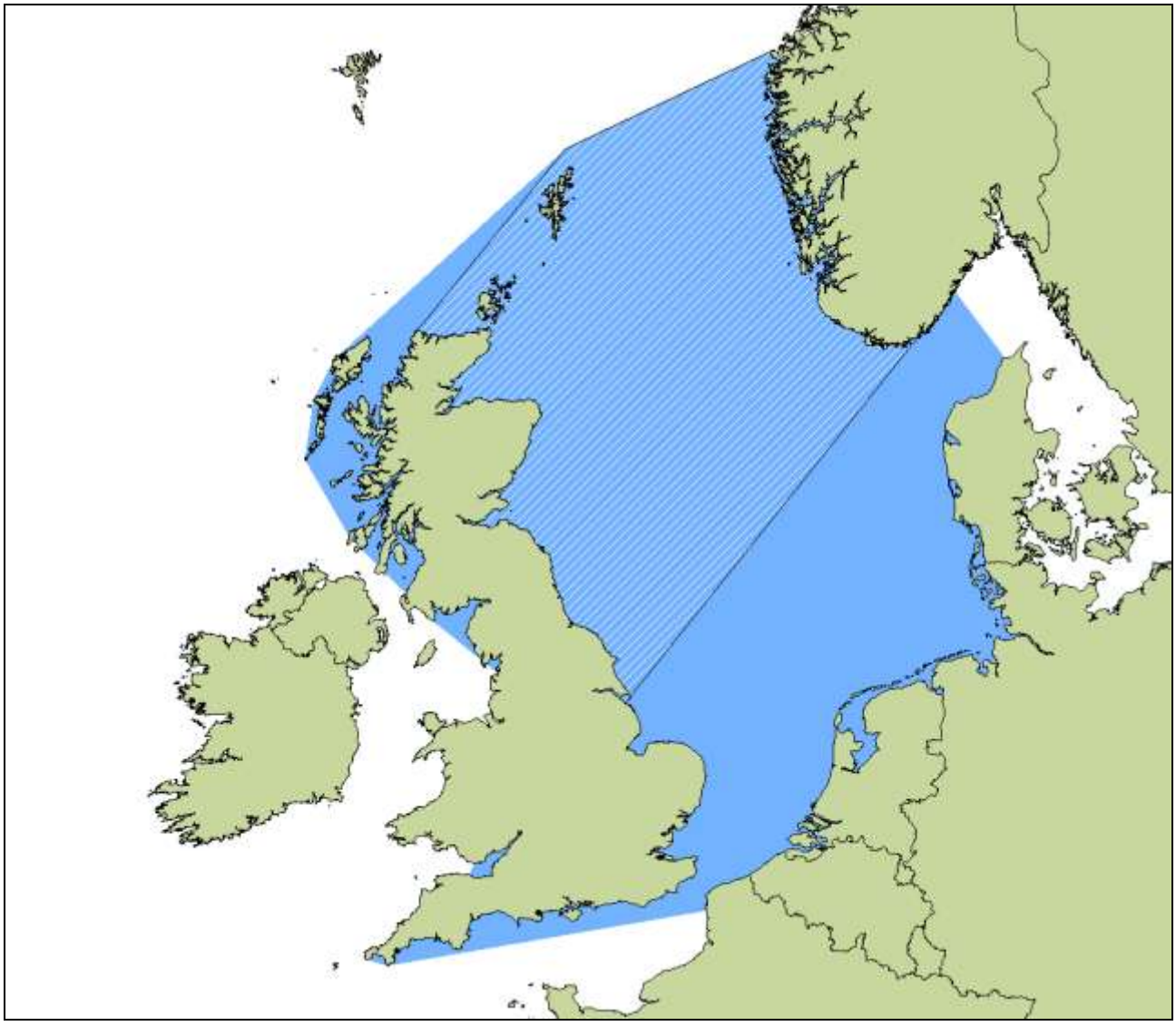


The blue area on this map shows the migration zone predicted to be crossed by Red-breasted Mergansers in Britain and Ireland. The pale area represents the zone predicted to be crossed by a small number of birds from the continent that winter in Britain.

British breeding populations of Red-breasted Merganser are thought to be relatively sedentary, but there is an influx of birds in winter from populations that breed in Iceland (across northern parts of UK waters) to Scotland, northern England and Ireland, and probably from populations that breed in central Europe (across the North Sea) to the east coast of Britain. These birds probably migrate to Britain and Ireland from October to December and return between late February and May (Wernham *et al* 2002, Holt *et al.* 2012).

Goosander *Mergus merganser*

Goosander *Mergus merganser*	
SPA Species?	Yes (non-breeding population)
SPA Sites	2 sites on east coast of Scotland
Population Size (GB)	12,000
Population Size (International)	266,000 (NW & central Europe non-breeding)
Percentage of international population in GB	5%

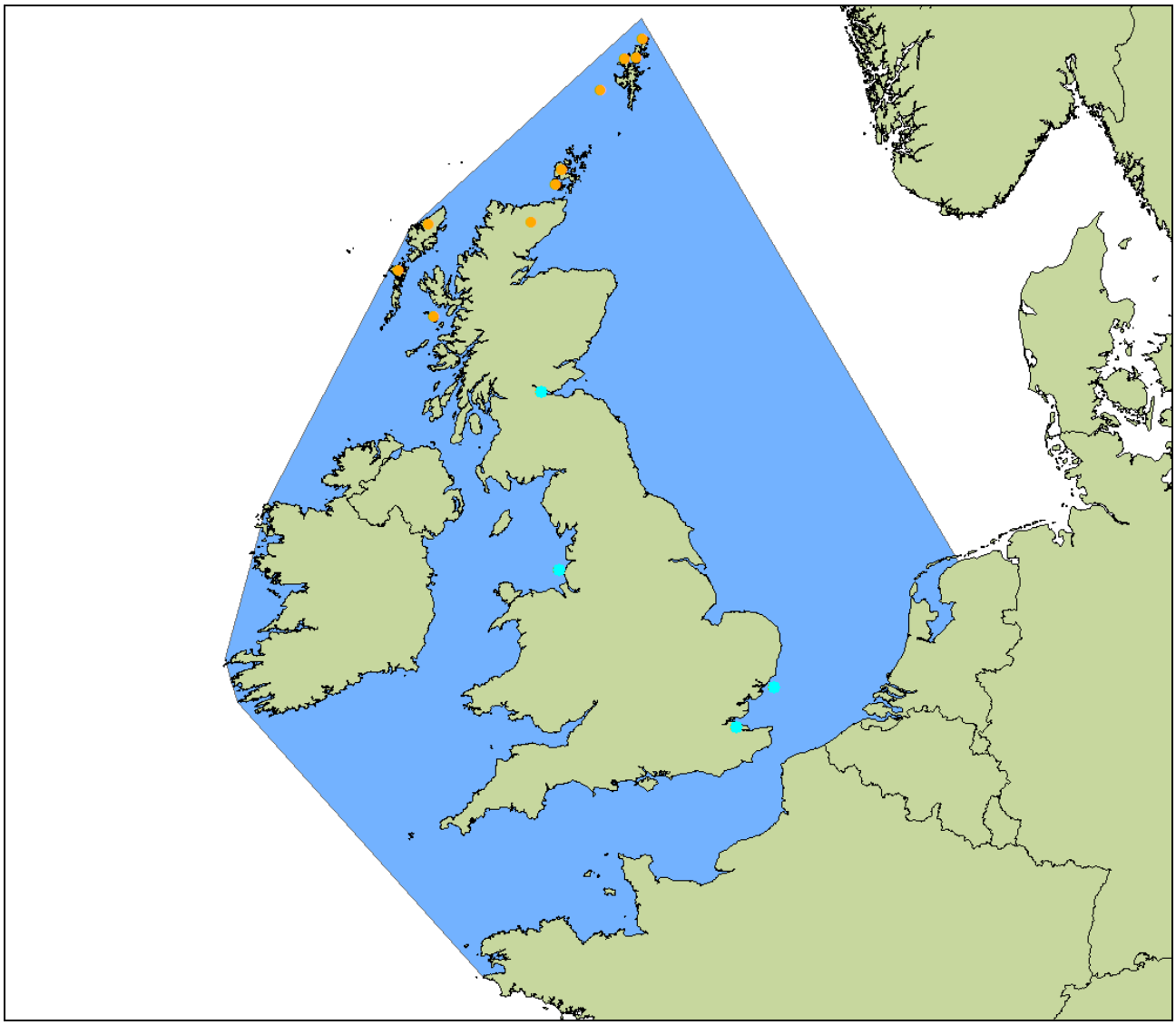


The blue area on this map shows the migration zone predicted to be crossed by non-breeding Goosanders into Britain, especially during periods of cold weather. The hatched blue area shows the area encompassing the predicted route taken by males from British-breeding populations on their moult migration (see below for details).

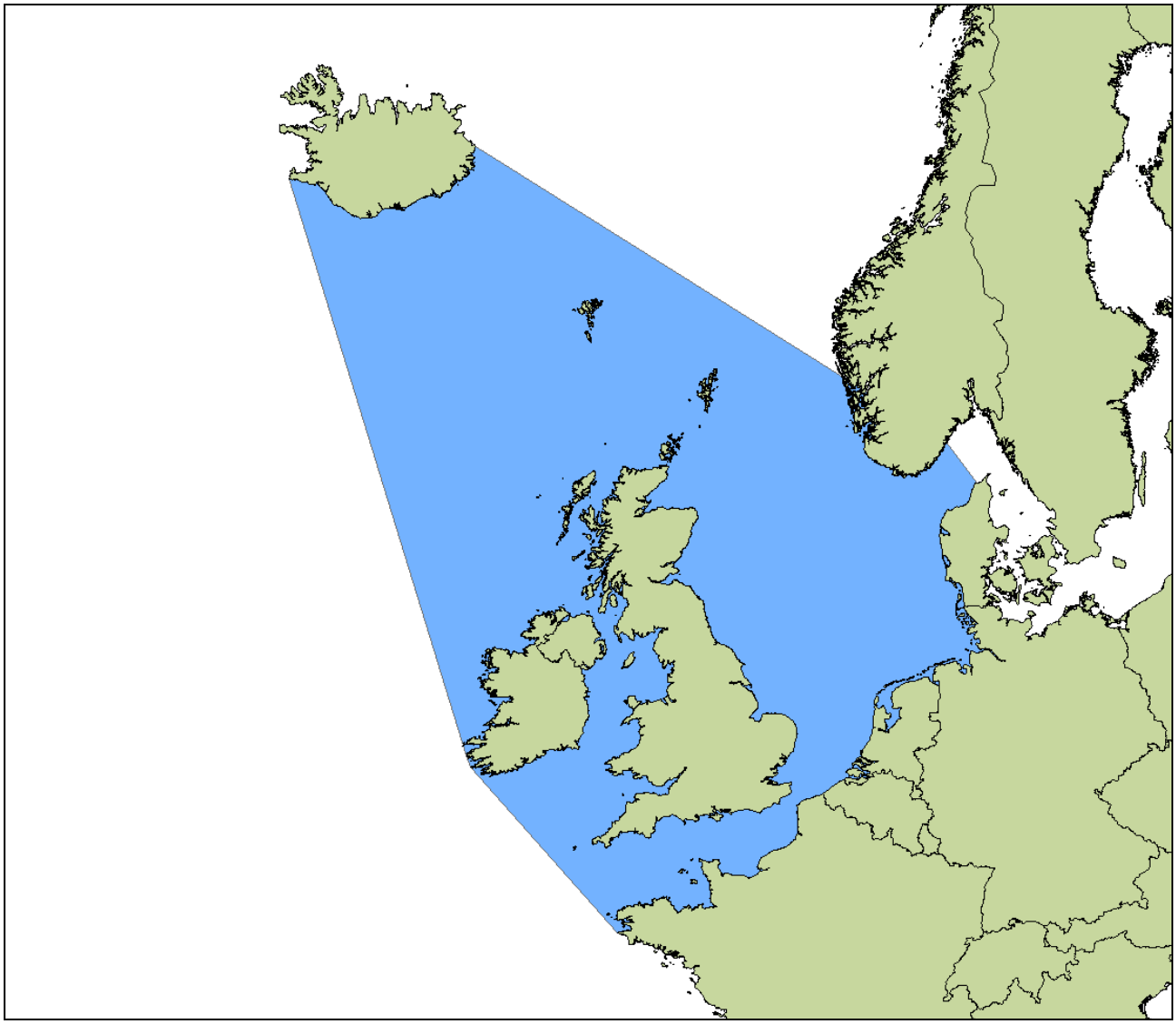
Goosanders occur throughout Britain but rarely in Ireland. Those that winter in Britain are thought to be largely derived from the British breeding population (Holt *et al*. 2010) but some may migrate from the near continent, especially to southeast England, during periods of cold weather. Males from British breeding populations migrate across the North Sea to moulting sites in Norway between June and September, returning to Britain between November and January. Most British-breeding females and juveniles are considered to remain in Britain throughout the year (Wernham *et al*. 2002).

Red-throated Diver *Gavia stellata*

Red-throated Diver *Gavia stellata*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding 10 sites in northern Scotland and Islands Non-breeding 4 sites (Firth of Forth, Liverpool Bay, Medway Estuary and Marshes, Outer Thames Estuary)
Population Size (GB)	935-1,500 breeding pairs 17,000 (non-breeding individuals)
Population Size (Ireland)	1,025 (non-breeding individuals)
Population Size (International)	150,000-450,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	4-12%



The blue area on this map shows the predicted migration zone potentially used by Red-throated Divers that breed in Britain and Ireland. Orange dots show SPA breeding sites while blue dots show SPA wintering sites for this species.



The blue area on this map shows the predicted migration zone potentially used by Red-throated Divers that migrate to Britain and Ireland during the non-breeding season.

Red-throated Divers are the features of UK SPAs for both their breeding and non-breeding populations. The two maps above show the potential migration routes taken by Red-throated Divers that either breed or winter in the UK. British-breeding birds are thought to travel shorter distances between breeding and wintering areas than those migrating from elsewhere. There is a general southerly movement away from breeding grounds in the autumn but wintering birds have a wide distribution all around British and Irish coasts. Birds from breeding grounds in Scandinavia and the Baltic states are thought to migrate mainly to the southern North Sea in winter.

Black-throated Diver *Gavia arctica*

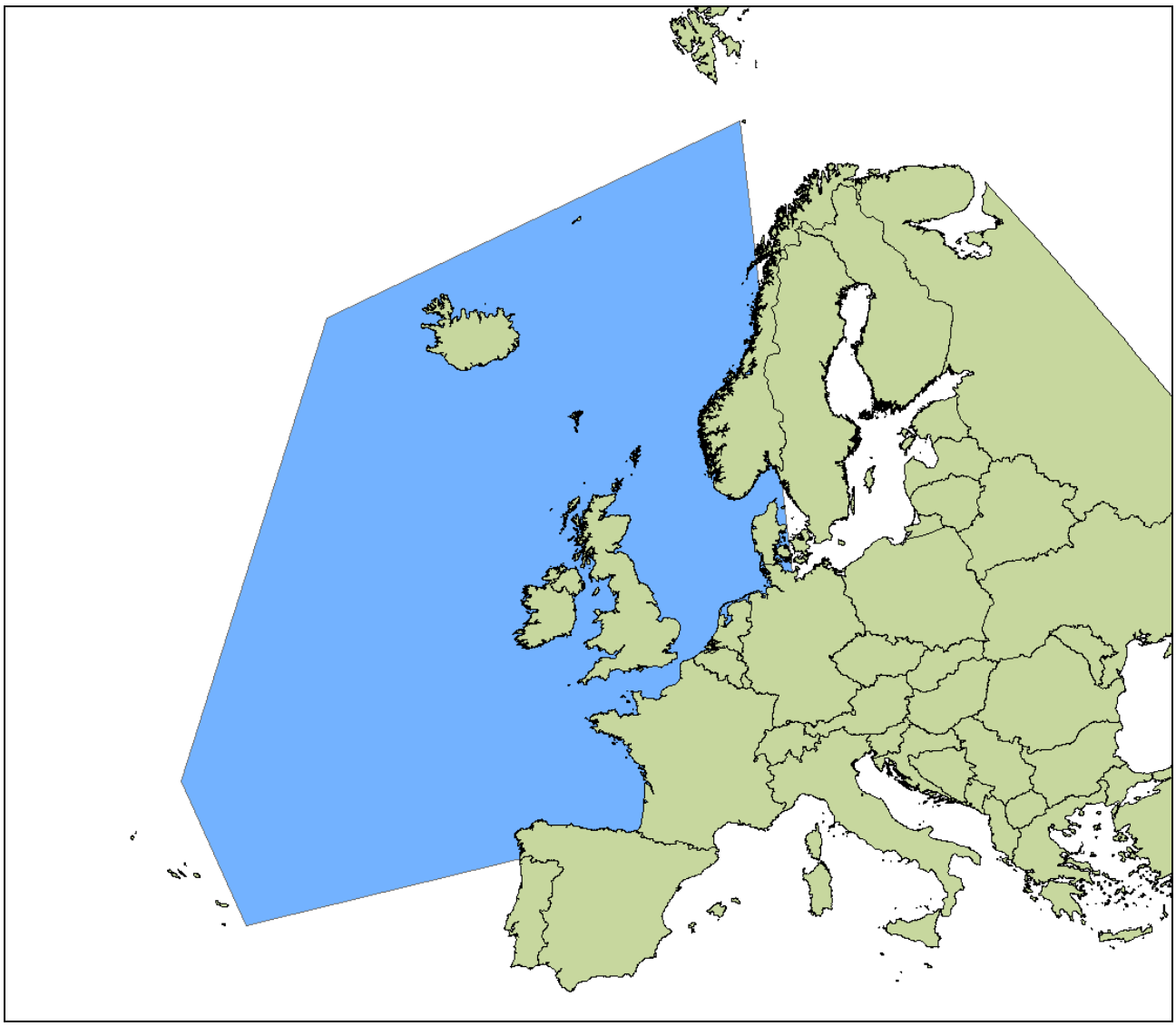
Black-throated Diver *Gavia arctica*	
SPA Species?	Yes (breeding population)
SPA Sites	11 sites in north and west Scotland and islands
Population Size (GB)	155-189 breeding pairs
	560 (non-breeding individuals)
Population Size (International)	250,000-500,000 (N Europe and W Siberia)
Percentage of international population in GB	0.1-0.2%

The orange dots on this map show the SPA breeding sites of Black-throated Divers that breed in Britain.

There is almost no information on the migration routes of Black-throated Divers from UK SPA breeding populations, and therefore no map has been drawn for this species. The UK-breeding population is joined by birds migrating from elsewhere in the winter, but there are no SPAs for the non-breeding population therefore it is not considered here.

Fulmar *Fulmarus glacialis*

Fulmar *Fulmarus glacialis*	
SPA Species?	Yes (breeding population)
SPA Sites	24 sites in Scotland and isles, 1 Northern Ireland
Population Size (UK)	504,756 (breeding pairs)
Population Size (International)	2,800,000-4,400,000 breeding pairs (Europe)
Percentage of international population in UK	11-18%

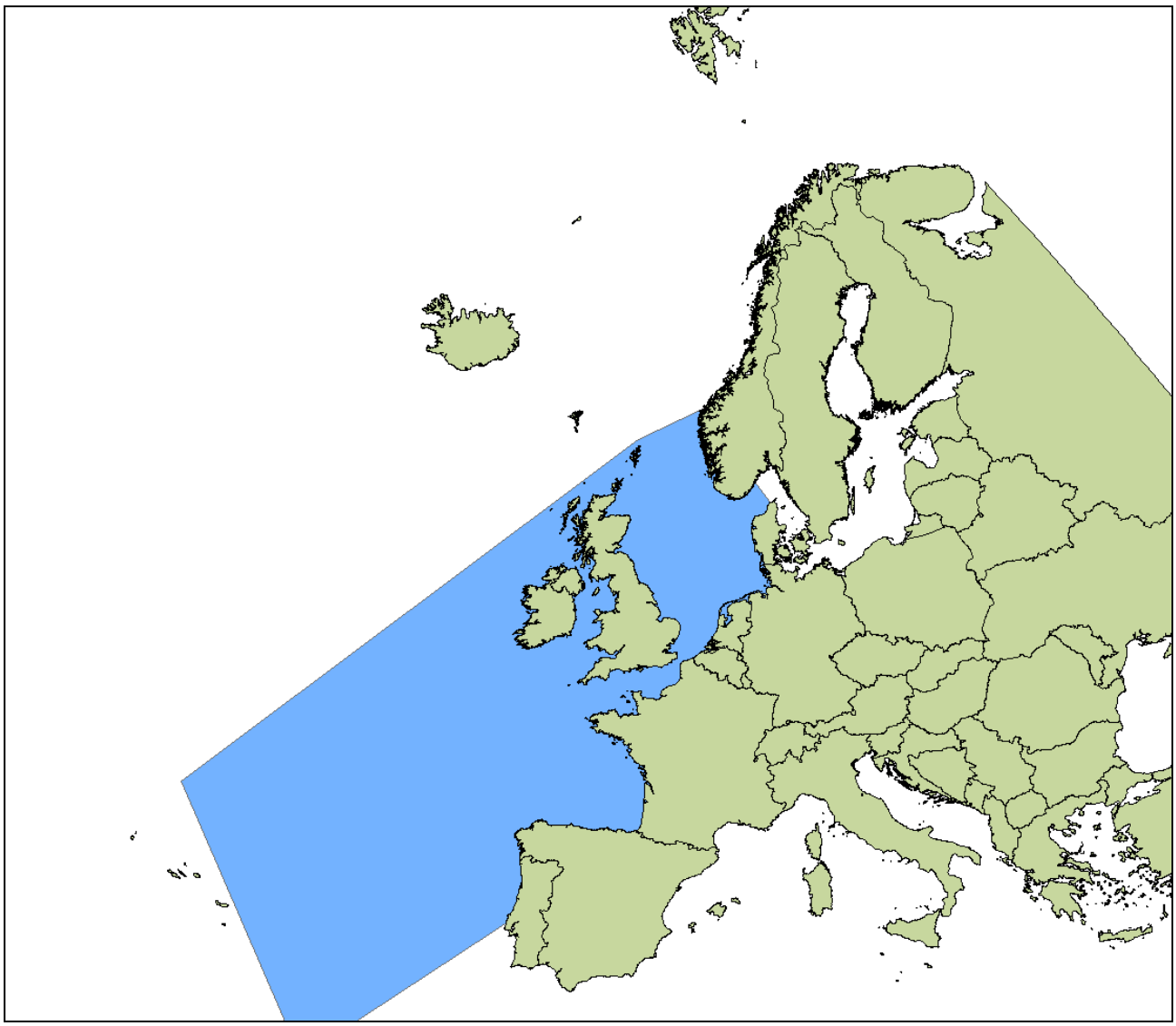


The blue area on this map shows the predicted migration zone potentially used by Fulmars that breed in Britain and Ireland. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the west.

Fulmars from breeding sites around the UK disperse in all directions during the non-breeding season, though many continue to attend colonies throughout the year. A number of tracking studies are ongoing on this species, and the data from these studies may be beneficial in improving understanding of the migratory/dispersive movements of Fulmars.

Manx Shearwater *Puffinus puffinus*

Manx Shearwater *Puffinus puffinus*	
SPA Species?	Yes (breeding population)
SPA Sites	4 sites (west Wales and Western Isles)
Population Size (UK)	281,382-319,499 (breeding pairs)
Population Size (International)	350,000-390,000 breeding pairs
Percentage of international population in UK	72-91%

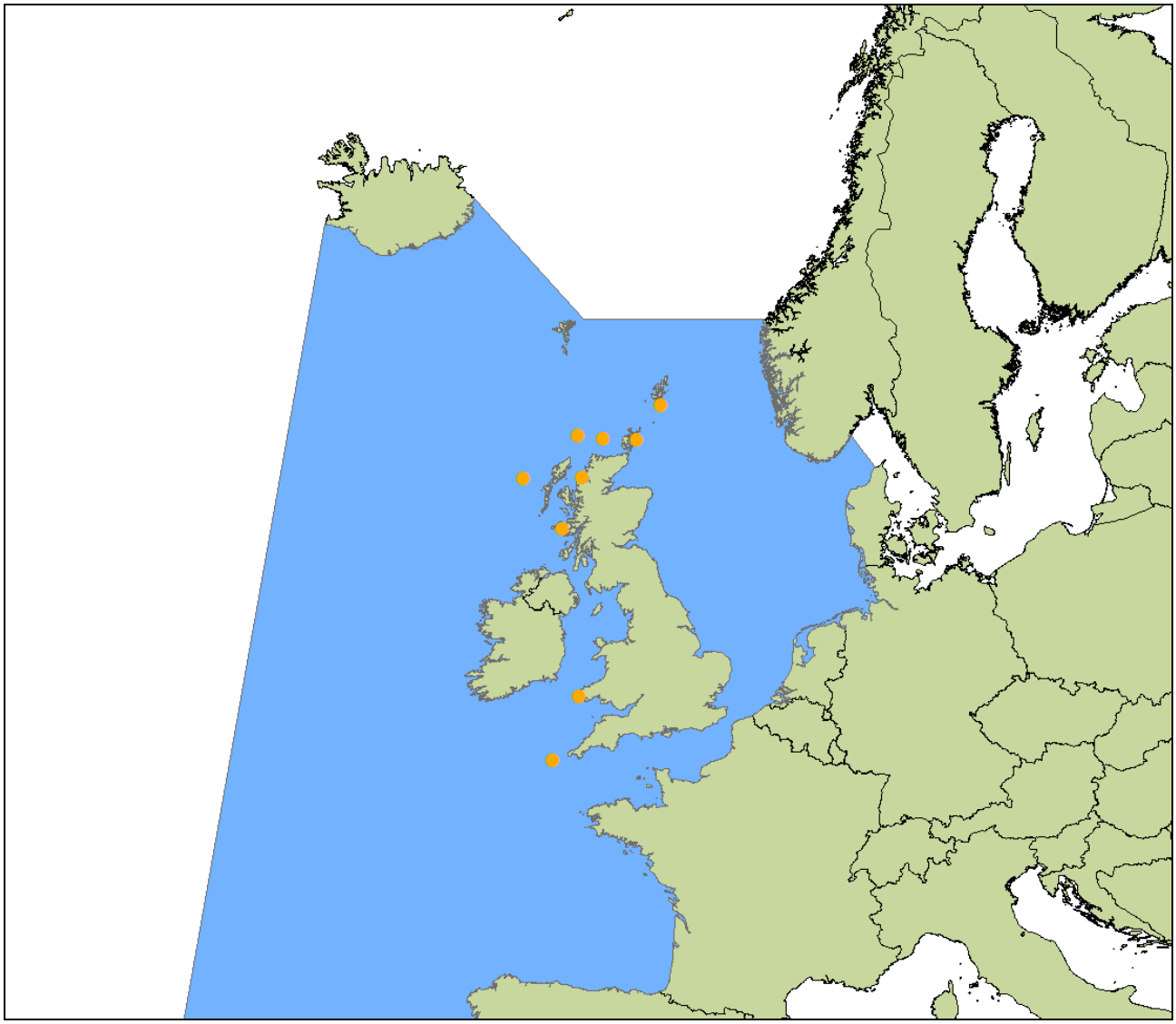


The blue area on this map shows the predicted migration zones potentially used by Manx Shearwaters. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the west and south, towards wintering areas along the coasts of South America.

The vast majority of Manx Shearwater migration occurs along the west of Britain with birds heading in a south-westerly direction from breeding colonies towards wintering grounds along the coasts of South America. The return migration is along a slightly more northerly route, with birds tending to arrive from closer to the west (rather than the south-west). Recent tracking studies (e.g. Guilford *et al*. 2009) have vastly improved our knowledge of the migration routes of this species and data from these studies may be useful in understanding the numbers of birds likely to pass through proposed wind farm sites on migration.

Storm Petrel *Hydrobates pelagicus*

Storm Petrel *Hydrobates pelagicus*	
SPA Species?	Yes (breeding population)
SPA Sites	9 sites around north and west coasts of Britain
Population Size (UK)	20,994-33,434 (breeding pairs)
Population Size (International)	430,000-510,000 breeding pairs
Percentage of international population in GB	4-8%

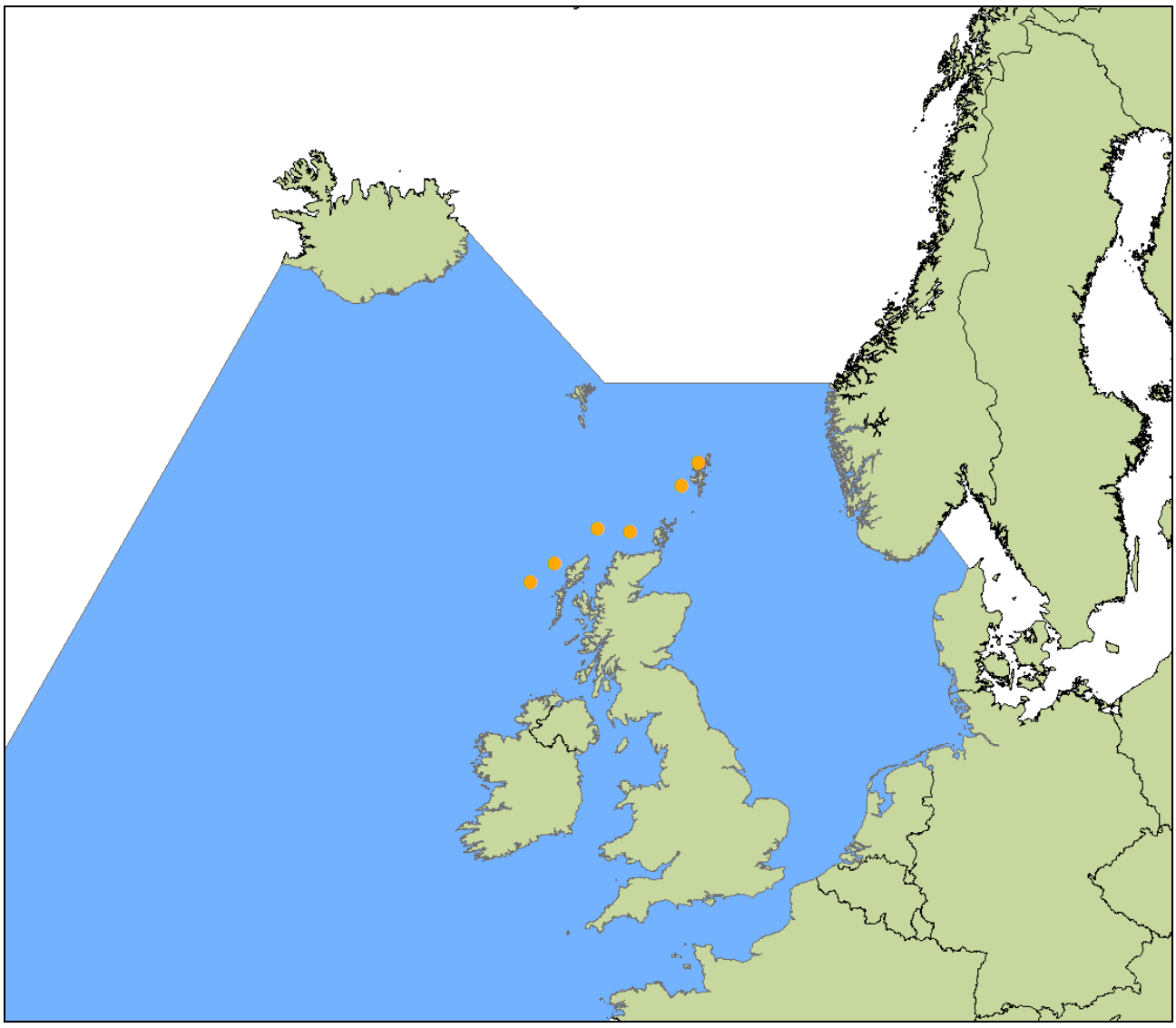


The blue area on this map shows the predicted migration zones potentially used by Storm Petrels that breed in the UK, while orange dots show SPA breeding colonies. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south.

Storm Petrels may disperse in any direction from UK breeding grounds to pelagic feeding grounds. It is thought that birds move south to wintering grounds over a long period in late summer and early autumn, and wintering grounds are probably off the coasts of western and southern Africa, though a lack of ringing recoveries means that this is not certain.

Leach's Petrel *Oceanodroma leucorhoa*

Leach's Petrel *Oceanodroma leucorhoa*	
SPA Species?	Yes (breeding population)
SPA Sites	6 sites on islands north of Scotland
Population Size (UK)	36,432-64,883 (breeding pairs)
Population Size (International)	120,000-220,000 (Europe)
Percentage of international population in UK	16-54%

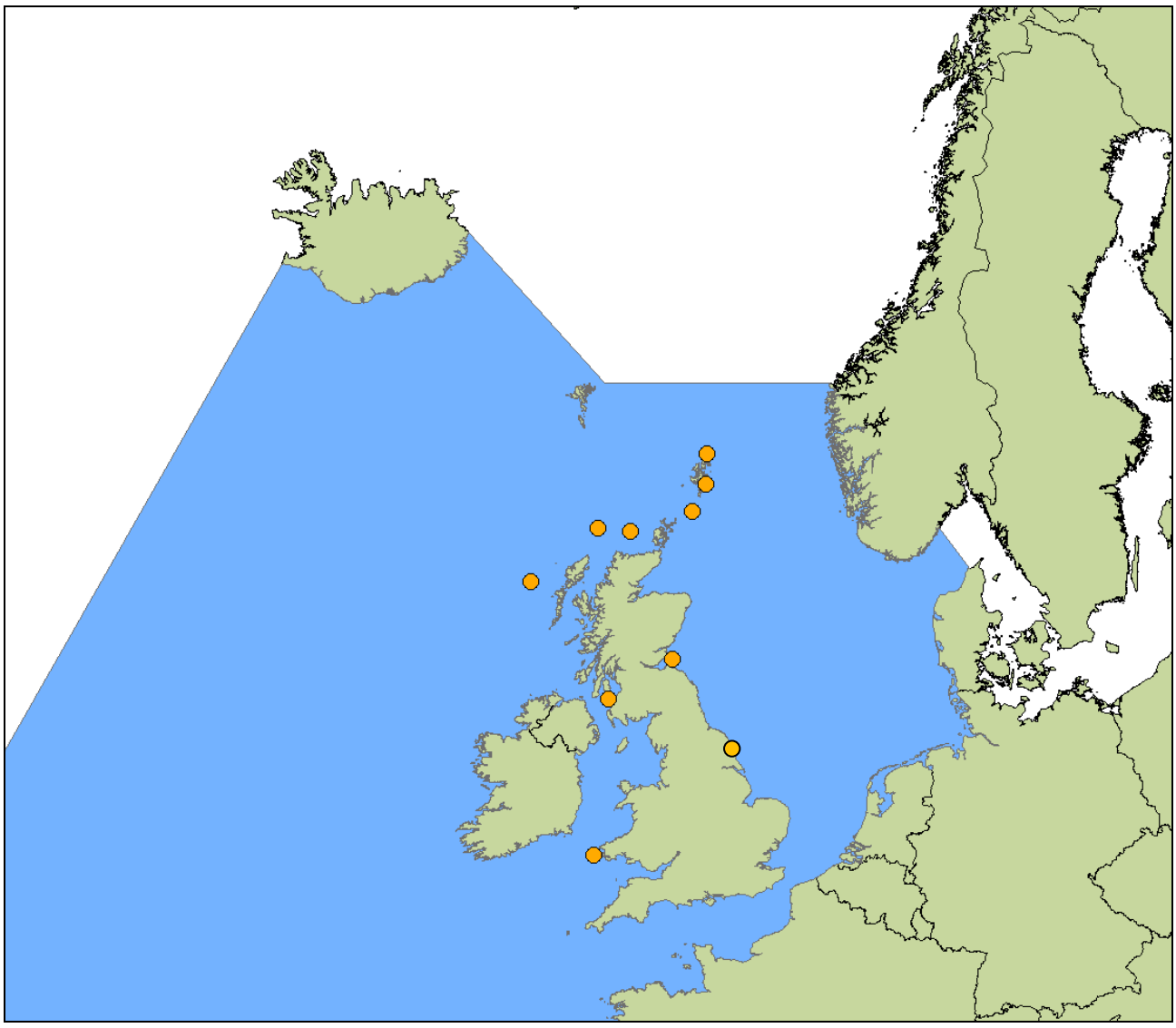


The blue area on this map shows the predicted migration zones potentially used by Leach's Petrels that breed in the UK, while orange dots show the locations of SPA breeding sites. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south and west.

This species makes regular movements between breeding colonies and pelagic feeding grounds, probably in the mid-Atlantic. There is some dispersal between breeding sites on Scottish islands and islands off Norway. Wintering sites are probably further south in the Atlantic (anywhere between the Bay of Biscay and the South Atlantic) but there are no ringing recoveries linking breeding colonies and wintering grounds and so this is extremely uncertain. Wrecks (high number of dead/dying birds washed ashore) tend to occur along western coasts following stormy weather in autumn and winter.

Gannet *Morus bassanus*

Gannet *Morus bassanus*	
SPA Species?	Yes (breeding population)
SPA Sites	10 coastal sites around UK (mainly northerly)
Population Size (UK)	218,546 (nests)
Population Size (International)	300,000-310,000 breeding pairs (Europe)
Percentage of international population in UK	70-73%



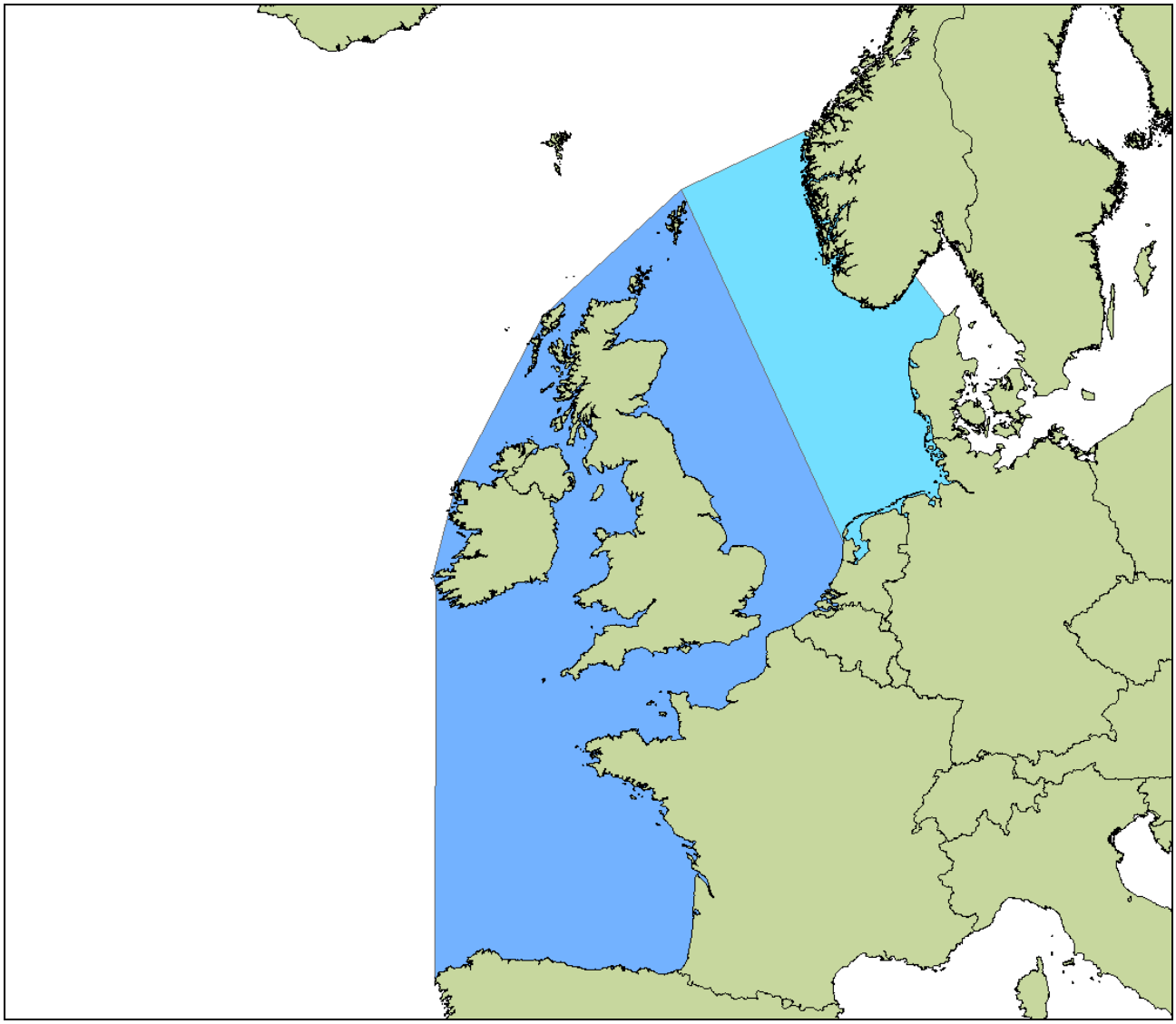
The blue area on this map shows the predicted migration zones potentially used by Gannets that breed in the UK, while orange dots show SPA breeding sites. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south and west.

Gannets migrate south at the end of the breeding season, with birds, especially juveniles, moving as far as the Gulf of Guinea off West Africa. However, some adults may remain at the breeding colony for much of the year (January to November). Some of the birds that breed on the east coast may stay in the North Sea or migrate round the north of Scotland and down the west coast of Ireland, or south through the English Channel, to the Bay of Biscay, Mediterranean or NW/W Africa (Kubetzki *et al.* 2009). The protracted breeding season of Gannets combined with individual variation in migratory behaviour means that the migration of Gannets between breeding colonies and wintering sites occurs over a long period. Gannets

have been the subject of a number of recent tracking studies and it would be extremely valuable to examine data from these studies to improve estimates of the numbers of birds migrating along different routes, and the timing of those migrations.

Cormorant *Phalacrocorax carbo*

Cormorant *Phalacrocorax carbo*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 7 coastal sites around UK
	Non-breeding 32 coastal and inland sites
Population Size (GB)	8,355 (breeding pairs)
	35,000 individuals (non-breeding)
Populaiton Size (Ireland)	13,710
Population Size (International)	120,000 (*carbo*, NW Europe)
Percentage of international population in GB & Ireland	41%



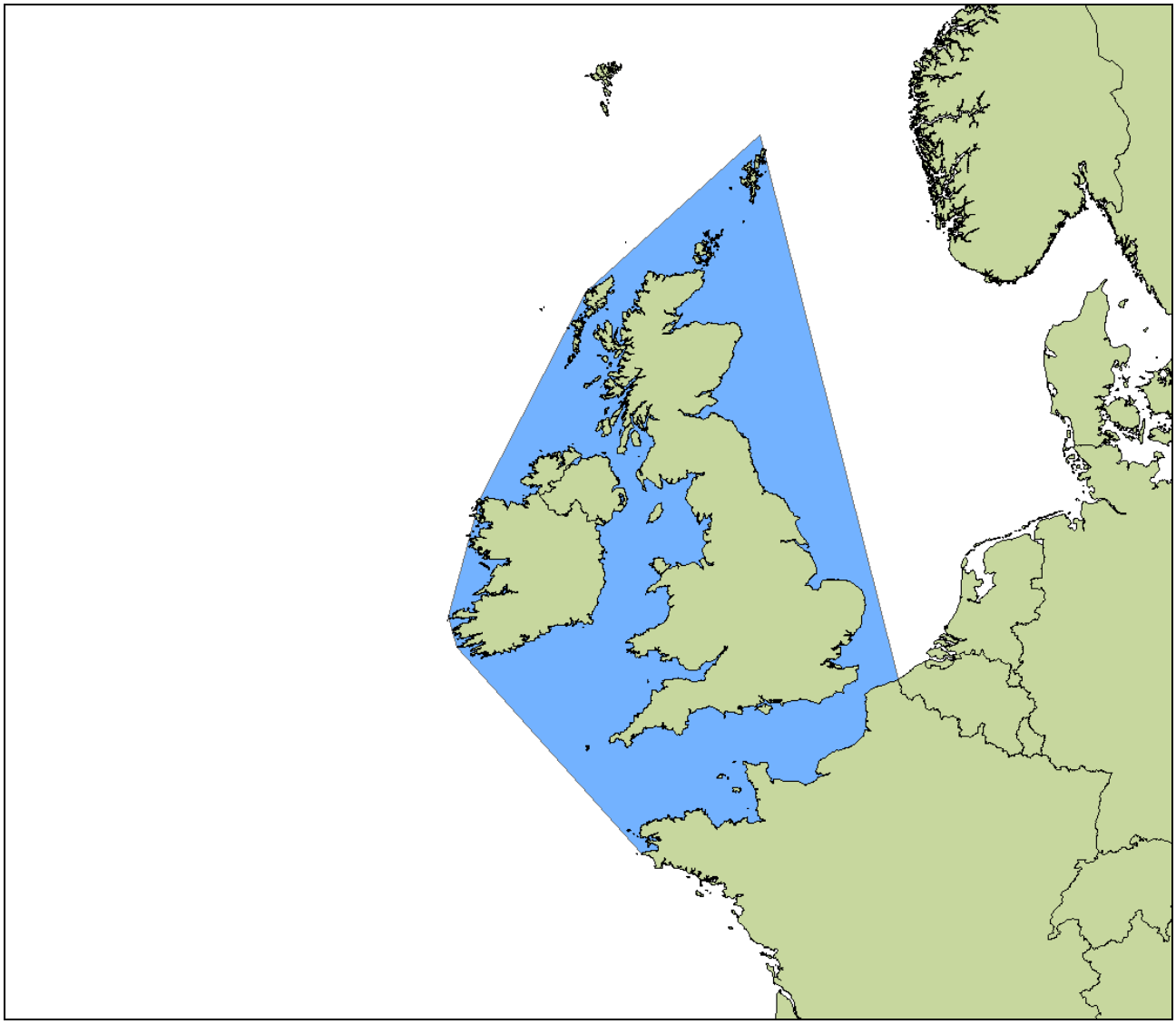
The blue area on this map shows the predicted migration zones potentially used by the majority of Cormorants that breed in the UK, while the pale blue shows the area used by a smaller number of birds that move from Britain to Scandinavia, or by birds that visit the UK in winter from breeding sites in Europe.

Many of the Cormorants that breed in the UK remain close to their breeding colonies throughout the year, but some migrate southwards to wintering sites along the coast of France, Portugal and northern Spain (with migration routes for these birds within UK waters likely to be concentrated in the Irish Sea and western Channel), and a few moving to Scandinavia. Autumn migration occurs from July onwards, with birds returning to breeding colonies over a long period from November to May. Some birds that breed in

continental Europe move to the UK during the winter. Ringing recoveries suggest that the vast majority of these wintering birds are likely to migrate across the southern half of the North Sea, but some pass through all areas marked in blue.

Shag *Phalacrocorax aristotelis*

Shag *Phalacrocorax aristotelis*	
SPA Species?	Yes (breeding population)
SPA Sites	13 sites in Scottish Islands and Isles of Scilly
Population Size (UK)	27,477 (breeding pairs) 110,000 (non-breeding individuals)
Population Size (International)	199,000-205,000 (*aristotelis*)
Percentage of international population in UK	13-14% (breeding season) 54-55%(non-breeding season)



The blue area on this map shows the predicted migration zones potentially used by Shags that breed in the UK.

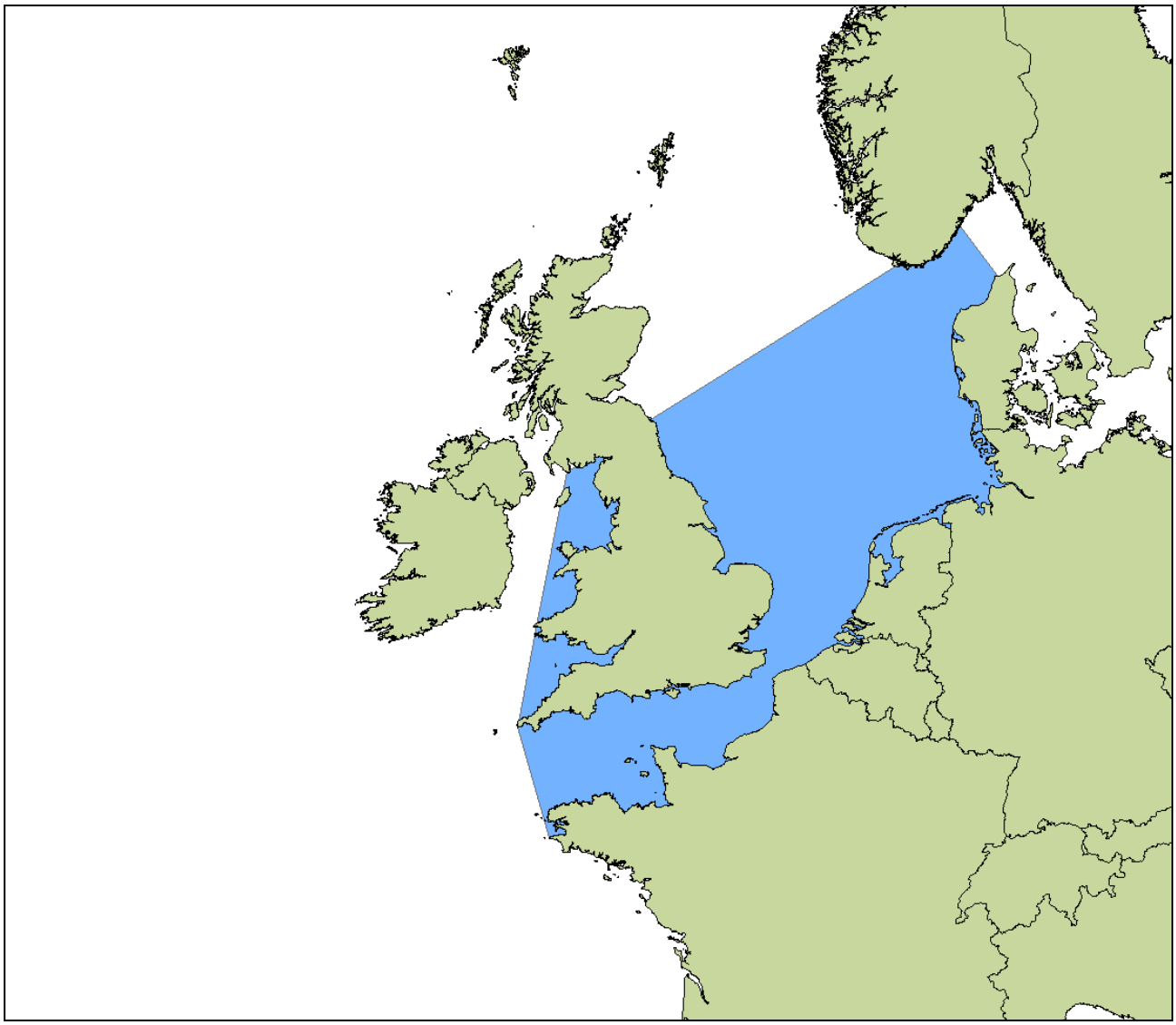
Some Shags disperse widely outside the breeding season but many remain within 50-100 km of breeding colonies throughout the year, except in the case of severe weather. They tend to stay reasonably close to land, hence few cross the North Sea. After fledging (which can occur between June and October) young birds tend to disperse further from the colony than adults, with all birds returning to areas near colonies in spring or early summer. There are differences in movement patterns between regions of the UK (see Wernham *et al*. 2002 for further details) but birds may disperse in either a northerly or a southerly direction from breeding colonies. Recent and ongoing tracking studies are a valuable source of data that

may be of use when examining the movement patterns of Shags in relation to proposed offshore wind farm development.

Bittern *Botaurus stellaris*

Bittern *Botaurus stellaris*	
SPA Species?	Yes (breeding and non-breeding populations
SPA Sites	Breeding season 5 sites, 4 in eastern England and Leighton Moss in NW England Non-breeding 10 sites in England
Population Size (GB)	87 males (breeding)[1] 600 (non-breeding)
Population Size (International)	5,850-6,700 (W Europe, NW Africa)
Percentage of international population in GB	3% (breeding) 10% (non-breeding)

[1] Breeding population size from Wotton *et al*. 2010.



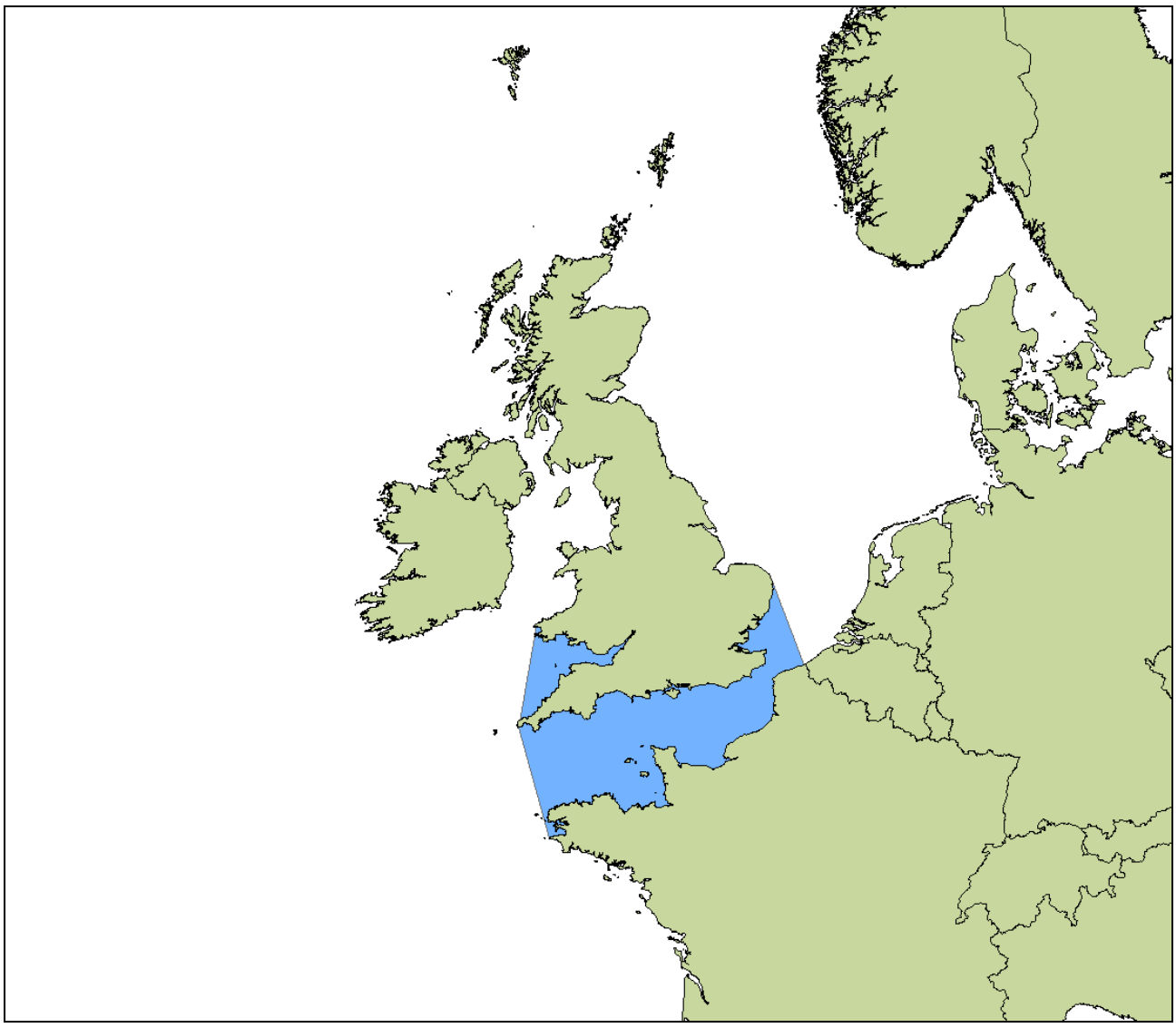
The blue area on this map shows the predicted migration zones potentially used by Bitterns that visit the UK during the non-breeding season.

The UK breeding population of Bitterns is relatively sedentary, although ringing recoveries suggest juveniles may disperse up to 200 km (Wernham *et al.* 2002), though of course some individuals may move shorter or longer distances. No UK-ringed Bitterns have been recovered overseas. However, during the winter, the breeding population is often supplemented by a large influx of birds from elsewhere in North-Western

Europe in response to harsh weather. Within the UK, Bittern populations are largely confined to eastern areas, with an additional population in Leighton Moss, in North-West England. As available evidence suggests that breeding populations of the Bittern are unlikely to come into contact with offshore wind farms, further research on this species in the breeding season should be seen as a low priority. However, given the cold-weather movements of Bitterns from continental Europe into the UK, research into the movements of wintering populations may prove valuable.

Little Egret *Egretta garzetta*

Little Egret *Egretta garzetta*	
SPA Species?	Yes (non-breeding population)
SPA Sites	3 sites on the south coast of England
Population Size (GB)	4,500
Population Size (International)	125,000-143,000 (W Europe, NW Africa)
Percentage of international population in GB	3%

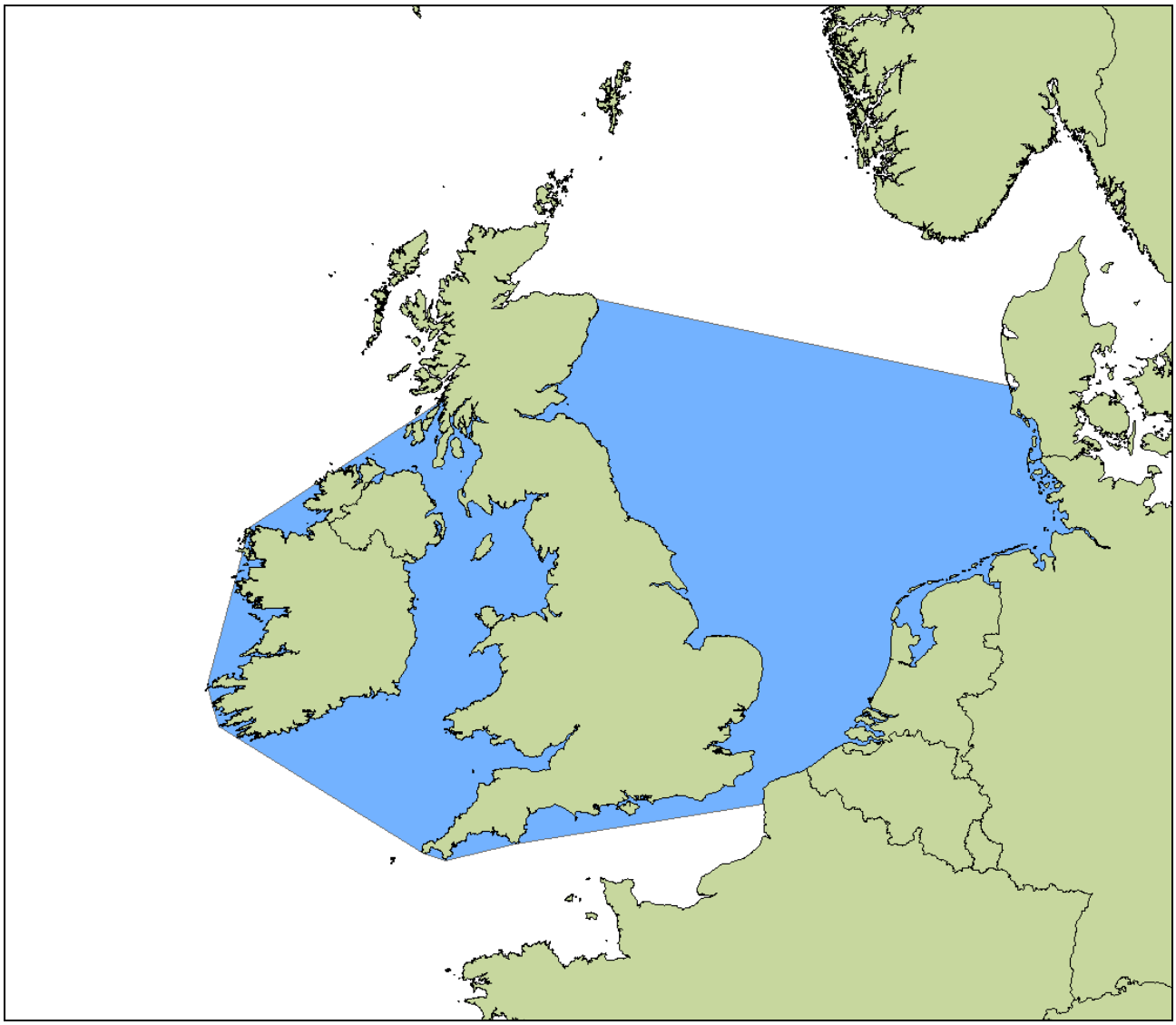


The blue area on this map shows the predicted migration zones potentially used by Little Egrets that visit the UK during the non-breeding season.

A northwards expansion of the Little Egret within Europe has meant that the species status in the UK has changed dramatically in recent years. Whilst records of Little Egret are limited during the breeding season, there is a substantial rise in numbers during the autumn and winter. Little information is available regarding the movements of British ringed birds, however, it is likely that many of the birds that arrive in the country do so from France. This is reflected in Little Egret being a feature of 3 SPAs on the south coast of England outside the breeding season.

Great Crested Grebe *Podiceps cristatus*

Great Crested Grebe *Podiceps cristatus*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 1 site (Loughs Neagh and Beg) Non-breeding 17 coastal and inland sites in England, Northern Ireland and south Scotland
Population Size (GB)	9,400 (breeding) 19,000 (non-breeding)
Population Size (Ireland)	5,385
Population Size (International)	290,000-420,000 (NW Europe)
Percentage of international population in GB & Ireland	3% (breeding) 6-8% (non-breeding)



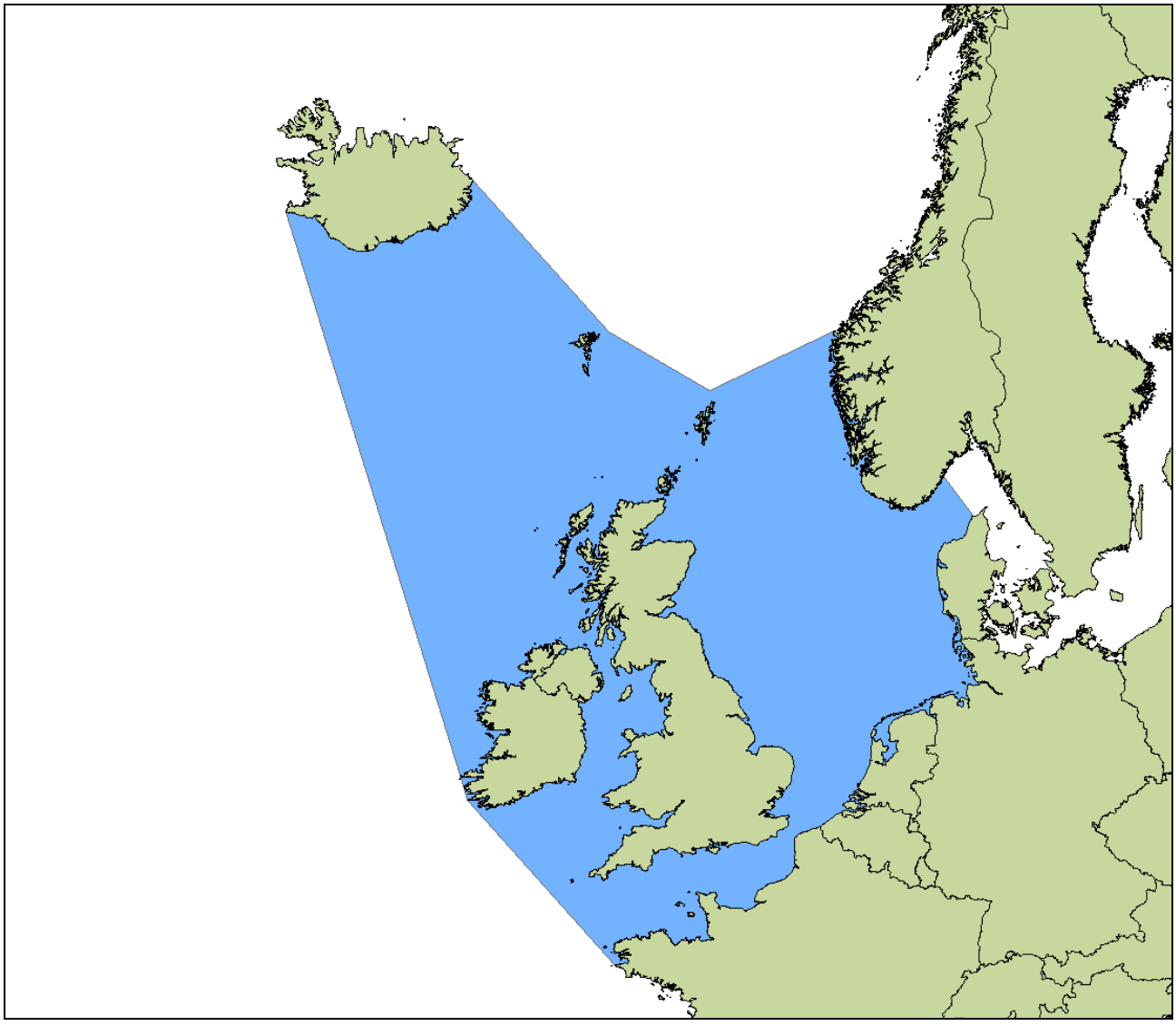
The blue area on this map shows the predicted migration zones potentially used by Great Crested Grebes in Britain and Ireland.

Great Crested Grebes are widespread within the UK. During the breeding season, Great Crested Grebes tend to be located on inland waterbodies, moving to coastal areas over winter (Wernham *et al.* 2002). Of 38 ringing recoveries for the Great Crested Grebe, 5 (13 %) involved movements between the UK and Continental Europe. However, it is not possible to draw conclusions about the movement of birds between

the UK and the continent based on such small sample sizes. As relatively little is known about population movements of the Great Crested Grebe, and they are often found in coastal sites, further research into the movements of this species should be a moderate priority.

Slavonian Grebe *Podiceps auritus*

Slavonian Grebe *Podiceps auritus*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 6 sites in northern Scotland Non-breeding season 3 sites (Exe Estuary and Firth of Forth (wintering), Loch Ashie (spring)).
Population Size (GB)	39-43 pairs (breeding) 1,100 (non-breeding)
Population Size (International)	4,600-6,800 (NW Europe)
Percentage of international population in GB	1% (breeding) 19% (non-breeding)



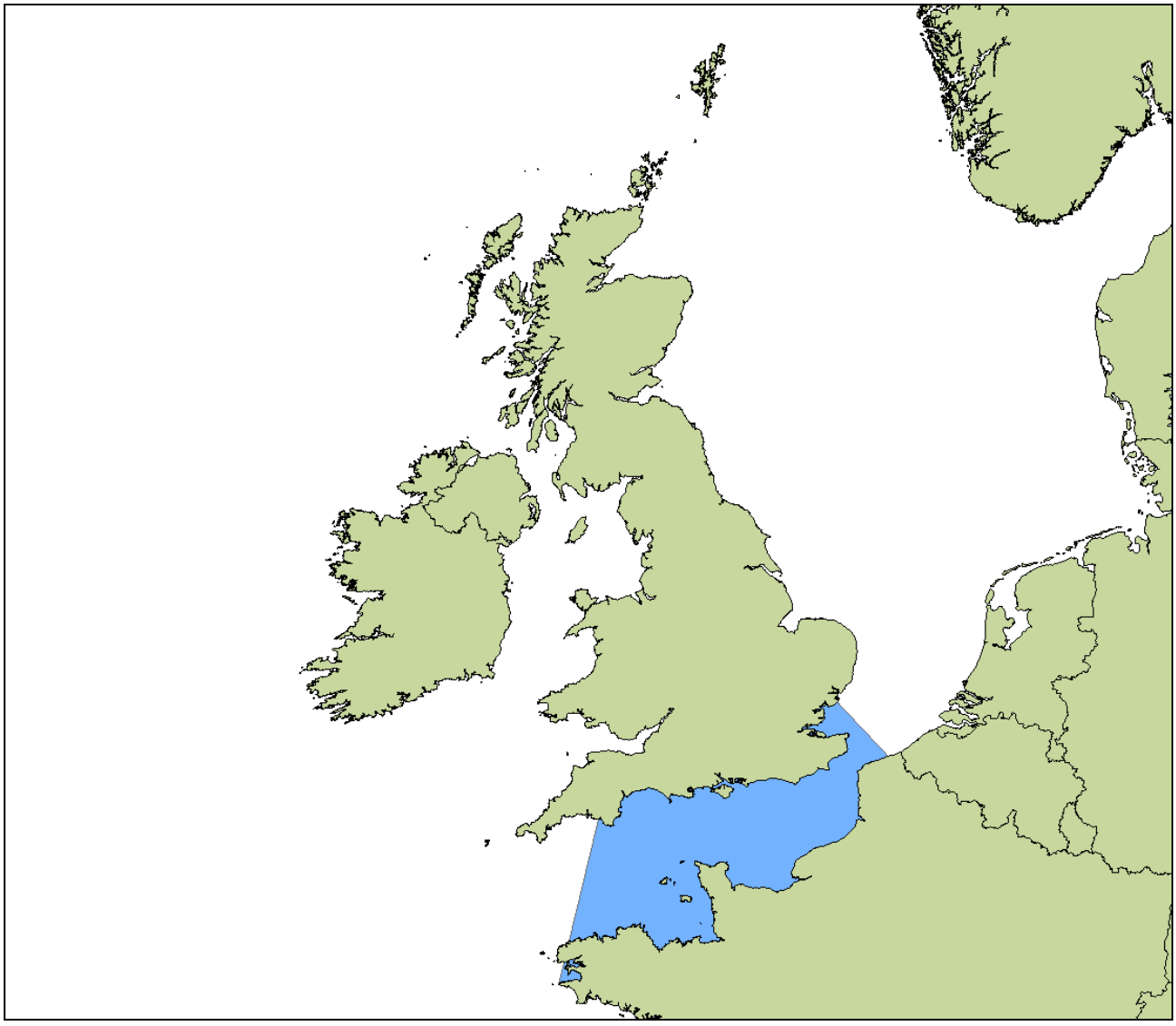
The blue area on this map shows the predicted migration zones potentially used by Slavonian Grebes in Britain.

The Slavonian Grebe has a Holarctic distribution and several recognized sub-species, of which two occur within the UK. Within the UK, a small proportion of the international population of the *arcticus* sub-species breed at sites in Northern Scotland. During the winter a large proportion of the international population of the *auritus* sub-species are recorded within the UK, however, a lack of ringing recovery information hinders any understanding of likely migration route (Wernham *et al.* 2002). The lack of knowledge surrounding

migration routes in this species, combined with the high proportion of the international population which winters within the UK mean that further research into the movements of this species outside the breeding season should be a high priority. In the meantime, assessments for proposed offshore wind farms must assume that Slavonian Grebes could potentially migrate across any of the waters around the UK.

Honey-buzzard *Pernis apivorus*

Honey-buzzard *Pernis apivorus*	
SPA Species?	Yes (breeding)
SPA Sites	1 site in southern England (New Forest)
Population Size (UK)	33-69 pairs
Population Size (International)	110,000-160,000 pairs
Percentage of international population in UK	0.04%



The blue area on this map shows the predicted migration zones potentially used by Honey Buzzards that breed in the UK.

The Honey Buzzard is widespread throughout the temperate and boreal regions of Europe. The Honey Buzzard is a long distance migrant, travelling to breed in sites in Southern England from tropical Africa via the strait of Gibraltar (Wernham *et al.* 2002). Whilst the Honey Buzzard is a feature of a UK SPA, only a small proportion of the international population occurs in the UK, consequently, it is likely to be of lower concern than other species in relation to assessments for offshore wind development.

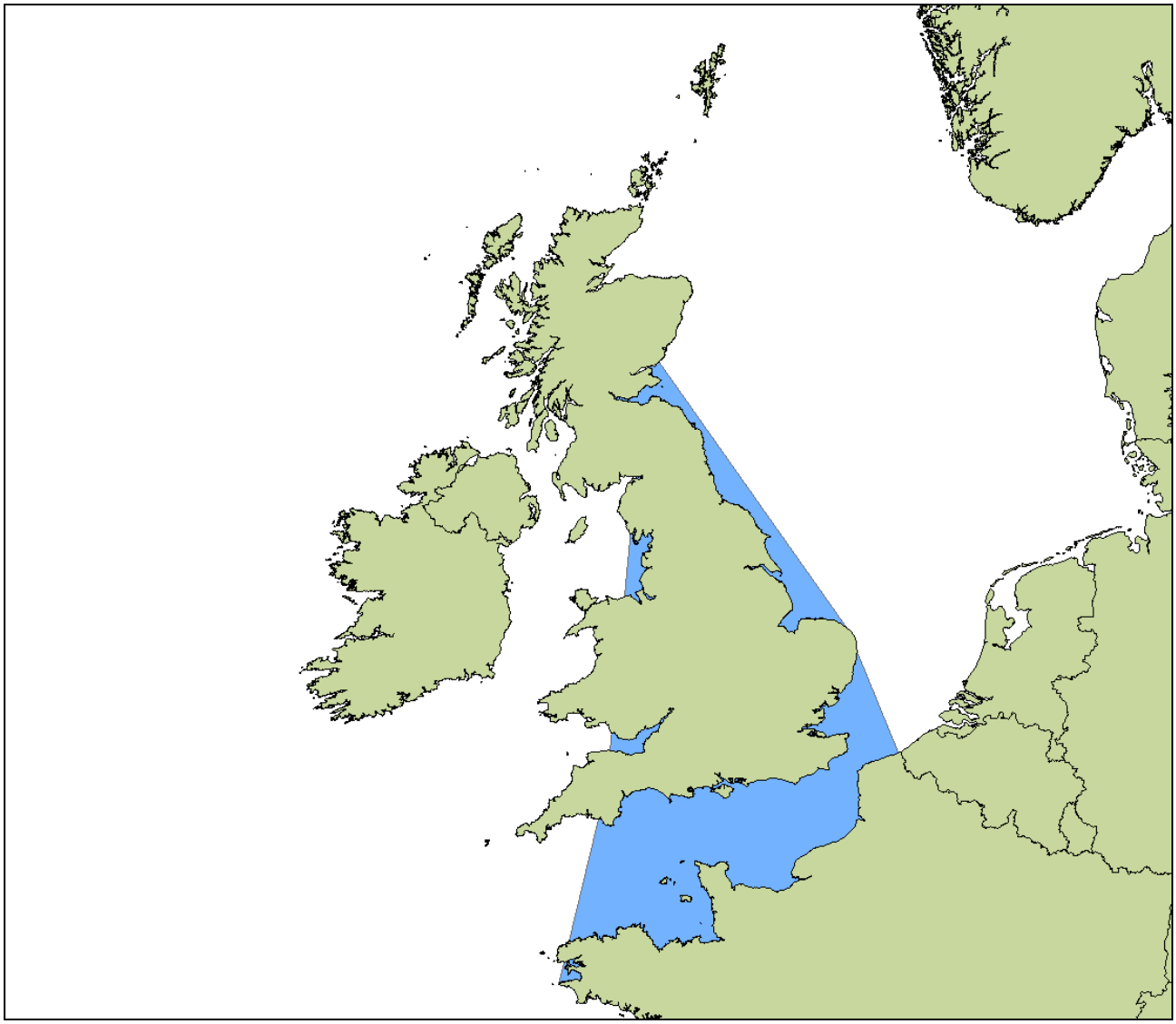
White-tailed Eagle *Haliaeetus albicilla*

White-tailed Eagle *Haliaeetus albicilla*	
SPA Species?	No but Annex 1
SPA Sites	None
Population Size (UK)	21 breeding pairs
Population Size (International)	5,000-6,600 breeding pairs (Europe)
Percentage of international population in UK	0.4%

This species is largely confined to the Western Isles of Scotland and nearby areas of the mainland, and movements between these islands and the mainland should be considered in assessments for offshore wind farms in this region. There have also been recent reintroductions in eastern Scotland between the Firths of Forth and Tay. A small number of birds have been tracked using satellite tags, and data from these studies would be valuable in assessing how this species may interact with proposed wind farm developments. However, this species is not thought to migrate over long distances and therefore is not of concern for the majority of UK wind farms that are outside its range.

Marsh Harrier *Circus aeruginosus*

Marsh Harrier *Circus aeruginosus*	
SPA Species?	Yes (breeding population)
SPA Sites	10 sites largely in coastal eastern England but also Leighton Moss (NW England) and Firth of Tay and Eden Estuary in Scotland.
Population Size (UK)	201 females
Population Size (International)	93,000-140,000 pairs
Percentage of international population in UK	0.2%



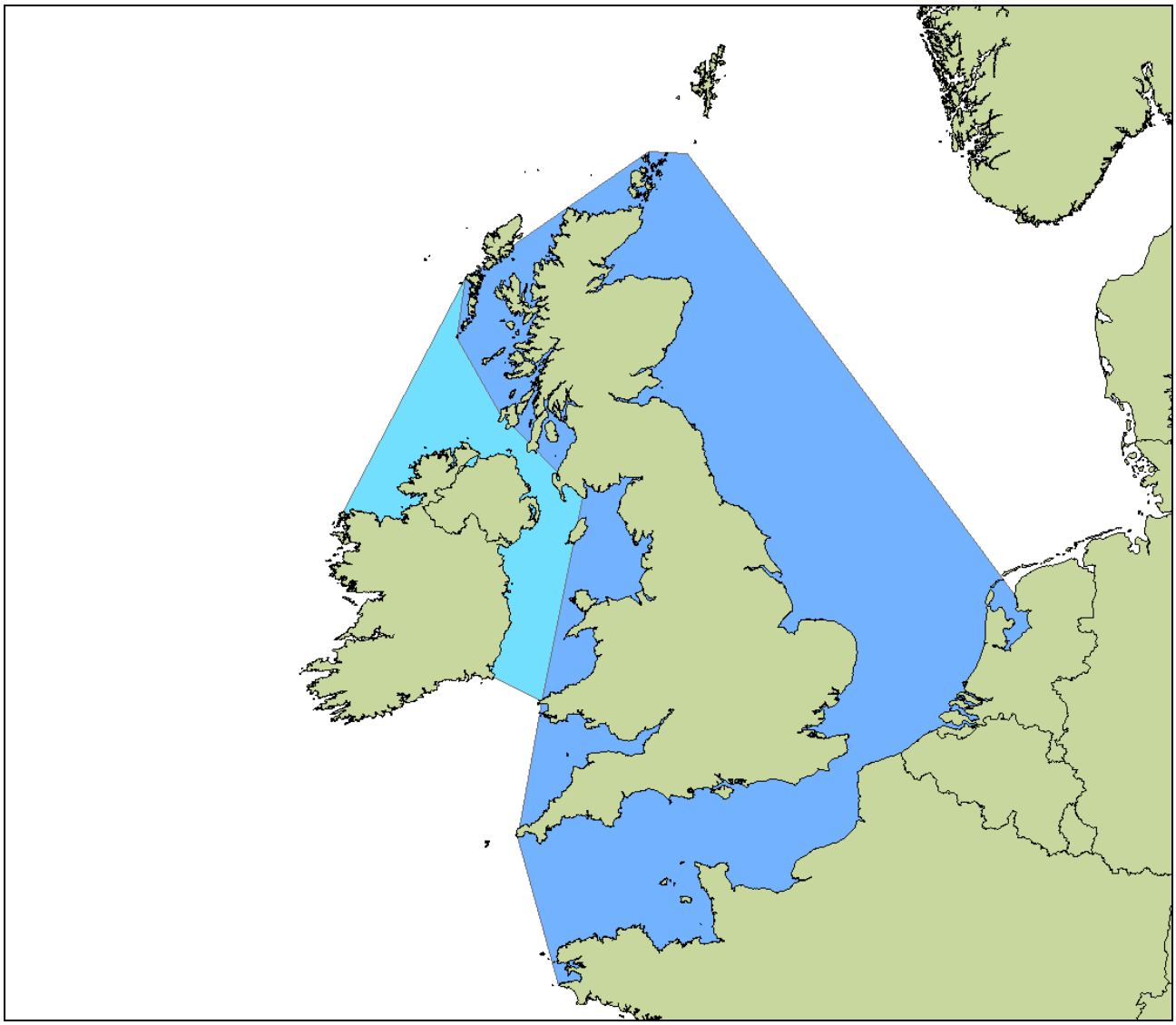
The blue area on this map shows the predicted migration zones potentially used by Marsh Harriers that breed in the UK.

The Marsh Harrier is a wide ranging species occurring throughout Europe, North Africa and Central Asia. The population within the UK are partial migrants, with some individuals remaining within the UK over winter, and others migrating to Southern Europe and sub-Saharan Africa. As the Marsh Harrier is a feature of 10 UK SPAs, and its migratory routes are poorly understood as a result of a limited number of ringing recoveries, further research into the movements of this species is a high priority. As the proportion of the population that migrates is uncertain, a precautionary assumption (to be used until better information is

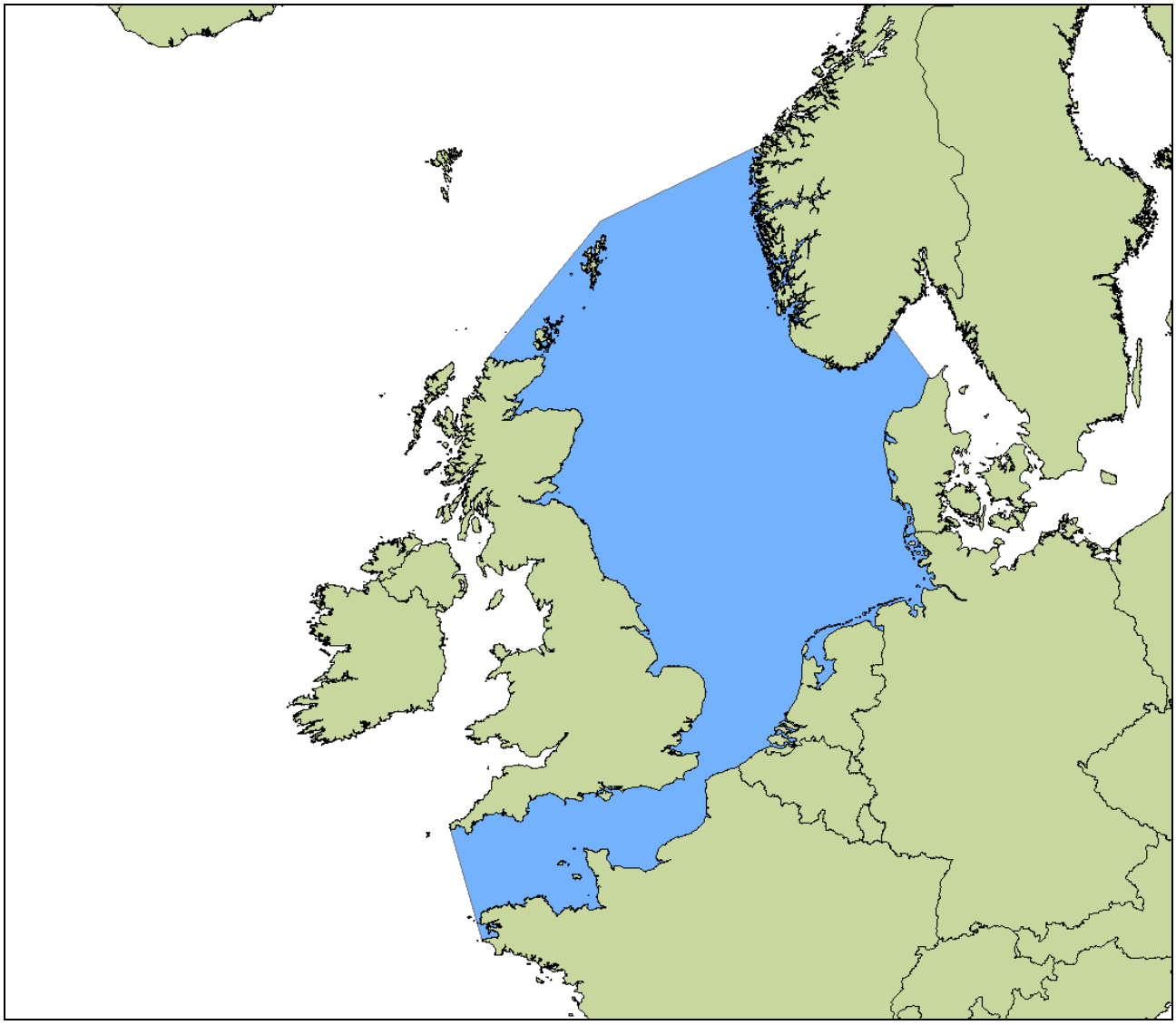
available) would be that the entire UK breeding population potentially migrates across the route shown in the above map.

Hen Harrier *Circus cyaneus*

Hen Harrier *Circus cyaneus*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 14 sites in Scotland, Wales and northern England Non-breeding 20 sites in south and east England and Scotland
Population Size (UK)	570 territorial pairs (breeding) 750 individuals (non-breeding)
Population Size (International)	32,000-59,000 pairs (breeding) >8,500 individuals (non-breeding)
Percentage of international population in UK	1% (breeding) <9% (non-breeding)



The above map shows the movements of UK-breeding Hen Harriers, with darker blue showing the main predicted migration zone and pale blue showing the areas encompassing the migration route followed by a small proportion of the population that moves to Ireland for the winter.

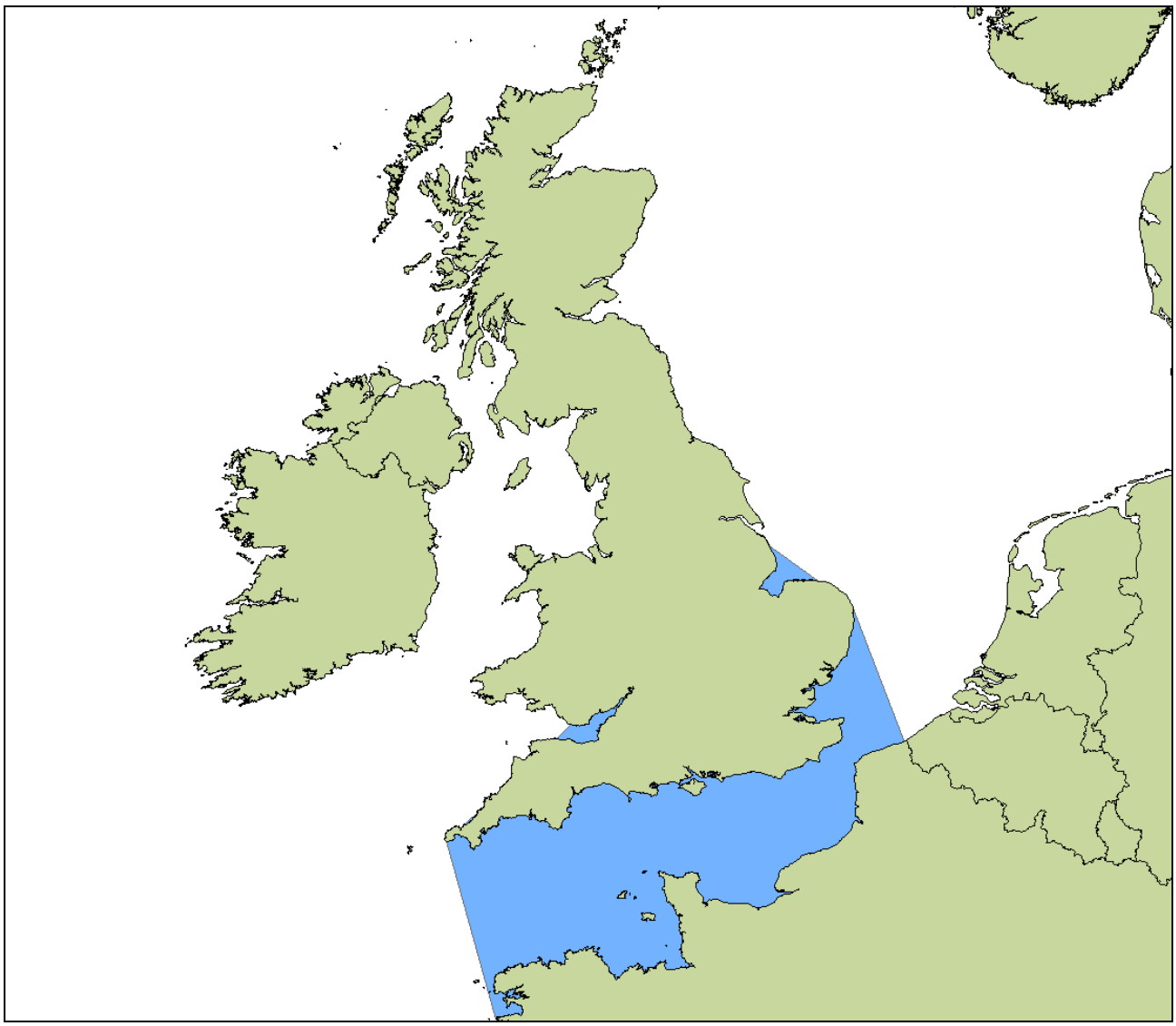


The blue area on this map shows the predicted migration zones potentially used by Hen Harriers that visit the UK during the non-breeding season.

The Hen Harrier is a wide-ranging species, occurring across the Palearctic region. In the UK, birds breed at a number of sites in Scotland, Northern England and Wales. Analysis of recovery data suggests that around half of first year birds remain in the country during winter. Of the remainder, a small proportion may winter in Ireland, but the bulk migrate south-wards, into France and the Iberian Peninsula, crossing the English Channel between Devon and Brittany. A far higher proportion of older birds, up to 75 %, winter within the UK (Wernham *et al.* 2002). During the winter, the population is supplemented by birds from Scandinavia and continental Europe, particularly in response to cold weather. As a high proportion of birds over-winter within the UK and the UK hosts a low proportion of both the breeding and non-breeding populations of the Hen Harrier, further research into the population movements of this species should be a low priority. A precautionary assumption for the purposes of offshore wind farm assessments would be that half of the UK breeding population potentially migrates along the route shown in dark blue in the first map, with up to 100 birds potentially migrating through the pale blue area. The number of birds that visit the UK from the continent in winter is uncertain; therefore we suggest that until better information becomes available, an assumption is made that up to half of the wintering population (i.e. 375 individuals) could potentially be migrants that follow the route shown in the lower map.

Montagu's Harrier *Circus pygargus*

Montagu's Harrier *Circus pygargus*	
SPA Species?	No but ANNEX 1
Population Size (UK)	7 territories
Population Size (International)	35,000-65,000 pairs
Percentage of international population in UK	0.01%

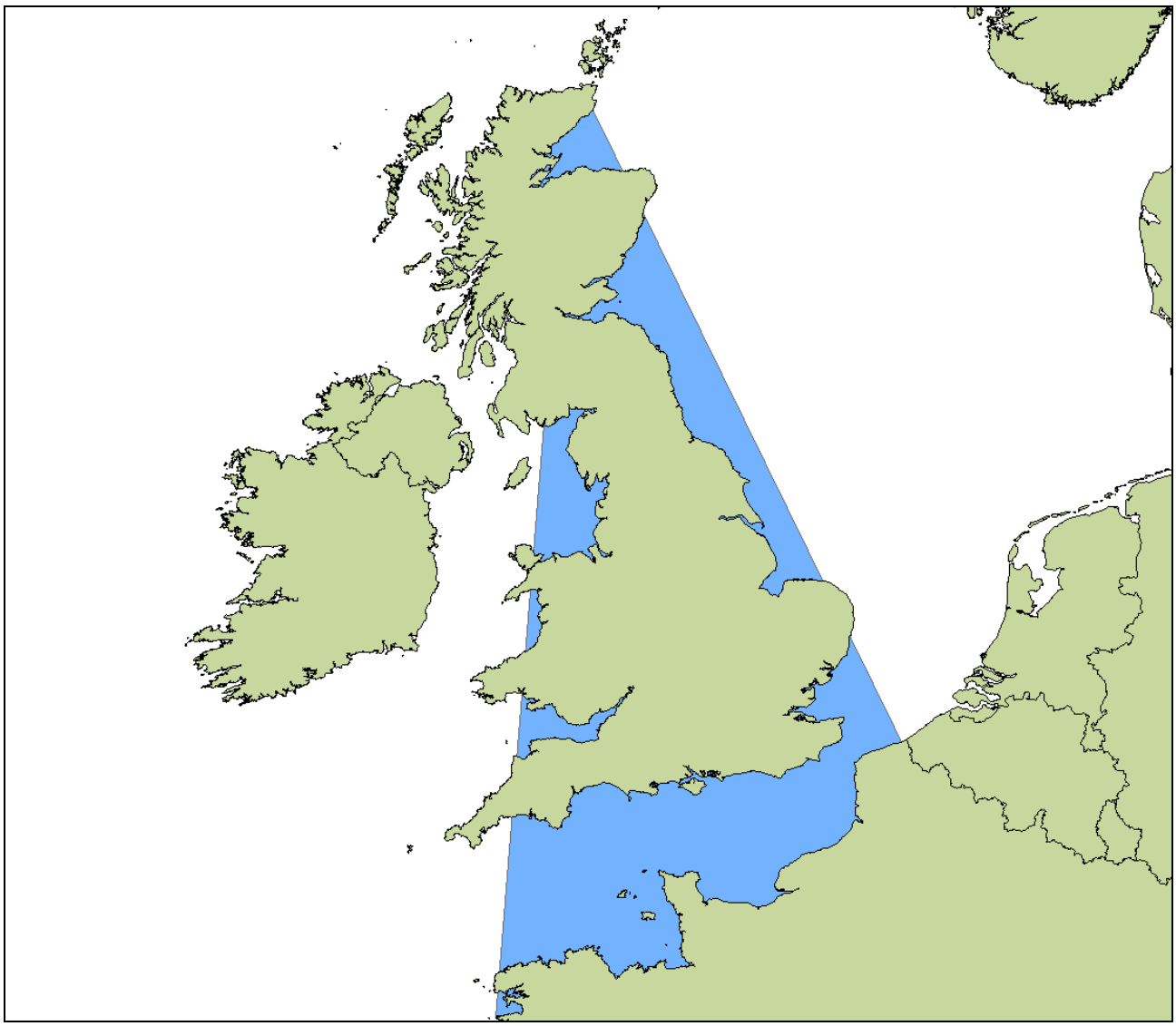


The blue area on this map shows the predicted migration zones potentially used by Montagu's Harriers that breed in the UK.

Montagu's Harrier is more restricted in its range than either the Hen or Marsh Harrier. The North-West European breeding population are wholly migratory, wintering in sub-Saharan Africa. Birds from the UK generally travel in a southerly direction via France and Spain to North-West Africa. The Montagu's Harrier is not a feature of any UK SPAs, and only a small proportion of the international population breeds within the UK.

Osprey *Pandion haliaetus*

Osprey *Pandion haliaetus*	
SPA Species?	Yes (breeding population)
SPA Sites	9 sites in eastern Scotland
Population Size (UK)	148 pairs
Population Size (International)	7,600-11,000 pairs
Percentage of international population in UK	2%

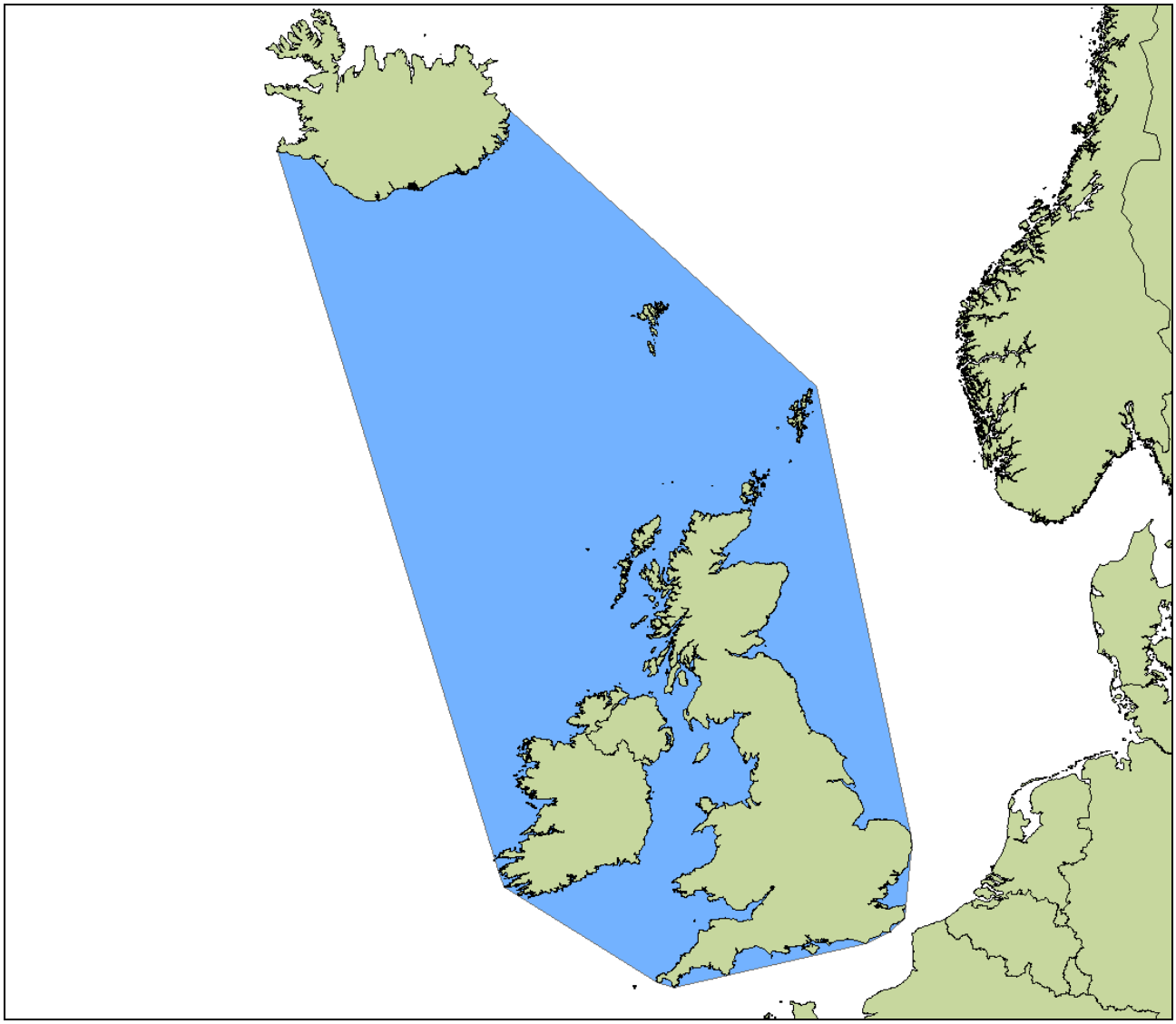


The blue area on this map shows the predicted migration zones potentially used by Ospreys that breed in the UK.

The Osprey is one of the UK's most charismatic bird species, which successfully recolonized the UK during the 1950s. During the breeding season, breeding sites, such as the RSPB's Boat of Garten Reserve are the focus of much media and public attention. It is a migrant species, which returns to its British breeding grounds from Western Africa in late March and early April. Following the end of the breeding season, birds migrate southwards, following a route via France and Spain, crossing into North Africa around Gibraltar (Wernham *et al.* 2002). This species has been the subject of a number of tracking studies, and data from these studies would be valuable in assessing how its migration routes may interact with proposed offshore wind farms.

Merlin *Falco columbarius*

Merlin *Falco columbarius*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 14 sites in northern England, Wales and Scotland. Non-breeding 1 site (Dorset Heathlands)
Population Size (UK)	1,330 pairs
Population Size (International)	31,000-49,000
Percentage of international population in UK	3%



The blue area on this map shows the predicted migration zones potentially used by Merlins that visit the UK during the non-breeding season.

The Merlin is a widespread species with an extensive Holarctic range. Two races, *aesalon* and *subaesalon* occur within the UK. The *aesalon* race breeds from Ireland to northwest Siberia. The majority of these birds remain within the UK throughout the year, typically travelling no more than 68 km (Wernham *et al*. 2002). In contrast, the *subaesalon* race breeds in Iceland, wintering in Britain and Ireland. As the majority of Merlin in the UK during the breeding season remain in the UK throughout the year, further research into the movements of this race should be a low priority. However, as a large proportion of the *subaesalon* race winters in the UK, further research into the movements of this population would be valuable.

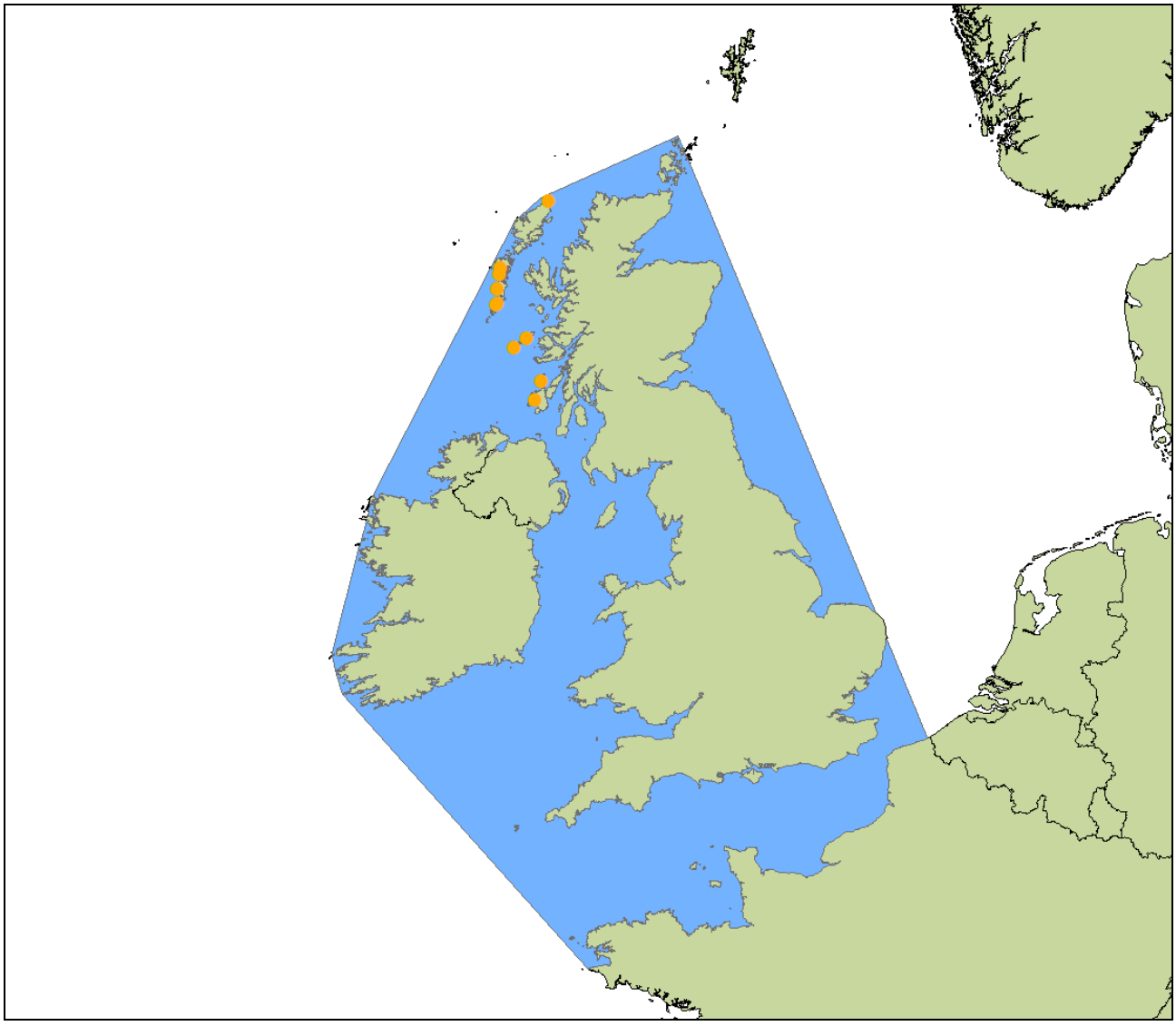
Spotted Crake *Porzana porzana*

Spotted Crake *Porzana porzana*	
SPA Species?	Yes
SPA Sites	3 inland wetlands in East England, 1 in Scotland
Population Size (UK)	73 territorial males
Population Size (International)	120,000–260,000 pairs (Europe)
Percentage of international population in UK	

Spotted Crakes occur in very small numbers in the UK and are features of three SPAs on inland freshwater wetlands. No map has been produced as there is almost no information available regarding their migration routes. However, we know that they must move in a southerly direction towards African wintering grounds. We suggest that the map produced for Corncrake (below) is also used for Spotted Crake until such time as better information becomes available.

Corncrake *Crex crex*

Corncrake *Crex crex*	
SPA Species?	Yes (breeding population)
SPA Sites	10 sites largely in Western Isles (but also Lower Derwent Valley)
Population Size (UK)	589 males
Population Size (International)	1,300,000-2,000,000 pairs
Percentage of international population in UK	0.04%

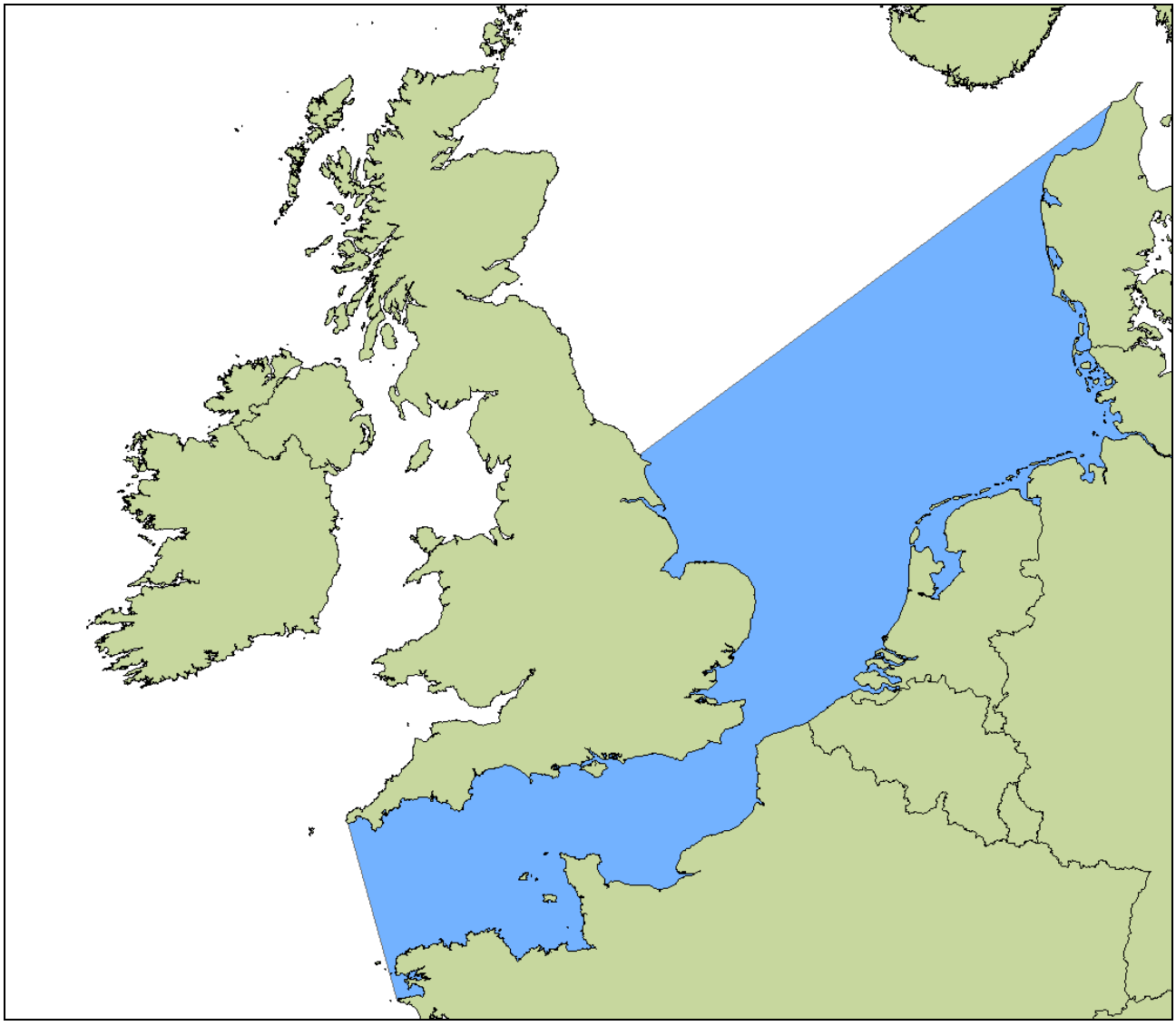


The blue area on this map shows the predicted migration zones potentially used by Corncrakes that breed in the UK, while the orange dots show SPA breeding sites.

Within the UK, the Corncrake is largely restricted to North-West Scotland. It is a largely migratory species, returning to the country at the start of the breeding season in late April. They return to their breeding grounds between late July and early September, typically passing through France and the Iberian Peninsula, before crossing into Africa via Morocco and wintering in sub-Saharan Africa (Wernham *et al*. 2002). Whilst only a small proportion of the international Corncrake population breeds within the UK, it is a feature of a large number of SPAs, consequently, further research into the movements of this species should be a moderate priority. In the meantime, as shown in the map above, a precautionary assumption would be that this species could potentially migrate via most parts of UK waters.

Coot *Fulica atra*

Coot *Fulica atra*	
SPA Species?	Yes (non-breeding population)
SPA Sites	6 sites in eastern England and Northern Ireland
Population Size (GB)	180,000
Population Size (Ireland)	33,160
Population Size (International)	1,750,000 (NW Europe non-breeding)
Percentage of international population in GB & Ireland	12%

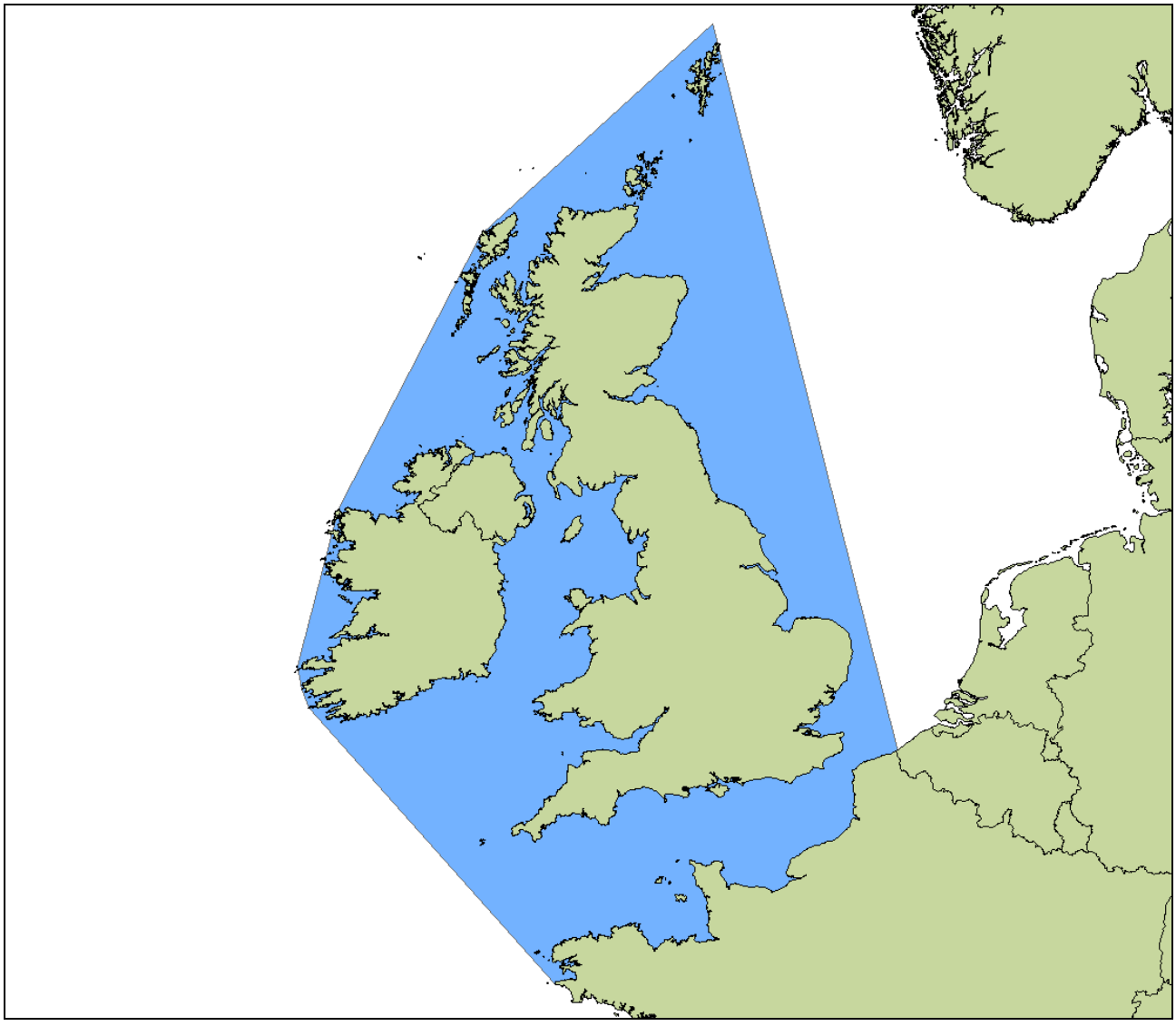


The blue area on this map shows the predicted migration zones potentially used by Coots that visit Britain during the non-breeding season.

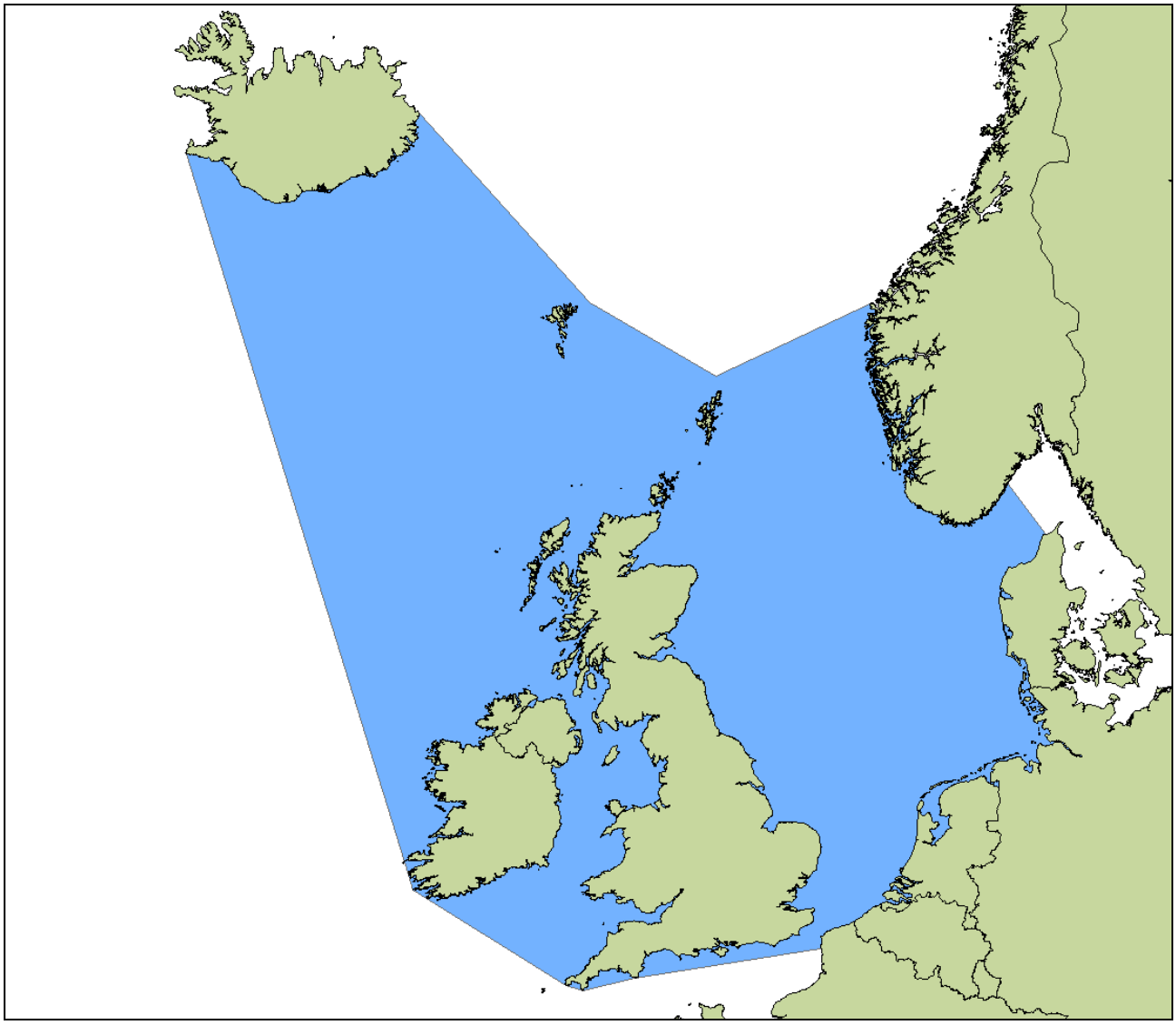
The Common Coot is a common and widespread species within the UK. Analysis of ringing recoveries reveals that Common Coots are largely sedentary within the UK, with some individuals remaining on the same waterbodies all year round (Wernham et al. 2002). Over winter, there is some evidence of a movement of birds into the UK from the Baltic, North Sea and North French coast. As the UK breeding population of Common Coot is largely sedentary and evidence of population movements into the country over winter is limited, further research into the movements of this species is a low priority. The numbers of birds following the route shown in the map above to wintering sites in Britain is unknown.

Oystercatcher *Haematopus ostralegus*

Oystercatcher *Haematopus ostralegus*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 3 sites in Western Isles
	Non-breeding 30 sites in various coastal areas
Population Size (GB)	113,000 pairs (breeding)
	320,000 individuals (non-breeding)
Population Size (Ireland)	67,620 individuals (non-breeding)
Population Size (International)	820,000 (*ostralegus*, N, W and central Europe)
Percentage of international population in GB & Ireland	28% (breeding)
	47% (non-breeding)



The blue area on this map shows the predicted migration zones potentially used by Oystercatchers that breed in the UK.



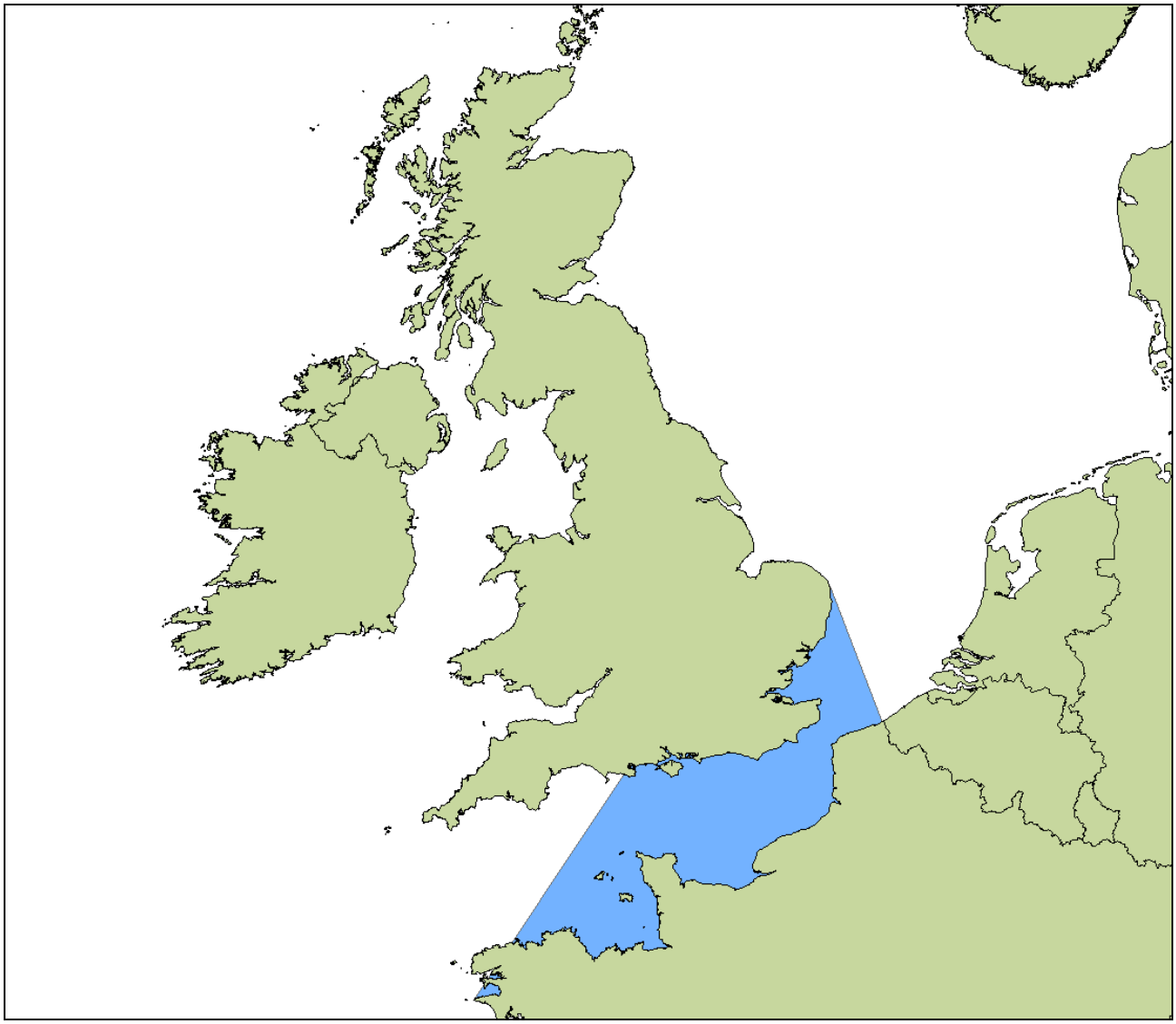
The blue area on this map shows the predicted migration zones potentially used by Oystercatchers that visit the UK during the non-breeding season.

The British breeding population of Oystercatchers has a tendency to move south in the non-breeding season, with birds in the north of Britain generally moving furthest. These movements take some birds across the Irish Sea or English Channel to France, Spain or Ireland, but many breeding birds, especially adults, will remain as residents in the UK throughout the winter. We therefore suggest that assessments for offshore wind farms could assume that half of the breeding population could potentially migrate across the routes shown in the first map. However, in the non-breeding season there is a large influx of Oystercatchers to Britain and Ireland from Norway, Iceland, the Faroe Islands and the Low Countries, with at least 200,000 additional birds migrating into the UK. Birds in the east of the UK in winter mostly come from Norway or the Low Countries, those in Ireland come from Iceland and the Faroe Islands, while those wintering elsewhere in the UK come from both directions. Most of these birds arrive in the UK in August or September and adults return to breeding areas in spring while immature birds remain at wintering sites throughout the year. Non-breeding populations of Oystercatchers form designated features of 30 different SPAs all around the coast of the UK, which supports 31% of the *ostralegus* population during the non-breeding season. Although the start- and end-points of migrations are relatively well known from ringing recoveries, and indicate that birds could migrate across almost any parts of UK waters, the exact routes followed by migrating Oystercatchers are not known. It would therefore be extremely valuable to conduct further research, perhaps involving tracking studies, to better understand Oystercatcher migration routes,

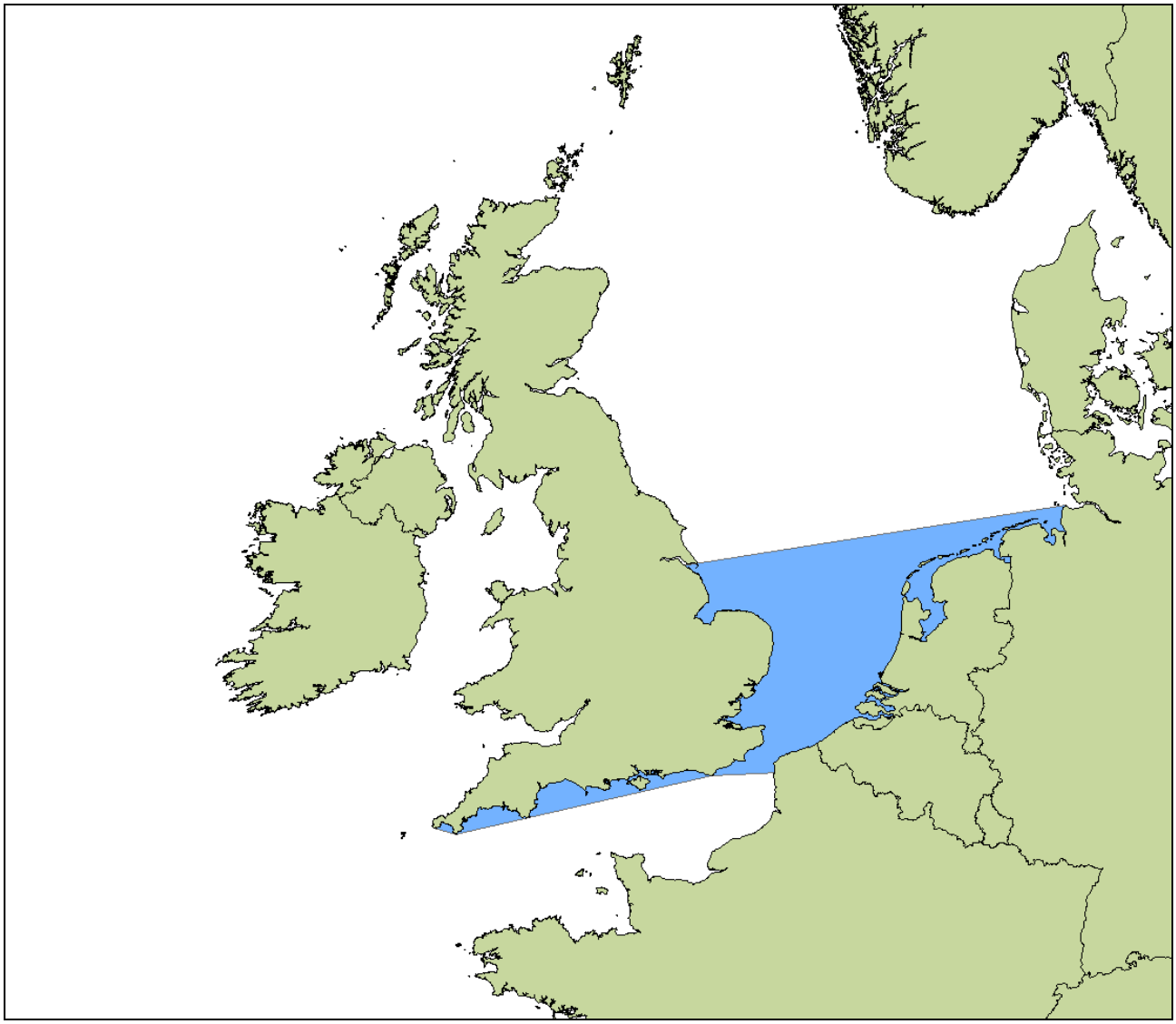
timings and flight heights. Internationally important numbers migrate across UK waters the current lack of understanding of migration routes and flight heights could pose a risk to consenting for offshore wind farms if the precautionary approach is adopted. Further research is thus a very high priority.

Avocet *Recurvirostra avosetta*

Avocet *Recurvirostra avosetta*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 6 coastal sites in SE England
	Non-breeding 16 coastal sites in S/SE England
Population Size (GB)	877 (breeding)
	7,500 (non-breeding)
Population Size (International)	73,000 (W Europe breeding)
Percentage of international population in GB	1% (breeding)
	10% (non-breeding)



The blue area on this map shows the predicted migration zones potentially used by Avocets that breed in the UK.

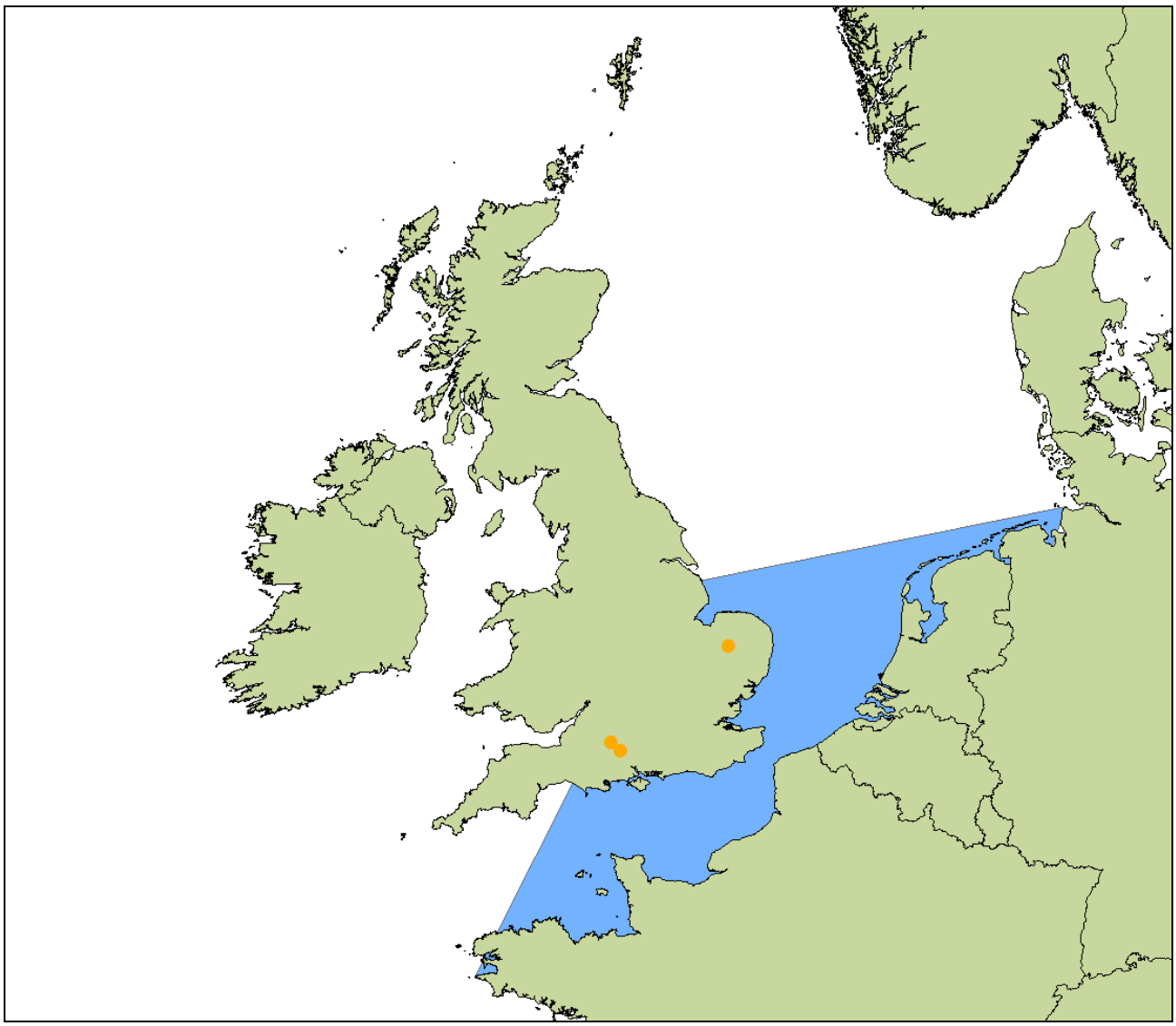


The blue area on this map shows the predicted migration zones potentially used by Avocets that visit the UK during the non-breeding season.

Avocets in the UK are concentrated on the south and east coasts of England throughout the year. In winter, there is an influx of birds from the Low Countries in addition to resident breeders (Holt *et al*. 2012). Some birds from the UK migrate south to sites in France, Iberia or North Africa. Key migration times are July-November and mid-March-mid-April (Wernham *et al*. 2002). Precise migration routes and timings are, however unknown. As Avocet is a feature of several SPAs, further research on this species would be useful, but it is not as high a priority as some other species such as Oystercatcher. The maps above show the potential extent of migration routes used by both breeding and wintering birds. As the proportion of the breeding population that migrates is unknown (though we think it is not all of them) a precautionary assumption could be to presume that the entire breeding population migrates along the migration route shown in the first map, and that the entire wintering population migrates along the route shown in the second map. This is likely to overestimate the numbers following each route, but numbers are still relatively low compared to some species.

Stone-curlew *Burhinus oedicnemus*

Stone-curlew *Burhinus oedicnemus*	
SPA Species?	Yes (breeding population)
SPA Sites	3 sites (Breckland, Porton Down, Salisbury Plain)
Population Size (GB)	347 pairs
Population Size (International)	110,000-170,000 (W Europe breeding)
Percentage of international population in GB	0.5%



The blue area on this map shows the predicted migration zones potentially used by Stone Curlews that visit the Britain during the breeding season. The orange dots show the three SPA breeding sites for this species.

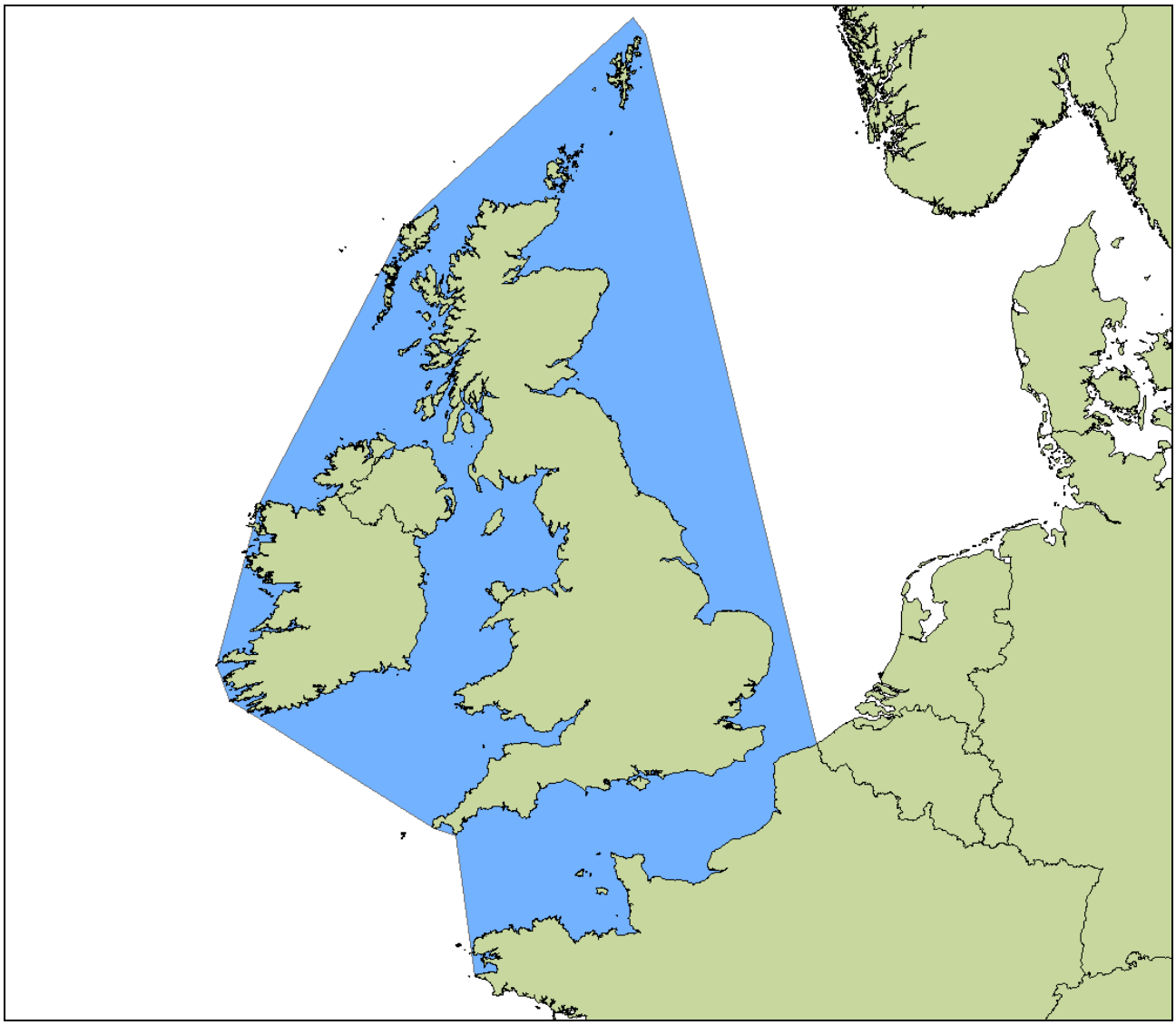
All Stone-curlews that breed in the UK are migratory, moving south to the Mediterranean and West Africa during winter. There are three key populations in southern and eastern England, represented by the three SPAs for Stone-curlew in Breckland, Porton Down and Salisbury Plain. Ringing recoveries indicate that the majority of UK Stone-curlews probably cross the English Channel to France in autumn (mainly October) before continuing southwards. However, they may follow a more easterly route across the southern North Sea on return migration in spring, as indicated by recoveries and sightings of colour-ringed birds in the Netherlands and Belgium at this time. There is no indication of significant passage of Stone-curlews from breeding sites elsewhere in Europe across UK waters. Understanding of precise migration routes and timings could be improved, perhaps using satellite telemetry. However Stone-curlew migration routes and

timings are already better understood than some other species thanks to intensive colour-ringing studies. It should be considered in assessments for offshore wind farm developments in the English Channel or southern North Sea from Norfolk southwards.

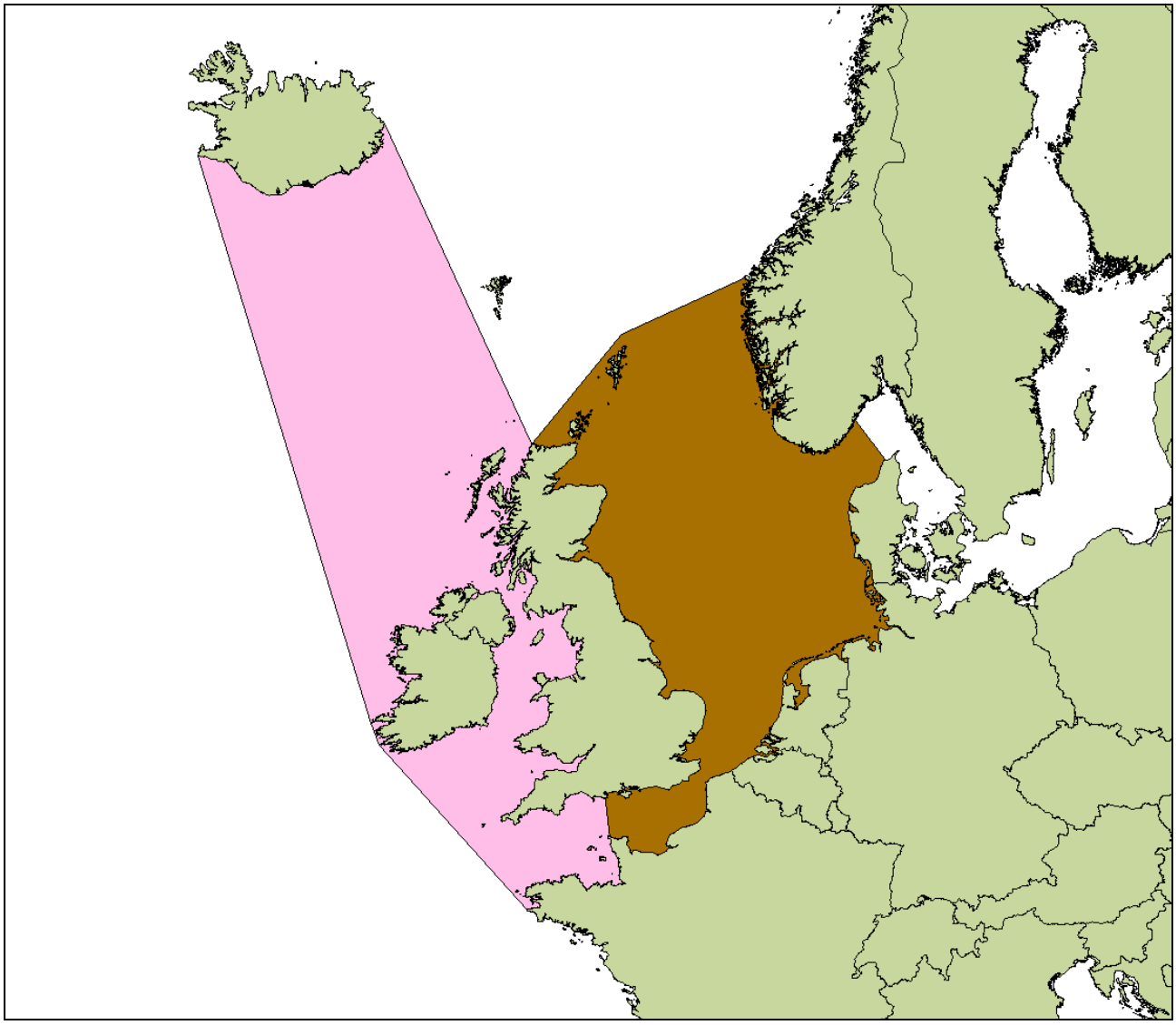
Ringed Plover *Charadrius hiaticula*

Ringed Plover *Charadrius hiaticula*	
SPA Species?	Yes (breeding and non-breeding (winter and passage) populations)
SPA Sites	Breeding season 5 sites (Scottish islands and North Norfolk coast) Non-breeding 28 wintering or passage sites in various coastal areas
Population Size (GB)	5,438 pairs (breeding)[1] 34,000 (non-breeding)
Population Size (Ireland)	14,580 (non-breeding)
Population Size (International)	73,000 (Europe & N Africa non-breeding)
Percentage of international population in GB and Ireland	15% (breeding) 67% (non-breeding)

[1]Population estimate from Conway *et al*. 2008.



The blue area on this map shows the predicted migration zones potentially used by Ringed Plovers that breed in the UK.



The pink area on this map shows the predicted main migration zone used by passage populations of Ringed Plover in both spring and autumn, while the brown area shows the additional zone used by some of these birds in autumn only. Birds of the subspecies *tundrea* are not marked here, but they can be found on the east coast in spring.

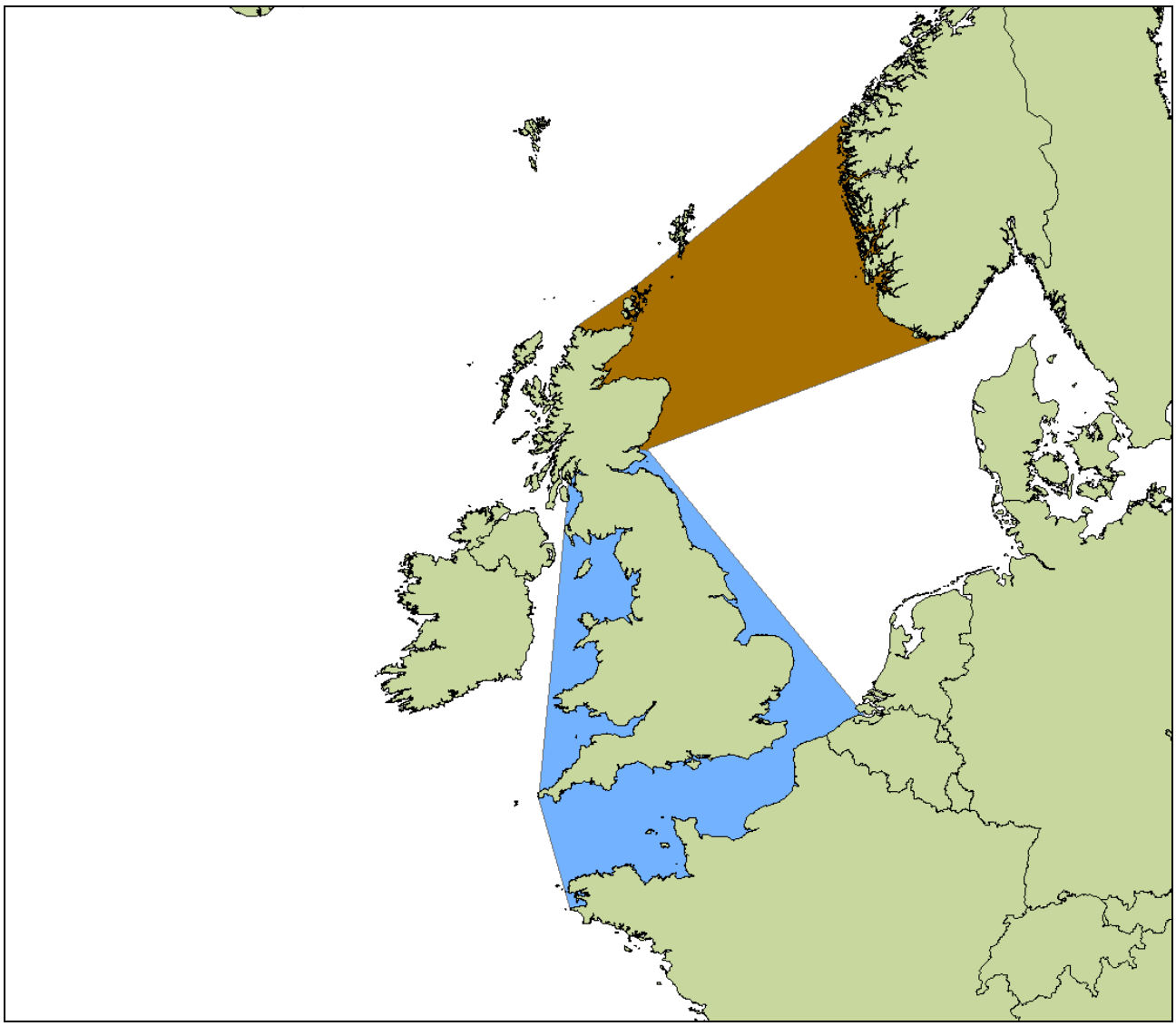
Ringed Plovers in the UK come from populations with two distinct migration strategies. Birds that breed in the UK often make relatively small movements between breeding and wintering sites, with many remaining in the UK, and some crossing either the Irish Sea or English Channel to wintering sites in Ireland or France, as shown in the first map above.

Conversely, a very large number of birds pass across the UK and Ireland (concentrated in the Irish Sea) on long-distance migrations between breeding sites in arctic Canada, Greenland, Iceland and Scandinavia and wintering sites in Spain and West Africa. In spring, these birds may cross the sea to stopover sites on the west coasts of the UK any time between February and May, while autumn migration takes place mainly in August and occurs on both the west and east coasts of the UK, indicating passage across the North Sea as well as the Irish Sea. Birds from the east coast of the UK tend to breed in Scandinavia, while those from the west coast tend to breed in Iceland or Greenland. The UK is an extremely important stopover site for this species, and the numbers migrating across UK waters are probably underestimated by the figures in the tables above, as there will be significant turnover. It would be prudent to assume that the entire international population could potentially follow the routes shown in the second map during passage

migration. Further study of the precise migration routes of this species would therefore be particularly valuable, but tracking methods that generate accurate locations and altitudes will not be possible on this species as the technology is not yet small enough. Until better information regarding migration routes of this species is available, it is important to consider it in assessments for offshore wind farms in all parts of UK waters, assuming that the entire population is distributed across the route shown in pink in spring, and distributed across the route shown in pink and brown combined in autumn.

Dotterel *Charadrius morinellus*

Dotterel *Charadrius morinellus*	
SPA Species?	Yes (breeding population)
SPA Sites	8 sites in northern Scotland
Population Size (GB)	510-750
Population Size (International)	40,000-120,000 (Europe breeding)
Percentage of international population in GB	0.8%



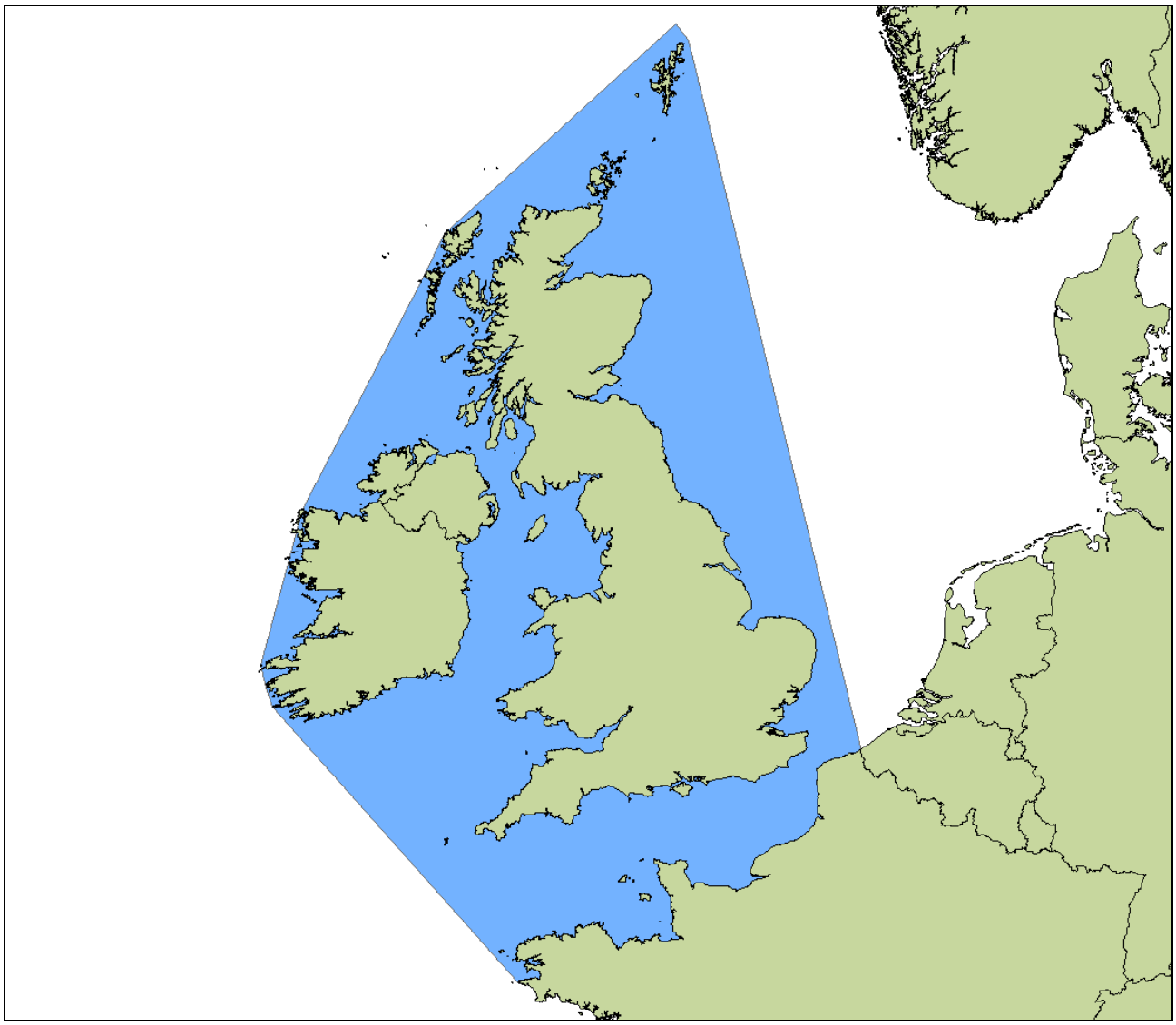
The blue area on this map shows the predicted migration zones potentially used by Dotterel that breed in Britain. The brown area shows the route used by some birds for movements between Scottish and Norwegian breeding grounds during the breeding season.

Dotterel breed throughout much of the Palearctic but Britain is the western limit of their breeding range. British breeding birds migrate southwards to Morocco during the winter. Spring passage across temperate Western Europe occurs between mid-April and late May on a broad overland front (Whitfield *et al*. 1996; Wernham *et al*. 2002) but with most birds arriving at Scottish breeding sites in early May. Some movements of both male and female birds between Scottish and Norwegian breeding grounds can occur during the breeding season (May-July), with small numbers (tens or low hundreds) of birds presumably crossing the northern North Sea at this time. Birds disperse around the Scottish Highlands prior to migrating and the majority of longer distance migratory movement southwards and out of the UK probably occurs in

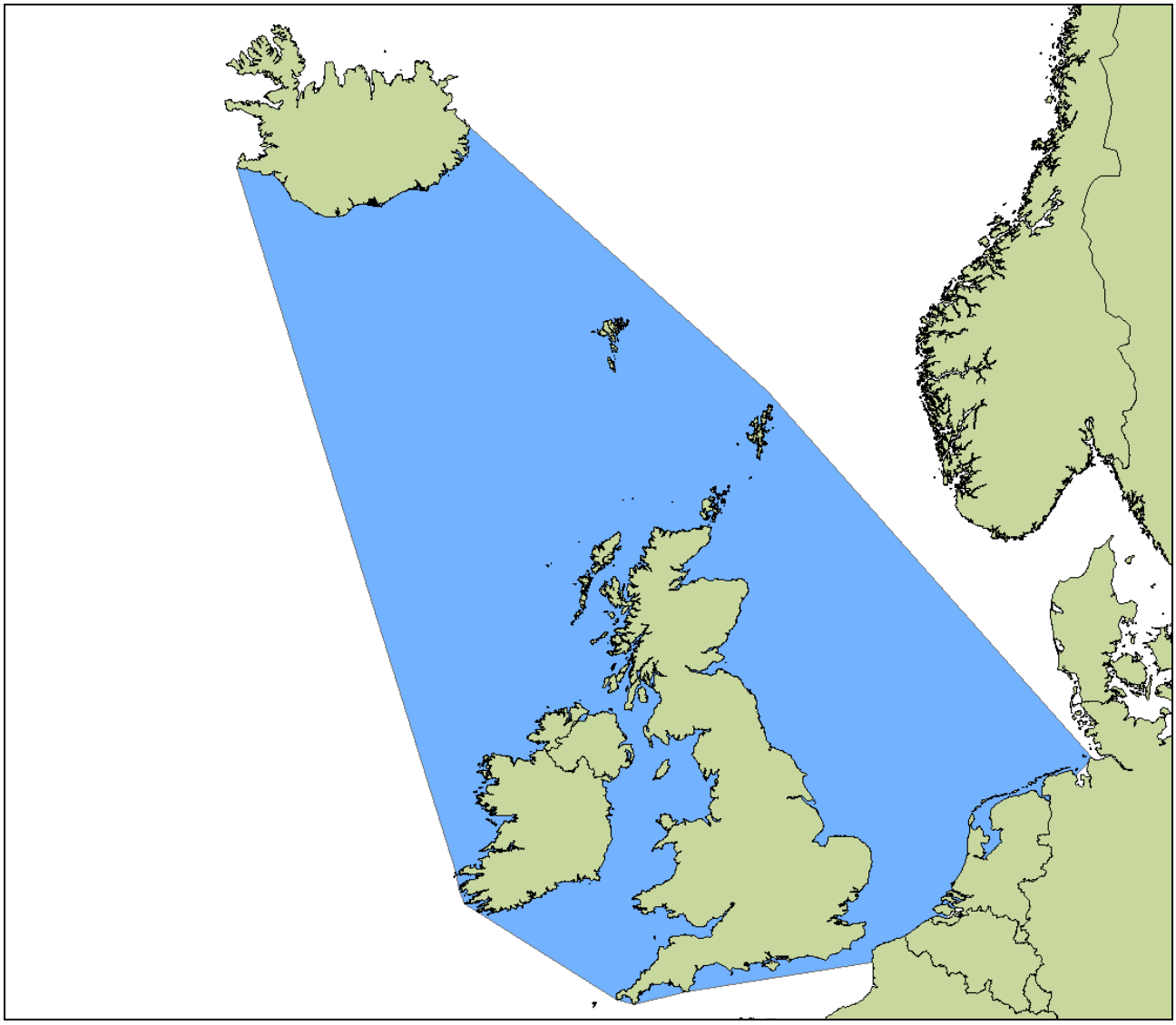
September and October possibly via the south-west of the country. Although there is a reasonably good high-level knowledge of migration patterns of this species, details of the routes these birds take across UK waters, the times at which sea crossings occur and the numbers of birds involved, are not known.

Golden Plover *Pluvialis apricaria*

Golden Plover *Pluvialis apricaria*	
SPA Species?	Yes (breeding and non-breeding)
SPA Sites	Breeding season 7 sites in northern England, Scotland and Northern Ireland Non-breeding 22 sites in various coastal areas
Population Size (GB)	22,600 pairs (breeding) 400,000 (non-breeding)
Population Size (Ireland)	166,700 (non-breeding)
Population Size (International)	140,000-210,000 (*apricaria*, NW Europe breeding) 930,000 (*altifrons*, Iceland and Faeroes breeding) 500,000-1,000,000 (*altifrons*, N Europe & Siberia breeding)
Percentage of international population in GB & Ireland	26% of *apricaria* population (breeding) 29-36% of three populations combined (non-breeding)



The blue area on this map shows the predicted migration zones potentially used by Golden Plovers that breed in the UK.

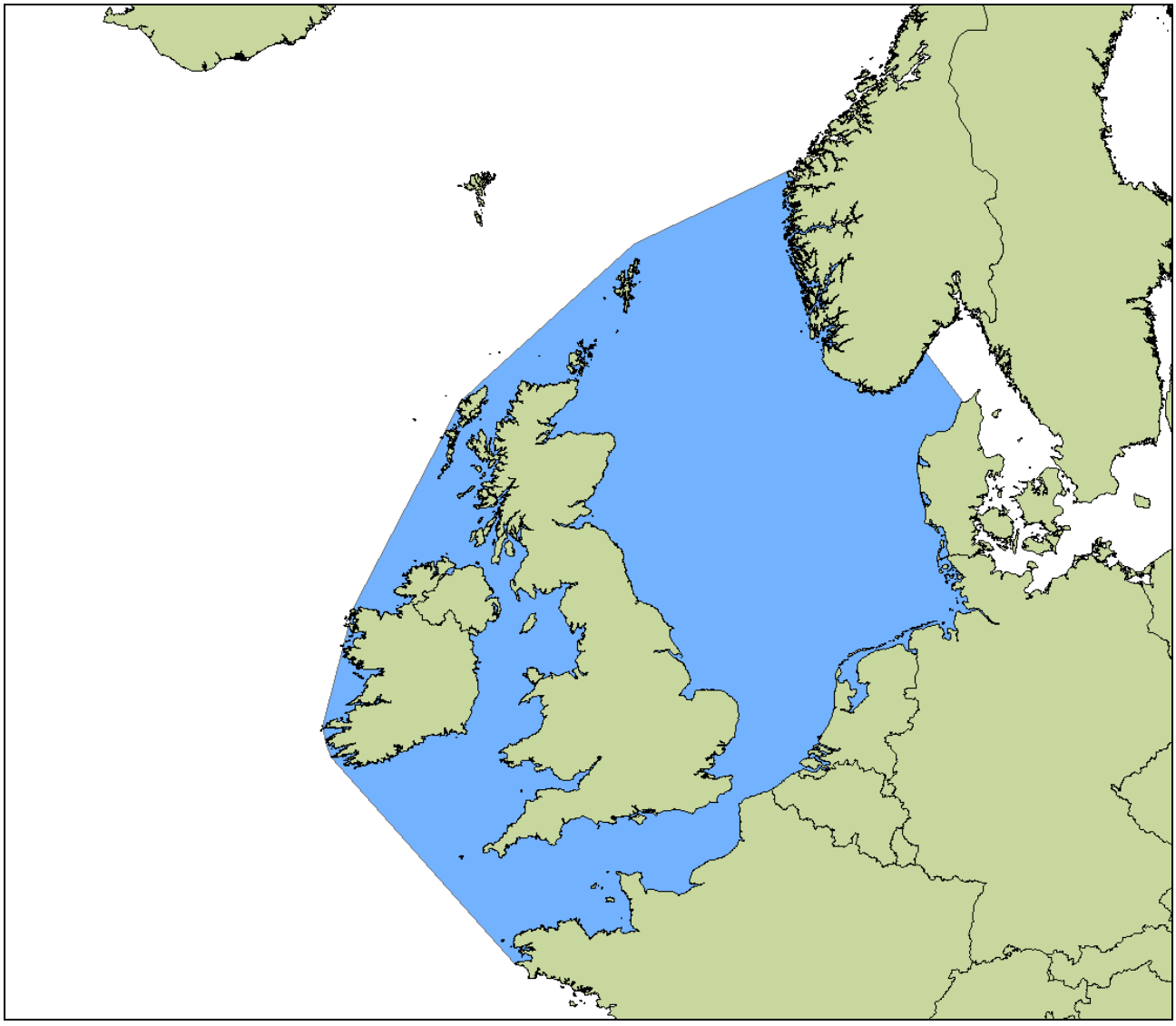


The blue area on this map shows the predicted migration zones potentially used by Golden Plovers that visit the UK during the non-breeding season.

Only the nominate race of Golden Plover breeds in the UK, but in winter three populations occur, with influxes of birds from Iceland and the Faeroes to Ireland and western Britain and from northern mainland Europe to eastern Britain (mostly via the Netherlands on passage). Some British breeders stay in the UK for the winter but others may migrate southwards to France, Iberia or North Africa (Wernham *et al*. 2000). This combination of three different populations moving in different directions mean that Golden Plovers could potentially be migrating across almost any UK waters. Birds migrating from the west coast and Ireland to Iceland are likely to pass across the Irish Sea and to the west and north of Scotland, those migrating from mainland Europe migrate across the North Sea (probably mostly the southern part of the UK between the Netherlands and the south-east coast of Britain), and those breeding in the UK probably migrate across the English Channel. Autumn migration occurs soon after chicks have left the nest, from late June until September, and most birds return to breeding grounds in the UK by February. However, birds may move long distances, potentially crossing the sea, at any time during the winter in response to harsh weather (Wernham *et al*. 2002). As the species is a feature of a number of SPAs in the UK, and fairly large proportions of these three populations migrate across UK waters, further work to improve understanding of migration routes, and in particular the relative numbers following each of the routes, would be valuable.

Grey Plover *Pluvialis squatarola*

Grey Plover *Pluvialis squatarola*	
SPA Species?	Yes (non-breeding)
SPA Sites	28 sites in various coastal areas
Population Size (GB)	43,000
Population Size (Ireland)	6,315
Population Size (International)	250,000 (East Atlantic non-breeding)
Percentage of international population in GB & Ireland	20%



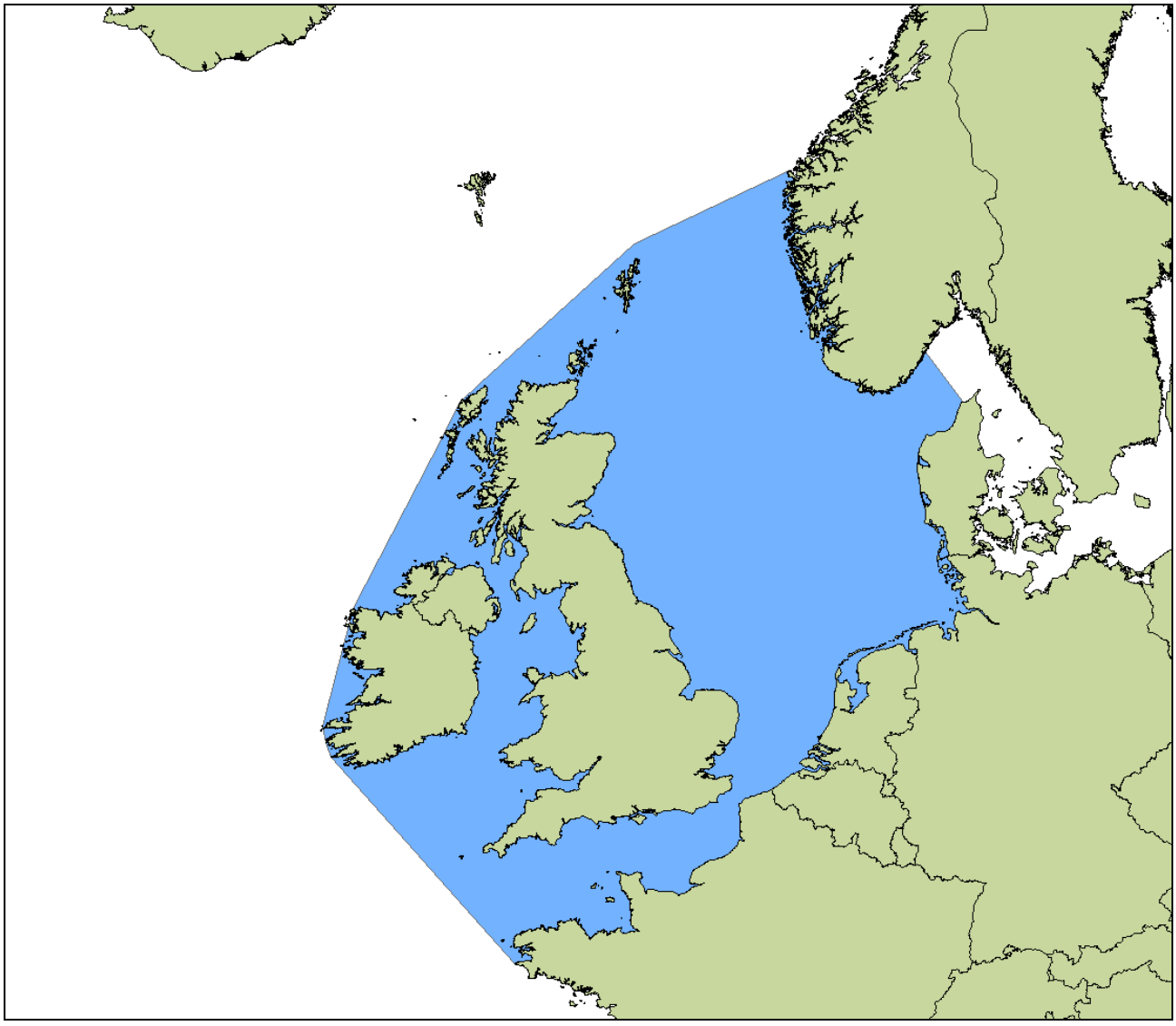
The blue area on this map shows the predicted migration zones potentially used by Grey Plovers that are features of SPA wintering sites in Britain and Ireland.

Grey Plovers occur as both passage migrants and winter visitors to coastal areas of the UK, with all birds coming from the Russian breeding populations (Wernham *et al*. 2002). Passage birds winter around the coasts of southwest Europe and northwest Africa. Autumn arrivals to the UK (presumably mainly involving crossings of the North Sea as birds come from the east) begin in late July and continue until October, but with a peak during September. Ringing recoveries indicate that the coast of Denmark is an important staging area for birds on their way to the UK in the autumn. Numbers subsequently decline during October and November as passage populations move out of the UK to the south and west, presumably flying across the English Channel at this time. There may be further movements of birds later in the winter, for example

between the Netherlands and the East Coast of the UK, but these probably involve smaller numbers of birds than the main autumn migration. Spring migration occurs from March, when passage birds arrive in the UK presumably crossing the English Channel again. WeBS counts demonstrate that numbers in the UK remain high until May suggesting that many passage and wintering birds remain in the UK until May at which point they migrate (presumably across the North Sea) to breeding sites to the east and north (Wernham *et al*. 2002).

Lapwing *Vanellus vanellus*

Lapwing *Vanellus vanellus*	
SPA Species?	Yes (non-breeding)
SPA Sites	37 sites in widespread coastal and inland areas
Population Size (GB)	620,000 (non-breeding)
Population Size (Ireland)	207,700 (non-breeding)
Population Size (International)	5,500,000-9,500,000 (Europe & W Asia breeding)
Percentage of international population in GB & Ireland	9-15%



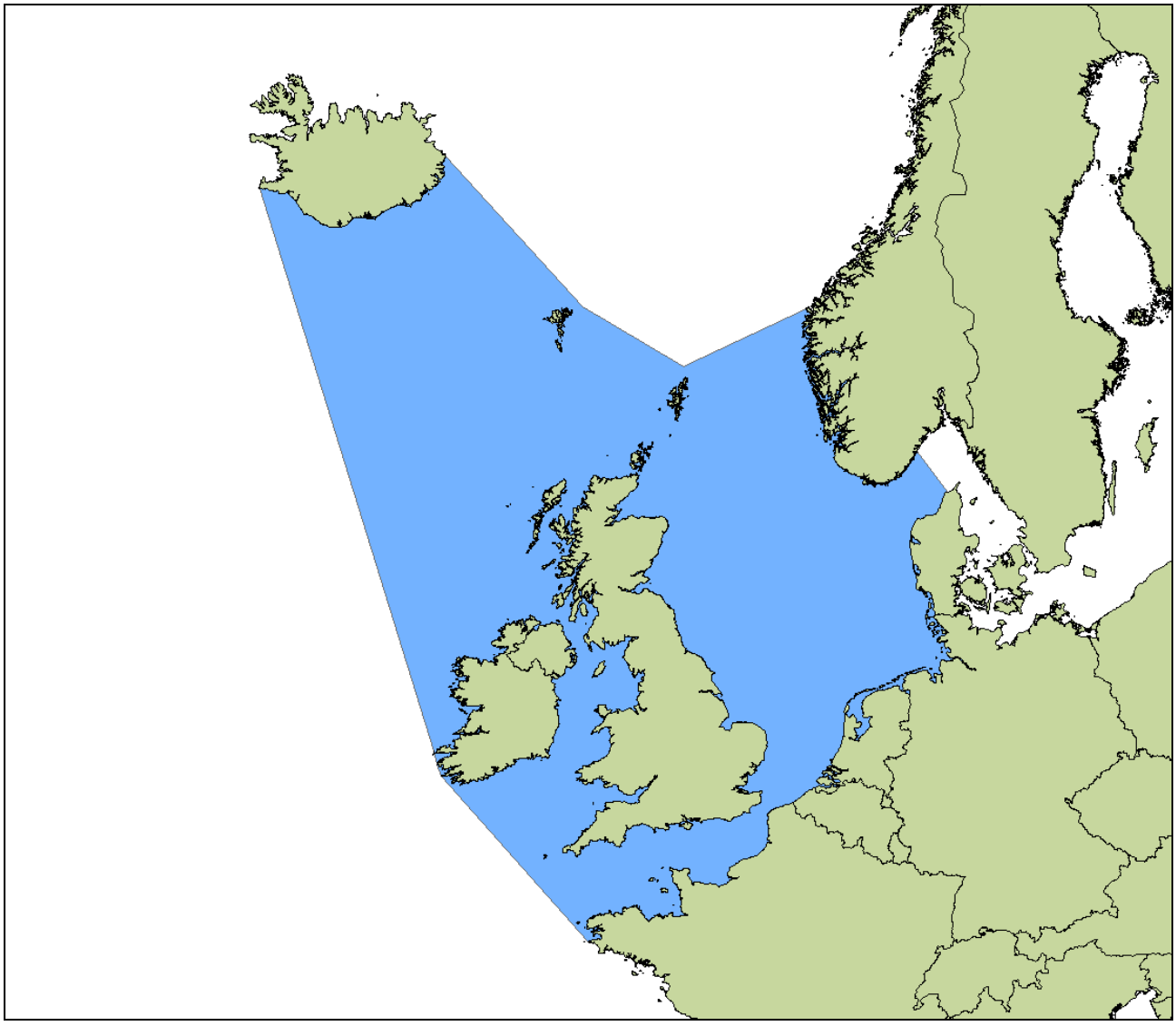
The blue area on this map shows the predicted migration zones potentially used by Lapwings that visit the UK during the non-breeding season.

Ringing recoveries suggest that British breeding Lapwings migrate mainly to the west, across the Irish Sea, and southwest across the English Channel to western France and Iberia, though the British breeding population is only partially migratory with many birds remaining close to breeding sites during the winter. During the non-breeding season, Lapwings migrate to the UK from late May, but with the majority of arrivals between late-September and early-November. In some years there may be substantial further movements during the winter as birds move south and west during periods of cold weather. Return migration in spring takes place mainly from March to May, with birds moving north-east and crossing the Irish Sea, North Sea or parts of the English Channel to move back to Britain from Ireland, or to continental

Europe from Britain. Many SPAs are designated for non-breeding Lapwings in the UK, and these are widespread throughout the country in both coastal and inland areas. Improved understanding of the precise migration routes of Lapwing and their timings might reduce the risk to consenting from this species, and thus is a medium to high priority.

Knot *Calidris canutus*

Knot *Calidris canutus*	
SPA Species?	Yes (non-breeding)
SPA Sites	25 sites in various coastal areas
Population Size (GB)	320,000
Population Size (Ireland)	18,970
Population Size (International)	450,000 (*islandica*)
Percentage of international population in GB & Ireland	75%



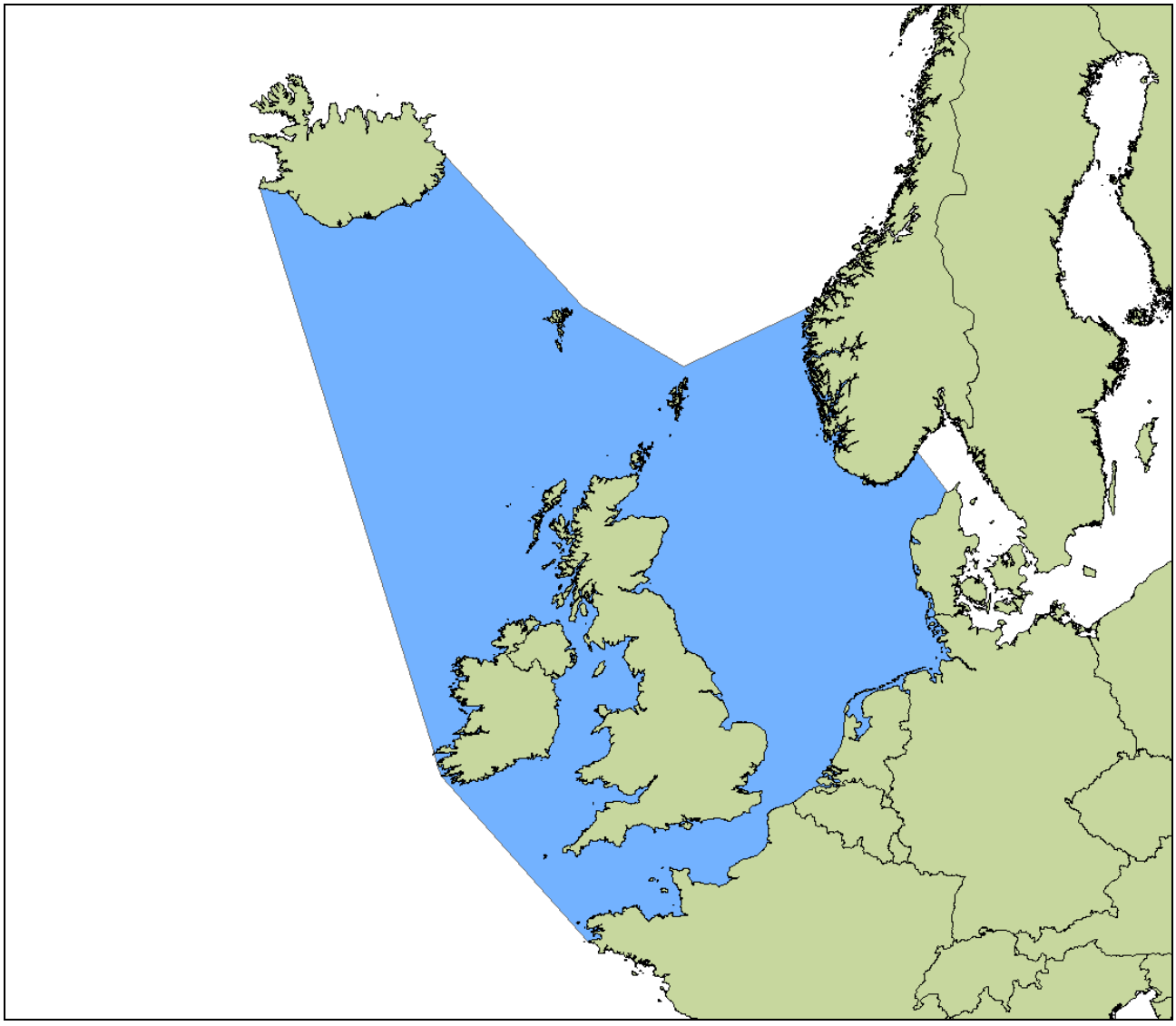
The blue area on this map shows the predicted migration zones potentially used by Knot that visit Britain and Ireland during the non-breeding season.

Knots that occur in Britain and Ireland are almost all of the race *islandica* though a smaller number of the nominate race (*canutus*) may occur occasionally on passage migration. They breed in the high Arctic (northern Greenland and Canadian islands) and migrate via staging sites in Iceland or Norway in autumn to wintering sites on large estuaries in western Europe, returning north to the breeding grounds via Iceland or northern Norway in spring, with some birds also staging at sites in the Wadden Sea in autumn or spring (Wernham *et al*. 2002). The UK is internationally important both as a wintering site and as a staging site in spring and autumn, supporting more than 70% of the *islandica* population, and with 25 estuaries designated as SPAs for this species. Large concentrations of moulting birds occur in autumn on the Wash,

Dee, Ribble and in Morecambe Bay. Autumn passage migration and arrivals of wintering birds across UK waters occurs from mid-July to September, but with the majority of arrivals in August (adults) or September (juveniles). Birds migrating between the UK and breeding grounds could travel across UK waters to either the west, east or north of mainland Britain depending on the route they take (via Iceland, Norway and/or the Wadden Sea), and the English Channel is also likely to be crossed by many birds that winter in France or further south. Further movements of birds between passage or moulting sites and wintering sites occurs between October and December, with many birds moving across the North Sea between the Wadden Sea and the UK, or across the English Channel between the UK and France. There are also considerable movements between estuaries within the UK at this time, with birds tending to move towards the north and west. In March, many birds (more than half of the British wintering population) move eastwards across the North Sea to staging sites in the Wadden Sea, but some remain in Britain congregating on large estuaries such as the Wash and Morecambe Bay. The majority of spring departures northwards for the breeding grounds occur in the first two weeks of May, and birds could be passing over the sea almost anywhere around the UK at this time, though probably with concentrations in particular areas where birds have departed from large estuaries. Although the timing and destinations of migrating Knot are relatively well known, we do not know precise details of the routes taken across the sea around the UK. Further research could be valuable to improve this understanding and thus reduce the risk to consenting posed by the current lack of information regarding where these birds cross the sea.

Sanderling *Calidris alba*

Sanderling *Calidris alba*	
SPA Species?	Yes (non-breeding – winter and passage)
SPA Sites	11 sites in various coastal areas
Population Size (GB)	16,000
Population Size (Ireland)	6,680
Population Size (International)	120,000 (E Atlantic non-breeding)
Percentage of international population in GB & Ireland	19%



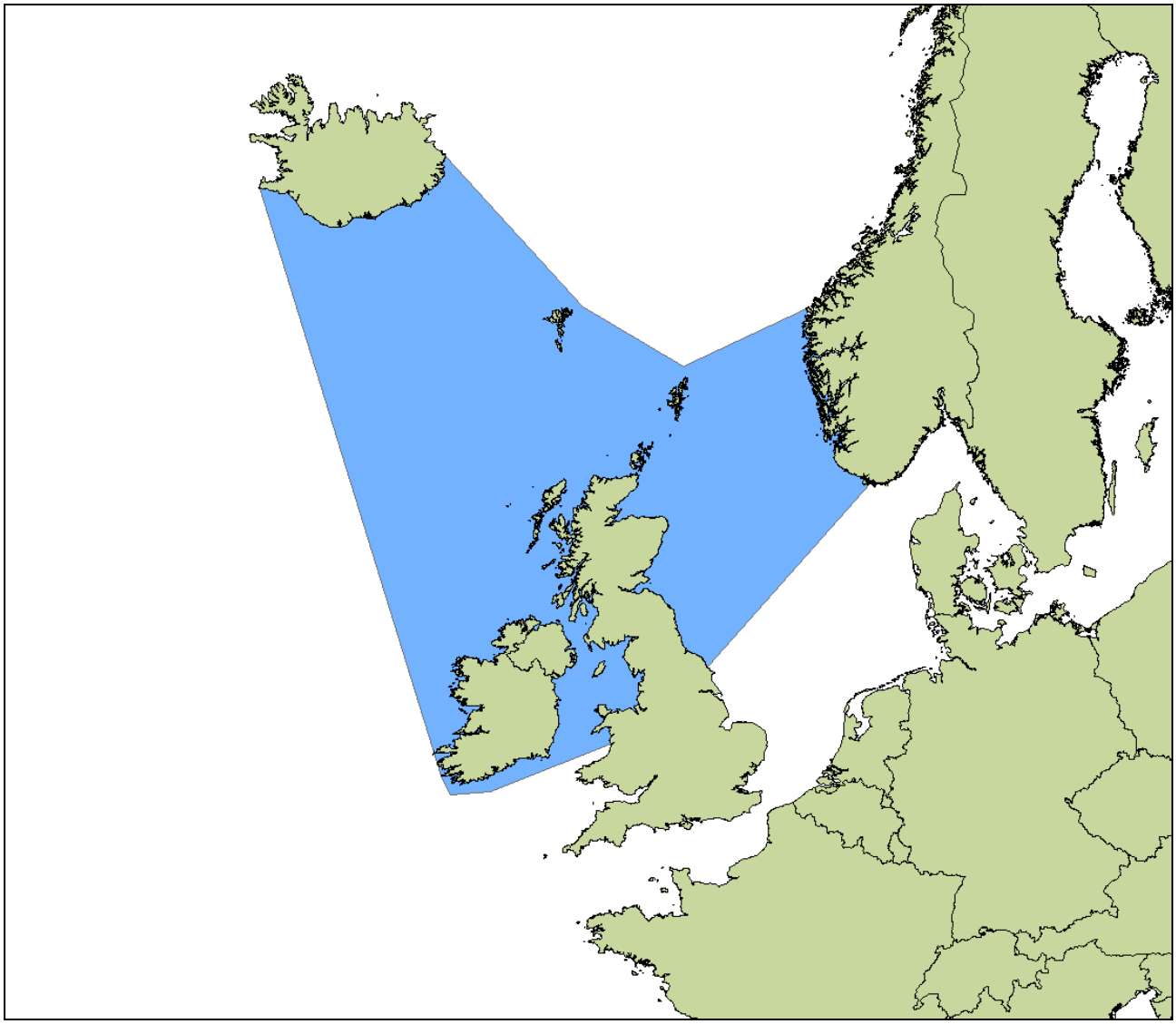
The blue area on this map shows the predicted migration zones potentially used by Sanderling that visit the Britain and Ireland during the non-breeding season.

Large numbers of Sanderling pass through staging and moulting sites on UK estuaries in spring and autumn, on passage migration from high-arctic breeding grounds to wintering sites further south in Europe or in West Africa. Britain is also an important wintering area for the species. Autumn passage migration occurs between late July and October, with further movements in October and November after birds have moulted. Estuaries along the east coast of the UK are important autumn stopover sites. In spring, both the west and east coasts of the UK host large numbers of passage birds, with spring migration lasting from late March until May (Wernham *et al*. 2002). The precise routes taken by Sanderling across the seas around the UK are not known. Birds could potentially pass over the sea almost anywhere around the UK, though

probably with concentrations in particular areas on routes to or from large estuaries. As the UK supports internationally important populations of this species, further research would be valuable to reduce the risk to consenting posed by the current lack of information regarding where these birds cross the sea.

Purple Sandpiper *Calidris maritima*

Purple Sandpiper *Calidris maritime*	
SPA Species?	Yes (non-breeding)
SPA Sites	3 sites in Scottish islands and NE England
Population Size (GB)	13,000
Population Size (Ireland)	3,330
Population Size (International)	50,000-100,000 (*maritima* E Atlantic non-breeding)
Percentage of international population in GB & Ireland	16-33%

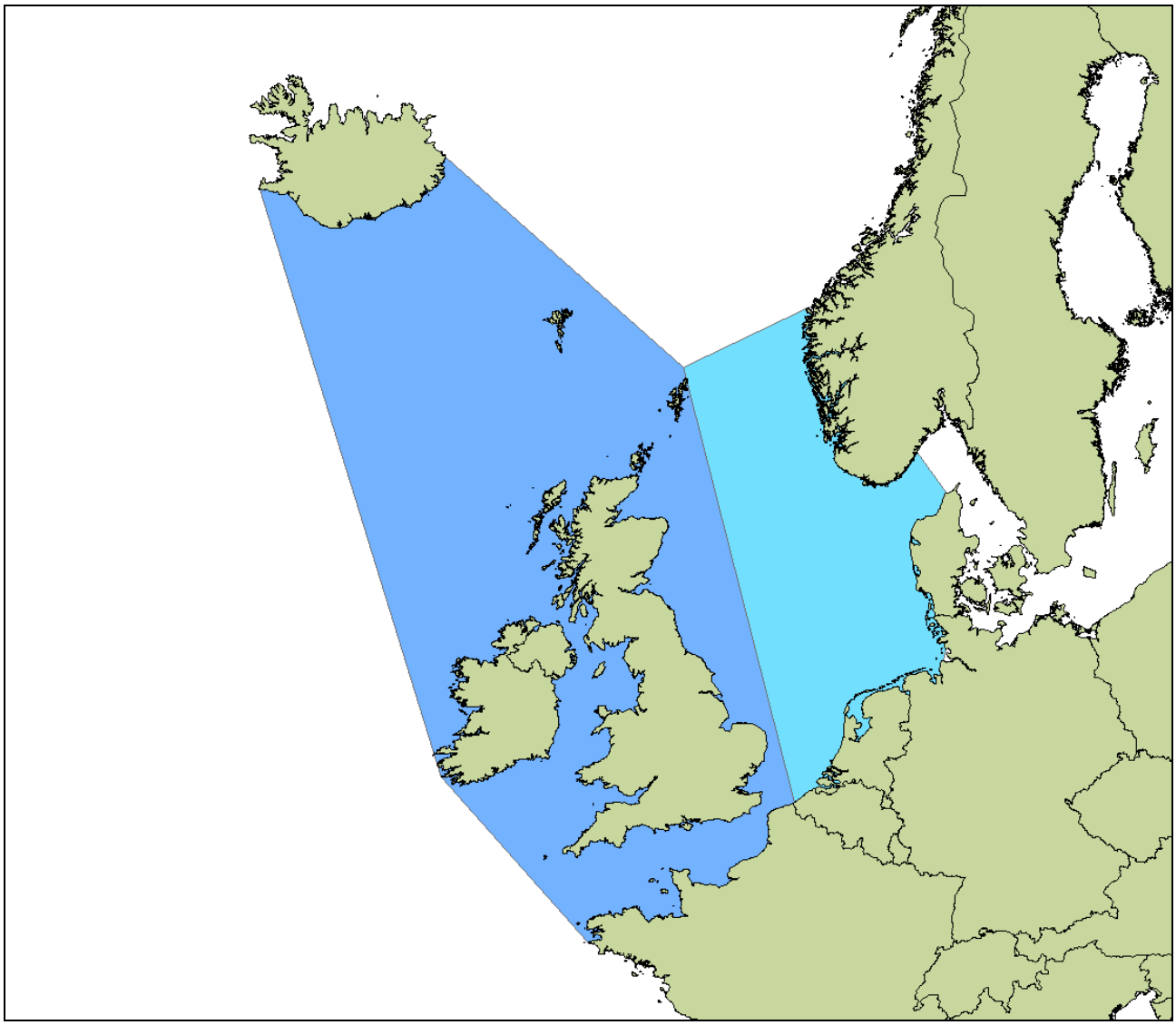


The blue area on this map shows the predicted migration zones potentially used by Purple Sandpipers that visit SPA sites in Britain and Ireland during the non-breeding season.

UK wintering populations of Purple Sandpiper comprise breeding birds from Norway, Greenland, arctic Canada as well as Russia and Svalbard, and wintering birds are concentrated in the north of the UK though also occur in south England in smaller numbers. Arrival and departure seasons are similar to those of other wader species, and while migration routes are not known precisely, some birds from the North Sea coast are known to pass through Orkney in spring. This species probably regularly migrates across the North Sea, and waters off the north and west coasts in order to reach the UK SPA sites where it is a designated feature.

Dunlin (breeding and passage populations) *Calidris alpina schinzii* and *arctica*

Dunlin (breeding and passage populations) *Calidris alpina schinzii* and *Calidris alpina arctica*	
SPA Species?	Yes (breeding)
SPA Sites	8 sites in northern England, Scotland and Scottish islands
Population Size (GB)	9,150-9,900 pairs (breeding)
Population Size (International)	23,000-26,000 (Britain & Ireland breeding) 940,000-960,000 (Iceland & Greenland breeding) 3,300-4,100 (Baltic breeding) 21,000-45,000 (*arctica*)
Percentage of international population in GB & Ireland	100% of Britain & Ireland population (breeding) 100% of Iceland/Greenland-breeding *schinzii* (passage) Unknown proportion of Baltic-breeding *schinzii* (passage) 100% of *arctica* (passage)

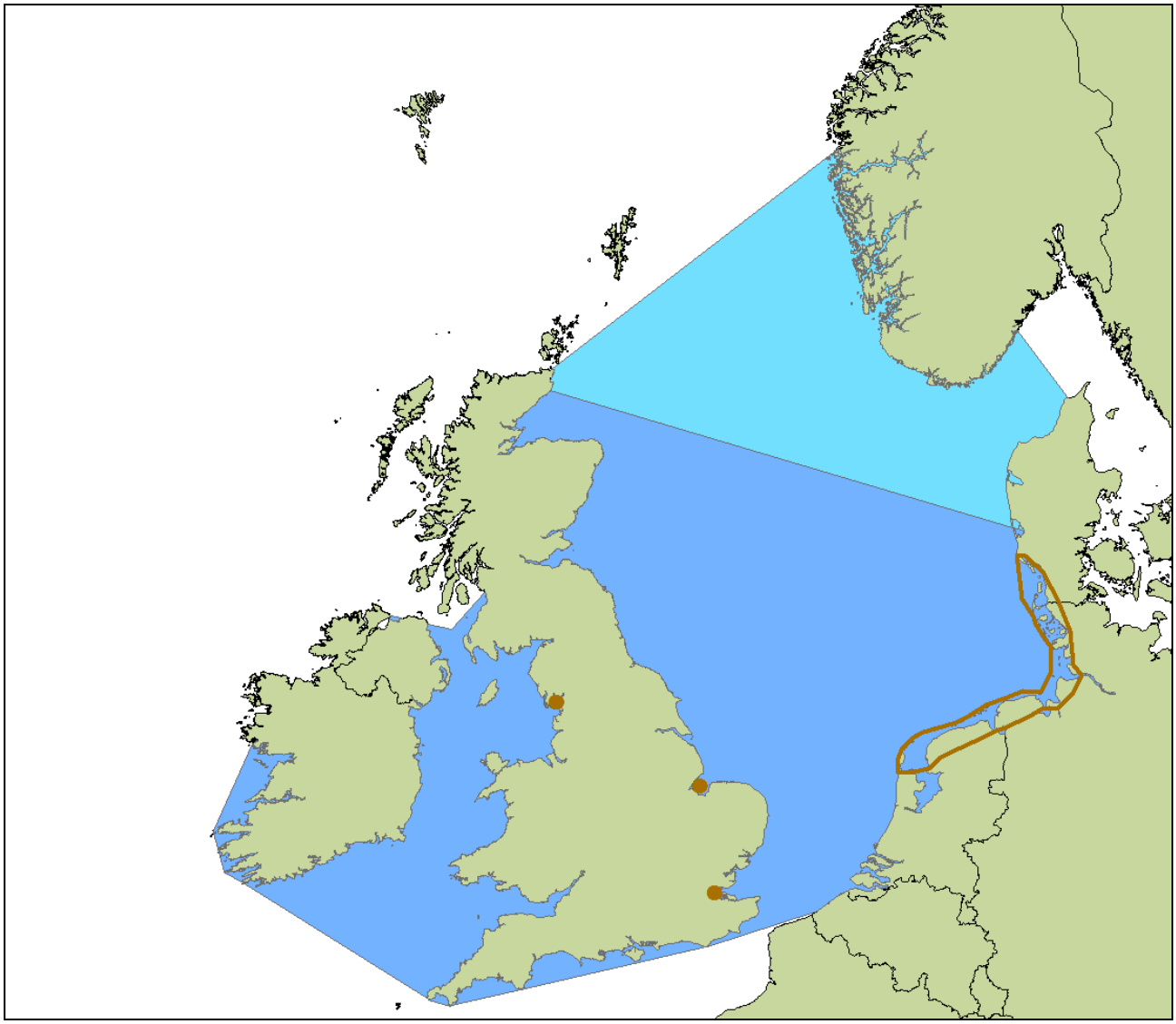


The dark blue area on this map shows the predicted migration zones potentially used by Dunlin of the *schinzii* and *arctica* races that either breed in Britain or pass through Britain and Ireland on migration from Iceland or Greenland (around 1 million birds in total). The pale blue area shows the additional zone followed by a few thousand birds from the Baltic-breeding *schinzii* population, some of which migrate via the UK.

Wetlands International (2012) considers the *schinzii* race of Dunlin as three distinct populations as detailed in the table above. British breeding Dunlin occur at upland sites in northern England and Scotland and on Scottish islands. Their migration routes take them south to West Africa via the coasts of western France and Iberia, but a few also winter locally, and thus birds from this population may pass over almost all parts of UK waters (Wernham *et al*. 2002), though exact routes are not known and it is possible that there are concentrations in certain areas and gaps elsewhere. Key migration periods for the British-breeding population are April and May for spring migration and birds leave the UK from mid-June to mid-August. Populations that breed outside the UK, especially those from Iceland, pass through the UK in very large numbers on passage migration to and from wintering sites mostly in north western Africa but also in southern Europe. Dunlin of the *arctica* subspecies that breeds in Greenland also pass through the UK on their migration to West Africa. Key migration periods when passage *schinzii* and *arctica* Dunlin cross UK waters are April – May and July – September. As with British breeding Dunlin, exact routes are not known and while it is possible that migration routes are concentrated in certain areas all parts of UK waters must be considered as potential migration routes for this species unless evidence becomes available to show otherwise. The numbers of birds occurring in the UK are probably vastly underestimated by peak counts from Wetland Bird Surveys, as the turnover of birds during the passage period means that peak counts will only record a fraction of the total birds using sites. Ringing recoveries and other research suggest that Britain and Ireland host almost all birds from the Icelandic breeding population of *schinzii* Dunlin and Greenland-breeding *arctica* Dunlin on passage (i.e. a total of around 1 million birds (range 961,000-1,005,000) excluding those that breed in Britain (an additional 23,000-26,000)) as well as some (probably low thousands) Baltic breeding *schinzii* (Wernham *et al*. 2002). It is therefore a very high priority for further research into precise migration routes and flight heights to reduce the risk to consenting posed by the current lack of information regarding where these birds cross the sea.

Dunlin (wintering population) ***Calidris alpina alpina***

Dunlin (wintering population) *Calidris alpina alpina*	
SPA Species?	Yes (non-breeding)
SPA Sites	38 sites in various coastal areas
Population Size (GB)	350,000
Population Size (Ireland)	88,480
Population Size (International)	1,330,000
Percentage of international population in GB & Ireland	33%



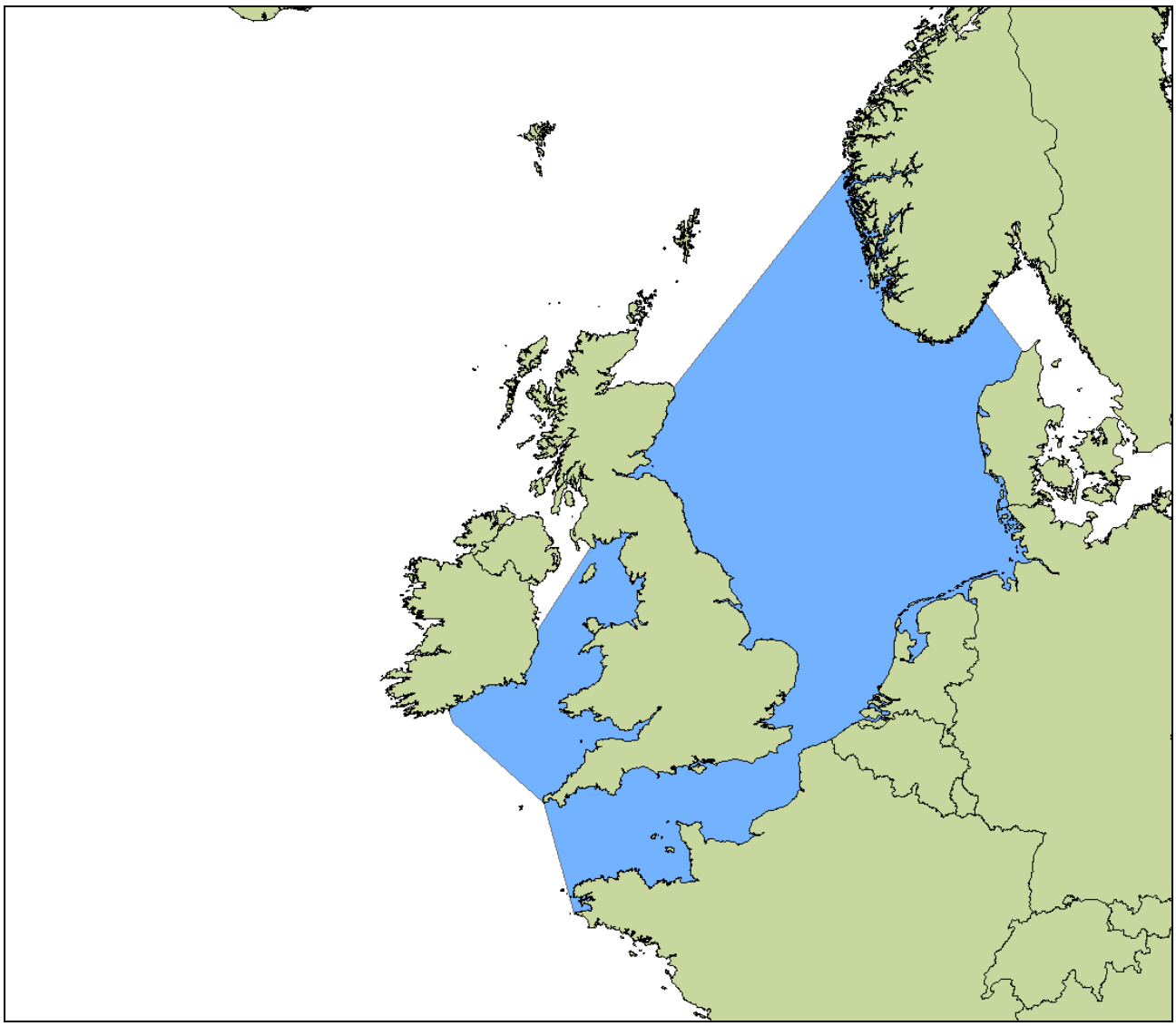
The dark blue area on this map shows the main predicted migration zone potentially used by Dunlin of the *alpina* race that visit Britain and Ireland during the winter. The pale blue area shows the additional route that could be followed by a proportion of the population that moults on UK estuaries rather than the Wadden Sea (though many such birds may use the dark blue area). The areas marked in brown are key moulting sites where birds aggregate in late summer before dispersing to wintering sites in the autumn.

Wintering Dunlin in the UK come from populations that breed in northern Scandinavia and Russia. Autumn migration covers a fairly long period as birds migrate first to moulting sites then disperse to wintering sites once they have completed their moult. Substantial numbers will cross the North Sea during July and August to moult on the Wash, Thames and Morecambe Bay (Boere 1976, Wernham *et al*. 2002), but the majority of the British and Irish wintering population (estimated at 438,480 birds) moult on the Wadden Sea before

moving across the southern and central North Sea to the UK in October and November, with some (88,480) continuing across the Irish Sea to Ireland (Wernham *et al*. 2002). Birds from moulting sites on UK estuaries also disperse at this time. Juvenile Dunlin migrate on a broader front than adults and most arrive in the UK and Ireland in September and October, probably crossing the North Sea or far-eastern parts of the English Channel, with Irish-wintering birds also crossing the Irish Sea. In spring, birds congregate on a few sites such as the Wash and Wadden Sea before returning to breeding grounds, with the majority of the wintering population crossing the North Sea during April and May. For the purposes of assessment, we suggest that assessments for proposed wind farms in the part of the North Sea shaded darker blue should assume that all of the 438,480 birds wintering in Britain and Ireland could potentially migrate across this area twice each year. Wind farms in the part of the North Sea shaded pale blue should assume that these 438,480 birds are distributed across a wider migratory front encompassing both the dark blue and pale blue parts of the North Sea. Wind farms in the Irish Sea should assume that the entire Irish population (88,480) crosses the Irish Sea twice annually.

Ruff *Philomachus pugnax*

Ruff *Philomachus pugnax*	
SPA Species?	Yes (non-breeding)
SPA Sites	8 sites in eastern and southern England
Population Size (GB)	800
Population Size (International)	1,000,000-1,500,000 (W Africa non-breeding)
Percentage of international population in GB	0.06%

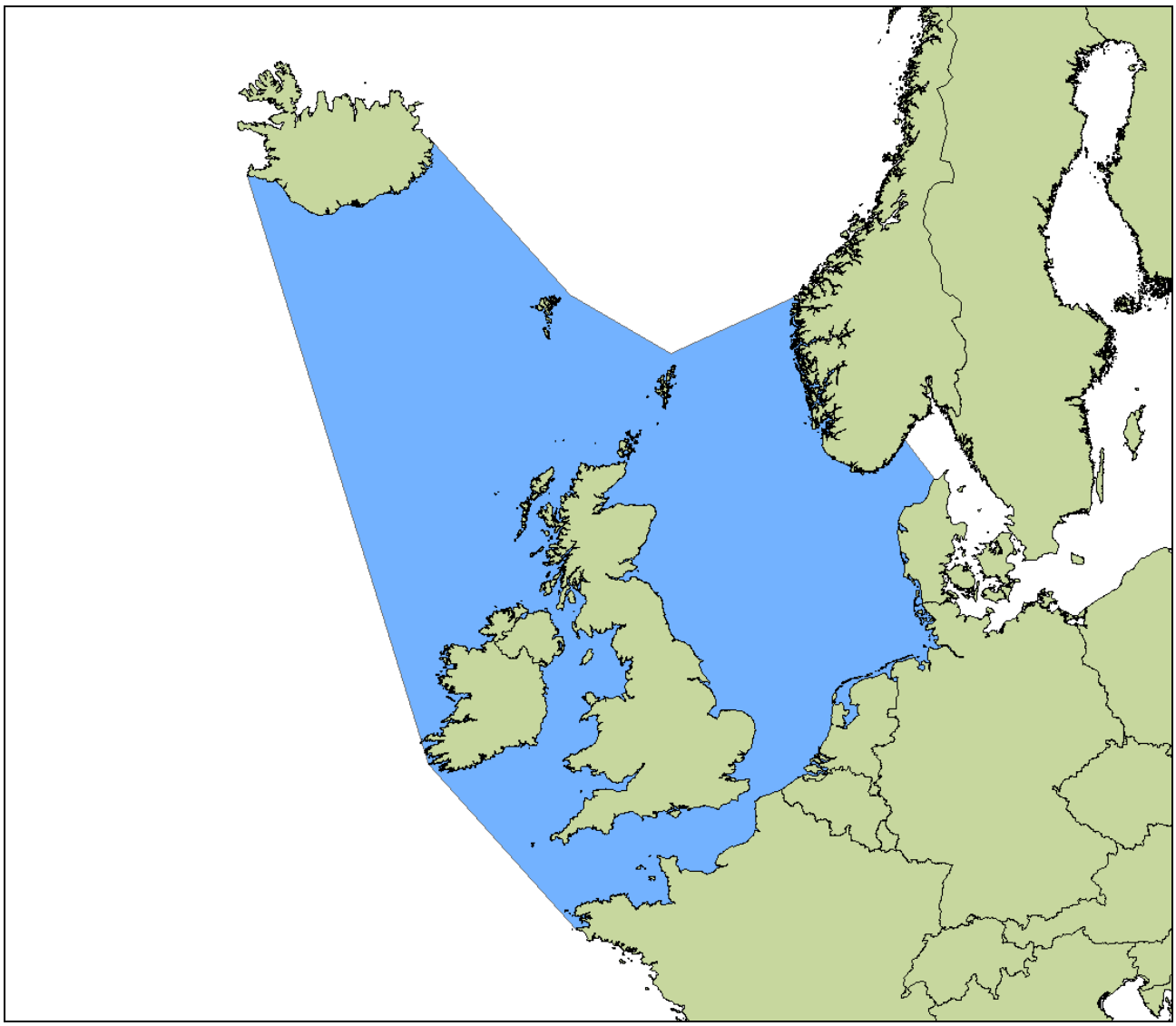


The blue area on this map shows the predicted migration zones potentially used by Ruff that visit the UK.

Ruff occur in Britain primarily on passage migration although a small number also breed or winter here. Passage birds migrate between breeding sites in Scandinavia or Russia to wintering sites in sub-Saharan Africa, North Africa or further south in Europe, probably moving primarily across the North Sea and English Channel, although migration routes are not well understood. In autumn, passage bird numbers peak in the UK from July to October but birds may also pass across UK waters at other times of year. In spring birds tend to follow a more easterly migration route with few passing across the UK (Wernham *et al*. 2002). The population estimate in the table above is based on count data and thus underestimates the numbers of passage birds due to turnover as birds move across Britain in autumn. Despite this underestimation, the UK probably still only hosts a few thousand Ruff, a small proportion of the international population, and thus they are a lower priority than other SPA species for further research.

Snipe *Gallinago gallinago*

Snipe *Gallinago gallinago*	
SPA Species?	Yes (non-breeding)
SPA Sites	1 site (Somerset Levels and Moors)
Population Size (GB)	1,000,000
Population Size (International)	>2,500,000 (Europe)
Percentage of international population in GB	<40%



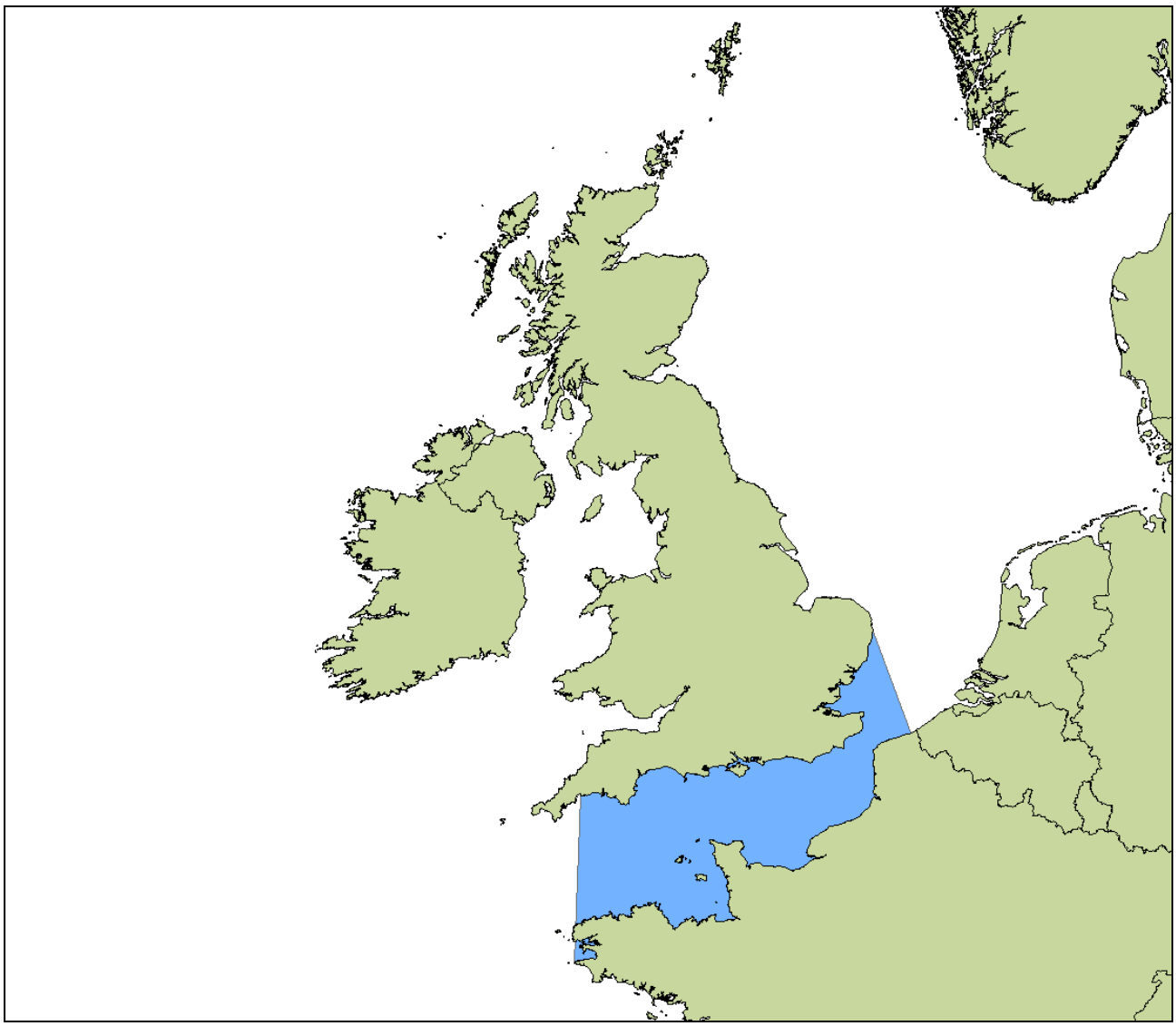
The blue area on this map shows the predicted migration zones potentially used by Snipe that visit Britain and Ireland during the non-breeding season.

Snipe breed throughout Europe with the nominate race occurring in most areas and *faeroeensis* in Iceland, the Faeroes, Orkney & Shetland. Within Britain, breeding birds are widespread but commonest in the north. Birds migrate in a south-westerly direction in the autumn (August to October) with some British breeders crossing the Irish Sea to Ireland or the English Channel to continental Europe. At the same time there is an influx of migrants from Iceland (especially to Ireland but also to Britain) and northern Europe (to Britain and Ireland), with these birds crossing the North and Irish Seas, and some continuing on from Britain across the English Channel. Return migration occurs during late March and April (Wernham *et al*. 2002). Precise migration routes taken by Snipe are not known and while it is possible that migration routes are concentrated in certain areas all parts of UK waters must be considered as potential migration routes for this species unless evidence becomes available to show otherwise. It is thought that more than a million

Snipe might migrate to or across Britain and Ireland each year, a high proportion of the international population. Only one SPA is designated for Snipe in the UK, but this underplays the importance of the UK as an internationally important wintering site for this species, as it is widespread throughout the country rather than being concentrated in particular areas that can be designated as SPAs. It is a high priority for further research to improve understanding of migration routes and flight heights to reduce the risk to consenting posed by the current lack of information regarding where these birds cross the sea.

Black-tailed Godwit (breeding population) *Limosa limosa limosa*

Black-tailed Godwit *Limosa limosa limosa*	
SPA Species?	Yes (breeding population)
SPA Sites	2 sites (Nene and Ouse Washes)
Population Size (GB)	44-52 pairs
Population Size (International)	160,000-180,000 (W Europe breeding)
Percentage of international population in GB	0.06%

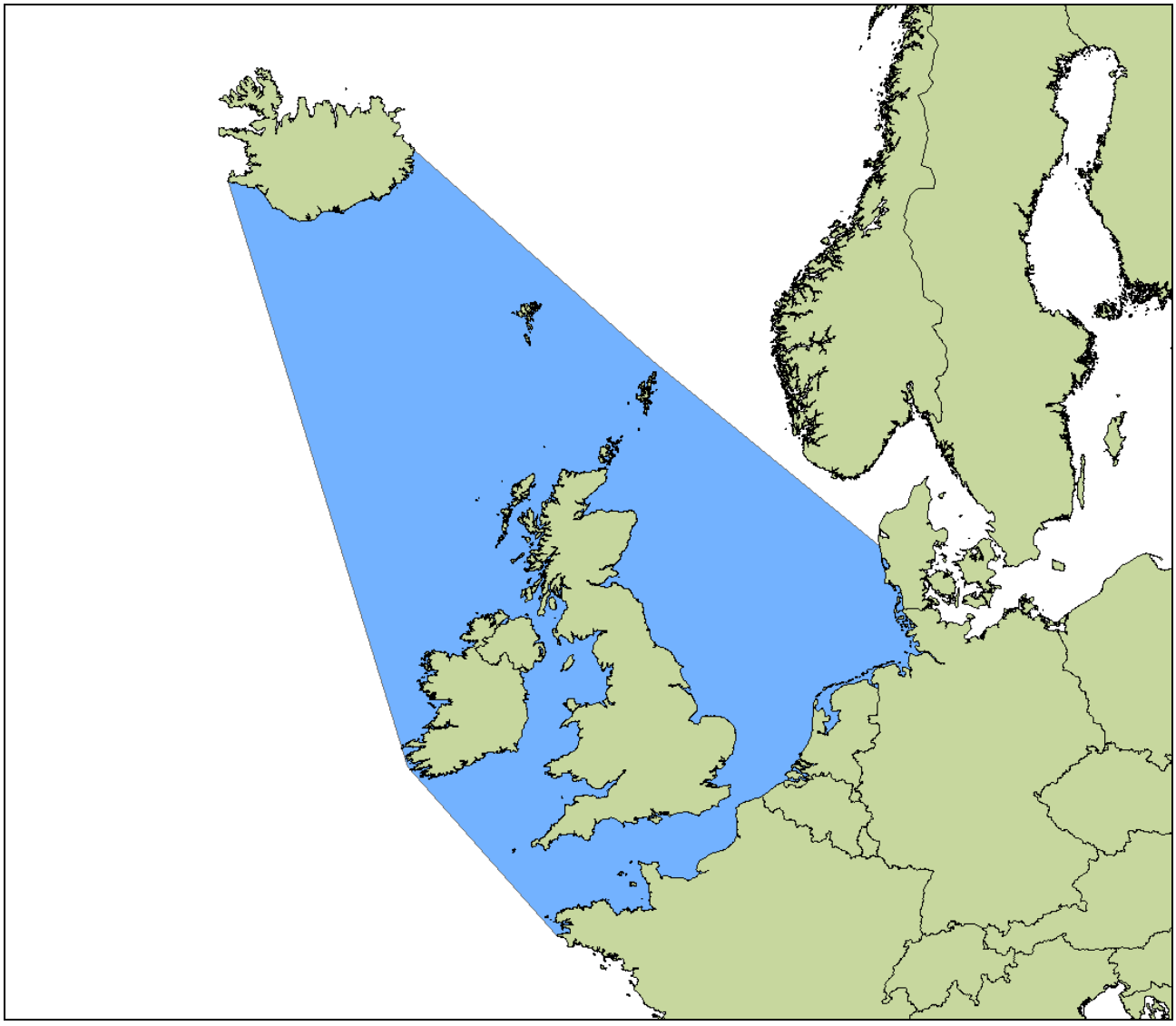


The blue area on this map shows the predicted migration zone potentially used by Black-tailed Godwits that breed in Britain.

The British breeding population of Black-tailed Godwits is very small and concentrated at the two main breeding sites which are designated as SPAs. These birds migrate to sub-Saharan Africa (or possibly Iberia) during the non-breeding season. Spring migration occurs during late March and April, and autumn migration during July. There are few ringing recoveries of British-breeding birds so precise migration routes are not known, however there is no evidence that continental-breeding birds migrate across Britain on passage (Wernham *et al*. 2002). Although there are SPAs designated for this subspecies in the UK, its very small population size means that it is a low priority for further research into migration routes.

Black-tailed Godwit (Icelandic) *Limosa limosa islandica*

Black-tailed Godwit *Limosa limosa islandica*	
SPA Species?	Yes (non-breeding population)
SPA Sites	27 sites in various coastal areas
Population Size (GB)	43,000
Population Size (Ireland)	13,880
Population Size (International)	50,000-75,000
Percentage of international population in GB & Ireland	100%



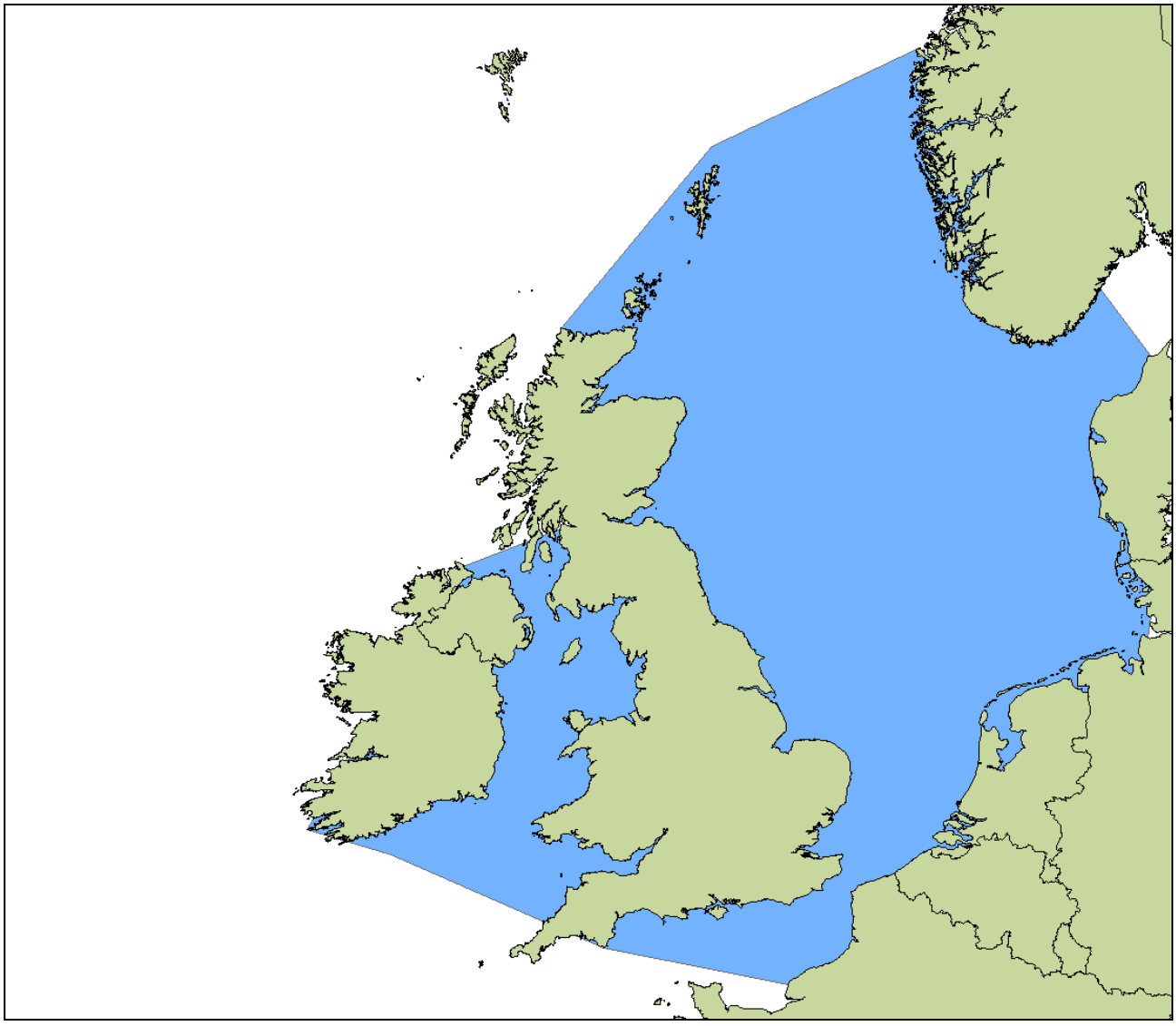
The blue area on this map shows the predicted migration zones potentially used by Icelandic Black-tailed Godwits that visit Britain and Ireland during the non-breeding season.

The vast majority of the Icelandic population of Black-tailed Godwits either winters in or migrates across the British Isles. Spring migration occurs from mid-April to early May (Gunnarsson *et al*. 2006) and autumn migration sees birds returning to the UK in July and August where they congregate in large moulting flocks before dispersing to wintering sites elsewhere in Britain, Ireland or continental Europe (Wernham *et al*. 2002). These post-moult dispersals see birds crossing the southern North Sea, Irish Sea and English Channel in autumn and early winter, returning in early spring. Precise migration routes between Iceland and the British Isles are not known, but as birds arrive in various parts of the British Isles in autumn it is possible that these routes could take birds across any parts of UK waters. Further understanding of the timing of

movements of this subspecies across UK waters in relation to offshore wind farm development zones could potentially be gained by analysis of the extensive colour-ring resighting data that has already been gathered by teams of researchers and bird ringers (led by Farlington Ringing Group and the University of East Anglia). However new data would be required to understand the precise routes across UK waters taken by birds on their long migrations to and from Iceland.

Bar-tailed Godwit *Limosa lapponica*

Bar-tailed Godwit *Limosa lapponica*	
SPA Species?	Yes (non-breeding population)
SPA Sites	23 sites in various coastal areas
Population Size (GB)	38,000
Population Size (Ireland)	16,280
Population Size (International)	120,000 (*lapponica*)
Percentage of international population in GB & Ireland	45%



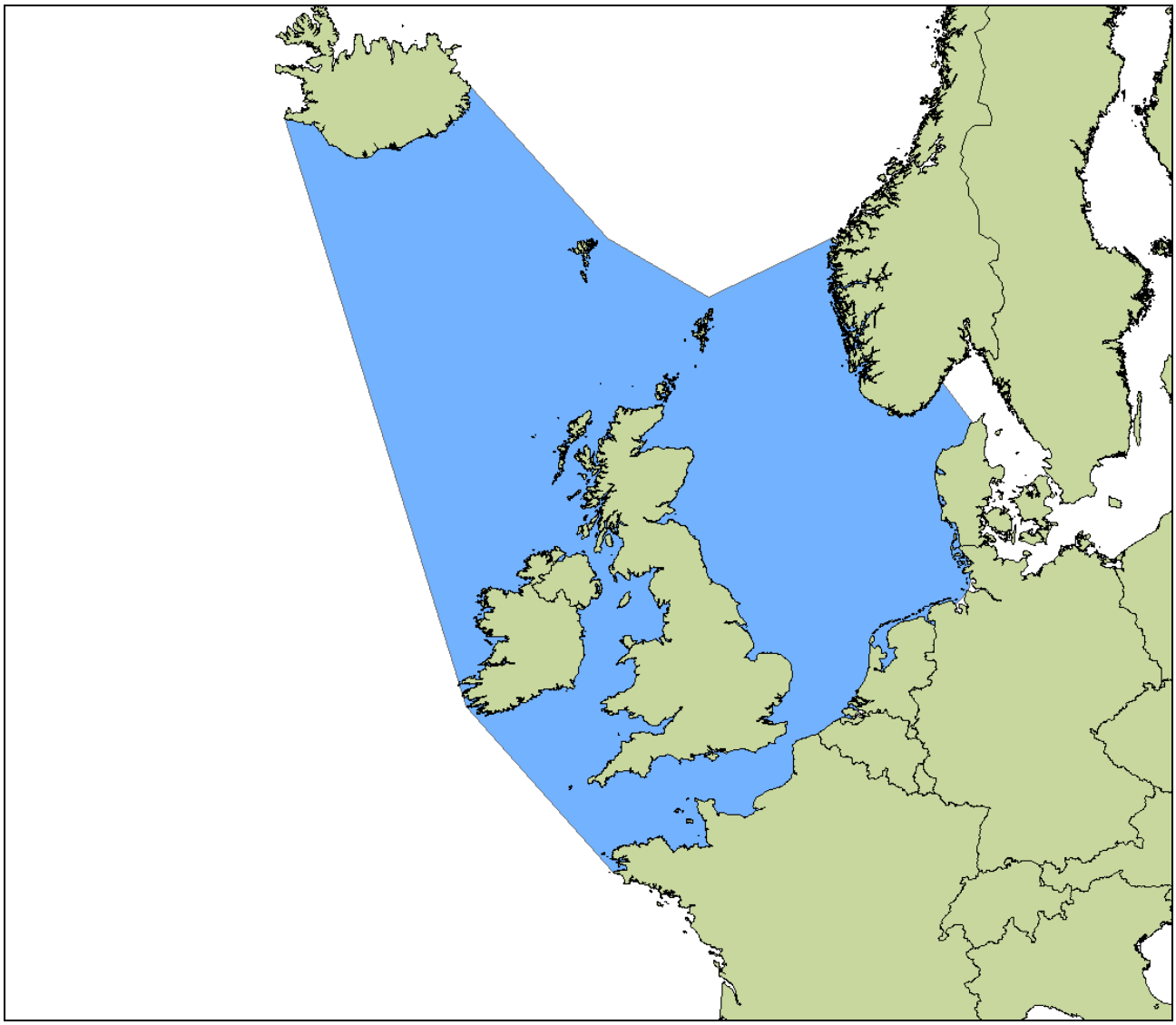
The blue area on this map shows the predicted migration zones potentially used by Bar-tailed Godwits that visit Britain and Ireland during the non-breeding season.

Bar-tailed Godwits that spend the winter in the UK come from breeding populations in Scandinavia and Russia. Their migration routes take almost the entire Britain and Ireland population (54,280 birds) across the North Sea, with some birds continuing across the Irish Sea (16,280) or English Channel (low thousands) while others remain in Britain throughout the winter. It should be noted that these numbers do not account for passage birds of the *taymyrensis* race, as no SPAs are designated for passage Bar-tailed Godwits. The majority of birds are concentrated on a few large estuaries in winter. Birds cross the North Sea to Britain mainly between July and September and return in February and March, with large numbers staging at sites in the Wadden Sea suggesting that migration routes are probably concentrated on paths to

this area from key wintering sites. As a large proportion of the international population of this species migrates across UK, and birds are concentrated in a small number of sites, further research such as tracking or radar studies would be valuable to improve understanding of the migration routes used by this species.

Whimbrel *Numenius phaeopus*

Whimbrel *Numenius phaeopus*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 1 site (Fetlar) Non-breeding (passage) 11 sites in coastal areas of England and Wales
Population Size (GB)	530 pairs (breeding) 3,840 individuals(spring passage)
Population Size (International)	600,000-750,000 (*islandicus* Iceland, Faeroes Scotland breeding) 190,000-340,000 (*phaeopus* Northern Europe breeding)
Percentage of international population in GB	0.2% of *islandicus* (breeding) 0.6% of *islandicus* or 0.4% of two populations combined (spring passage)

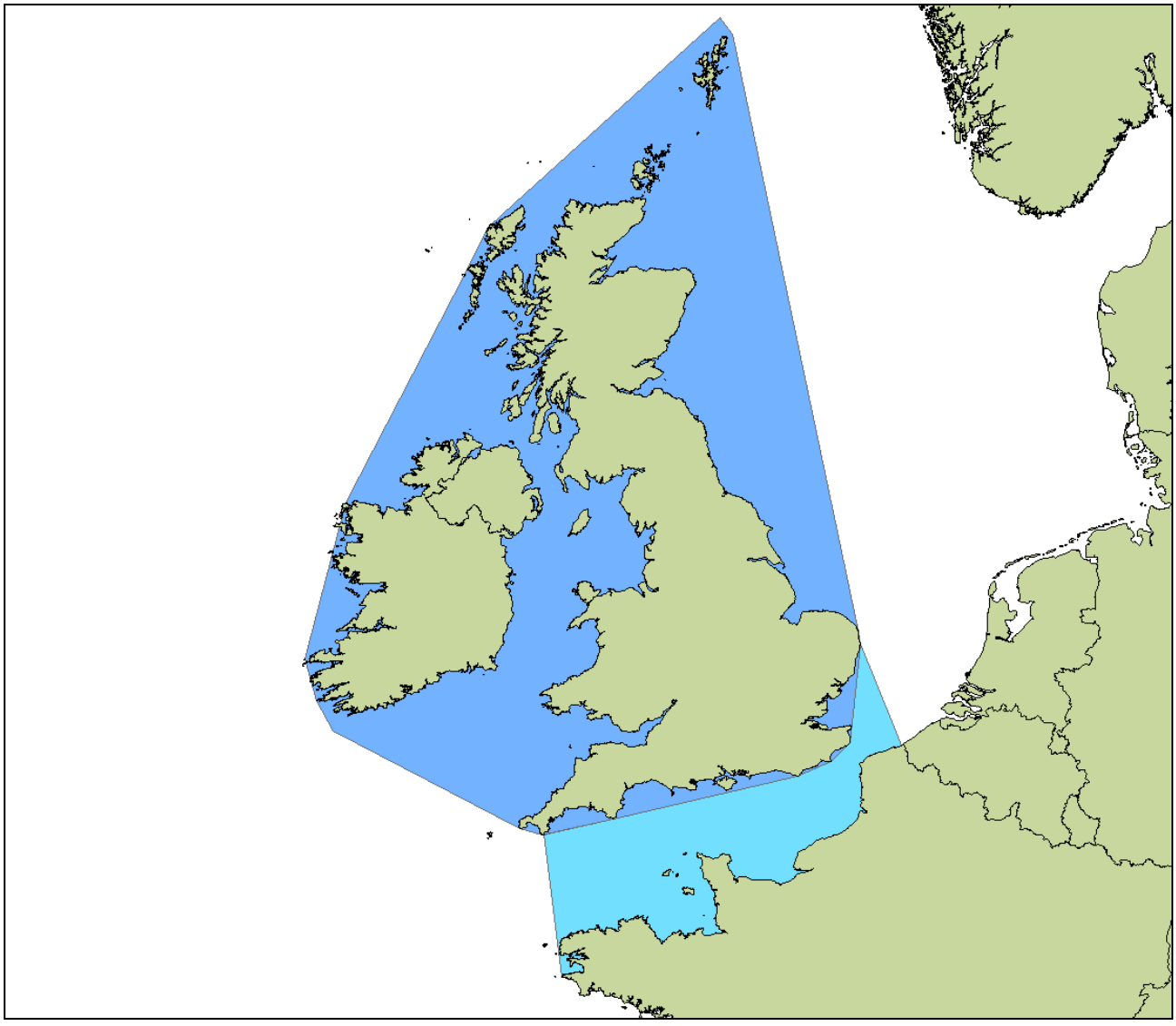


The blue area on this map shows the predicted migration zone potentially used by Whimbrel that migrate via Britain.

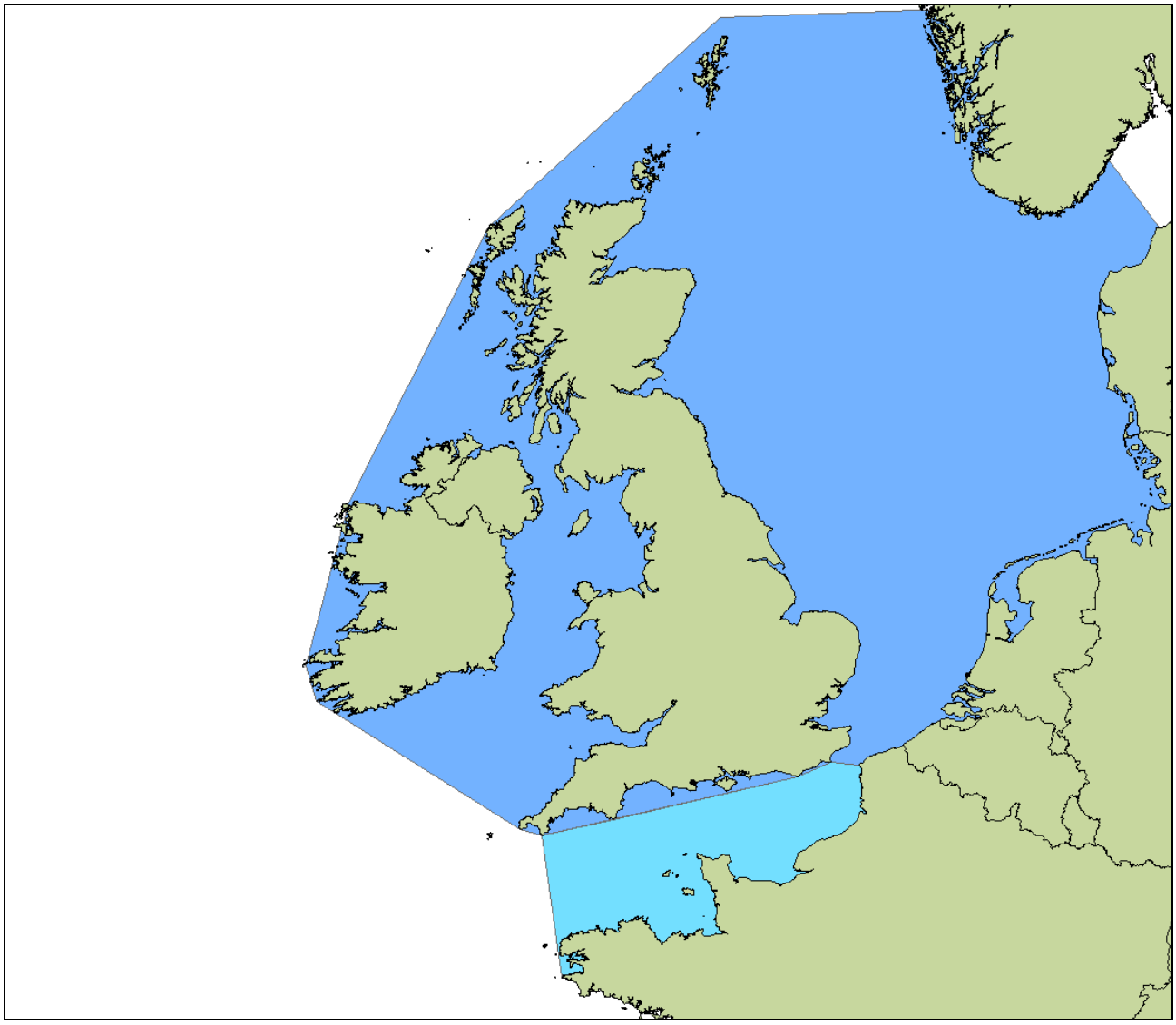
A small number of Whimbrel breed in the Shetland Isles but far larger numbers occur on passage migration, particularly in spring but also in autumn, when they can be found on all coasts of Britain and Ireland (Wernham *et al*. 2002). These passage birds breed in Iceland, Scandinavia and Russia and winter in West Africa, thus their migration routes take them across most parts of UK waters. However, they are known to use a small number of major staging sites where large concentrations of birds occur, thus it seems likely that migration routes could be concentrated in certain areas. However a broad front migration across UK waters must be assumed until better data are available to demonstrate otherwise. The British population size given in the table above is based on count data and will be an underestimate of the total numbers moving across UK waters due to the turnover of birds during passage migration. Further research on this species would be valuable to improve understanding of precise migration routes, and to estimate the turnover of birds at key sites in order to improve understanding of the total numbers passing across the UK.

Curlew *Numenius arquata*

Curlew *Numenius arquata*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 1 site (North Pennine Moors)
	Non-breeding 25 sites in various coastal areas
Population Size (GB)	107,000 pairs (breeding)
	140,000 (non-breeding)
Population Size (Ireland)	54,650 (non-breeding)
Population Size (International)	700,000-1,000,000 (*arquata*)
Percentage of international population in GB & Ireland	25% (GB breeding)
	19-28% (GB & Ireland non-breeding)



The blue area on this map shows the predicted migration zones potentially used by Curlew that breed in Britain.

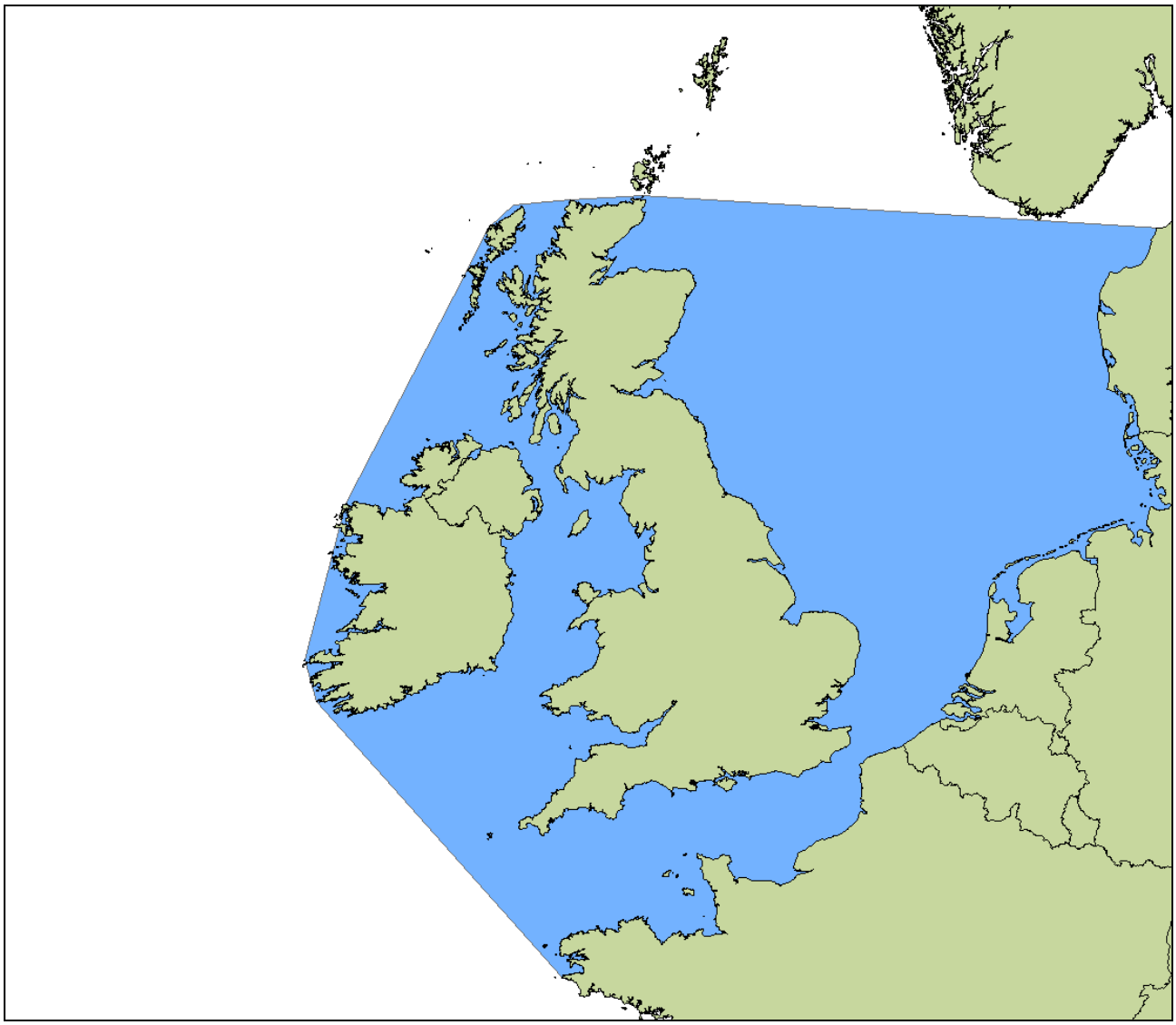


The dark blue area on this map shows the predicted migration zones potentially used by Curlew that visit Britain and Ireland during the non-breeding season. The pale blue area shows the zone followed by a small number of birds that continue southwards after passing through the UK.

Large numbers of Curlew migrate across the North Sea and Irish Sea, with much smaller numbers crossing the English Channel (Wernham *et al.* 2002). Autumn migration occurs from late June to October, and British-breeding birds return on spring migration between late January and March, but for foreign-breeding birds that winter in Britain spring migration is later, between March and May. Migration may occur on a broad front across the North and Irish Seas, or may be concentrated in particular areas. Further research, for example tracking studies, could improve our understanding of migration routes and is a high priority for this SPA species which has a large proportion of its international population migrating across UK waters. Tracking birds using tags that also record altitude would help to reduce the risk to consenting posed by the current lack of information regarding where these birds cross the sea and the heights they fly at while doing so.

Greenshank *Tringa nebularia*

Greenshank *Tringa nebularia*	
SPA Species?	Yes (breeding population)
SPA Sites	1 site in northern Scotland (Lewis Peatlands), 2 in England
Population Size (GB)	1,080 pairs (breeding) 4,790 (autumn passage) 610 (winter)
Population Size (Ireland)	1,265 (non-breeding)
Population Size (International)	190,000-270,000 (NW Europe)
Percentage of international population in GB	1% (breeding) 2% (passage) 0.2% (winter)



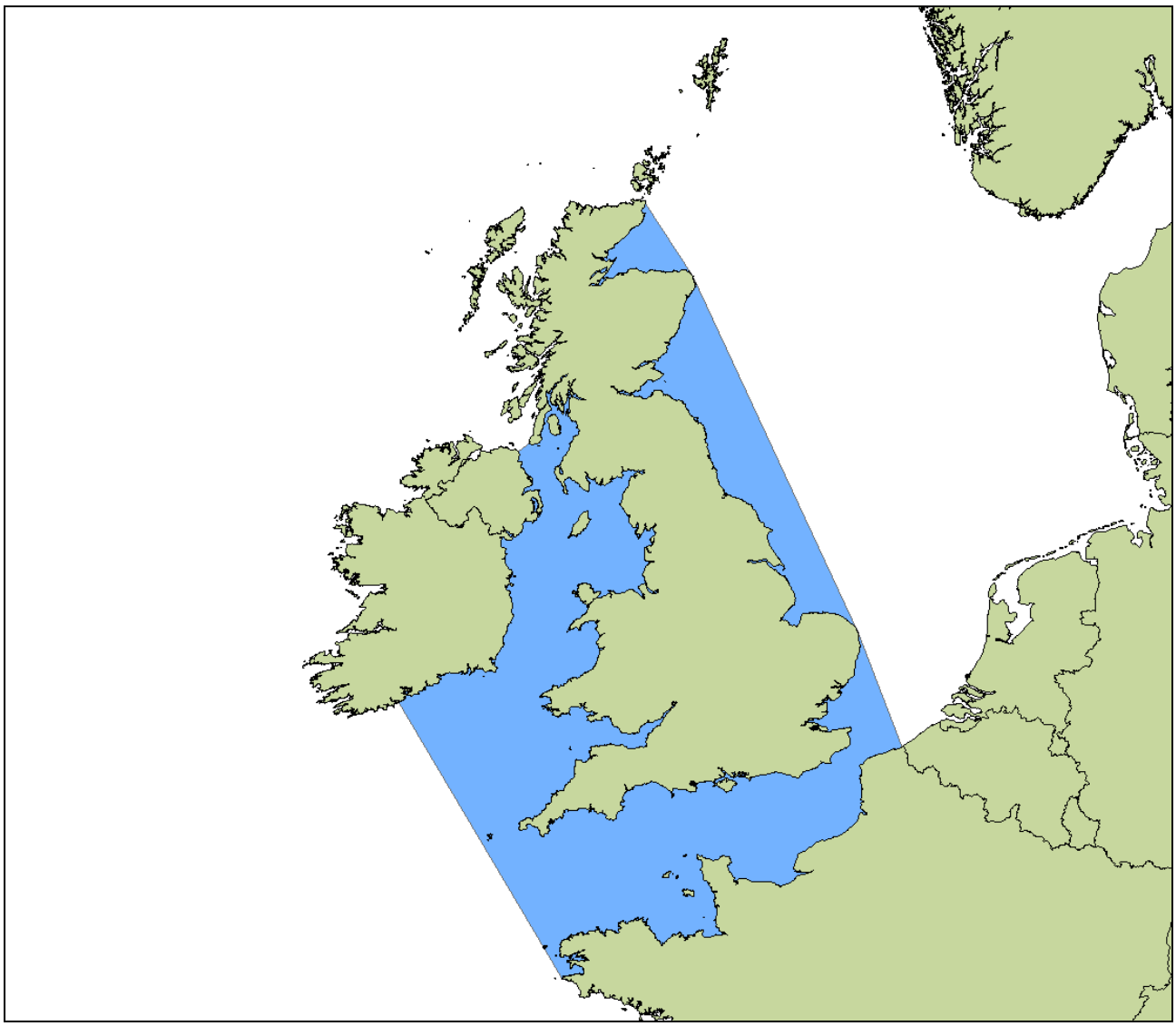
The map above relates to possible migration zones of Greenshank breeding at the two SPAs in northern Scotland, and does not cover non-breeding birds for which no SPAs are designated.

Breeding Greenshank are restricted to the Scottish uplands, but much larger numbers occur throughout Britain and Ireland on passage migration during the autumn and spring. Ringing recoveries are biased towards the south of England, where more birds have been ringed, and thus do not represent the range of

migration routes probably used by passage Greenshank across UK waters. The passage population estimate in the table above is based on count data and thus is an underestimate due to the turnover of birds moving through sites, but despite this it is still likely to be a relatively small proportion of the international population that migrates across UK waters. As passage birds occur all around the UK, it must be assumed that they could migrate across any UK waters. However, as there are no SPAs designated for passage Greenshank, they are not covered by the migration zone map above. The small number of birds breeding in the two SPAs are likely to migrate southwards during the winter, but their migration routes are not known. However it is suspected that they move to wintering sites in Ireland, western Britain, southwest Europe or northwest Africa.

Wood Sandpiper *Tringa glareola*

Wood Sandpiper *Tringa glareola*	
SPA Species?	Yes (breeding population)
SPA Sites	3 sites in northern Scotland
Population Size (GB)	4-8 pairs
Population Size (International)	900,000-1,200,000 (NW Europe breeding)
Percentage of international population in GB	0.001%

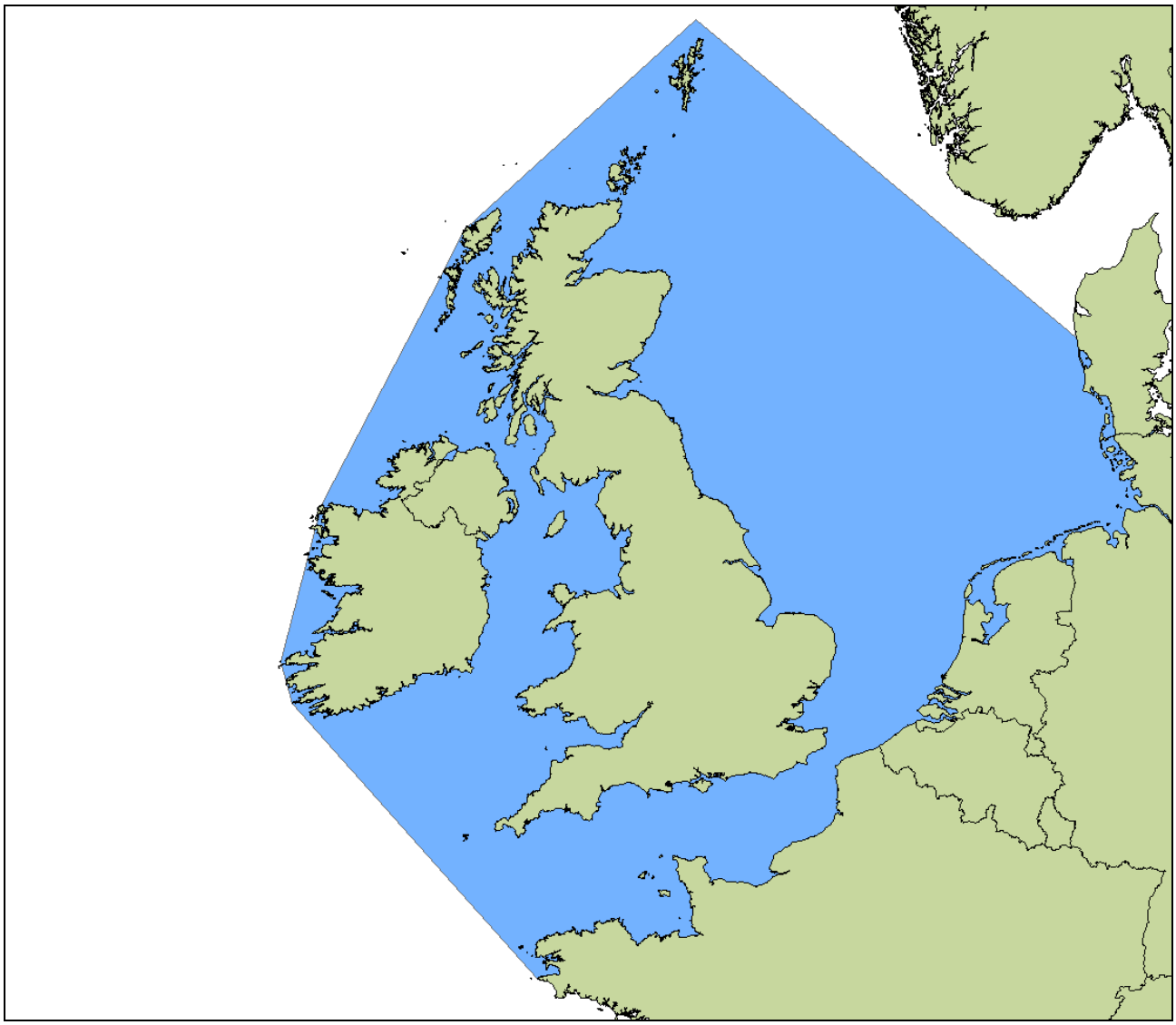


The blue area on this map shows the predicted migration zones potentially used by Wood Sandpipers that breed in Britain.

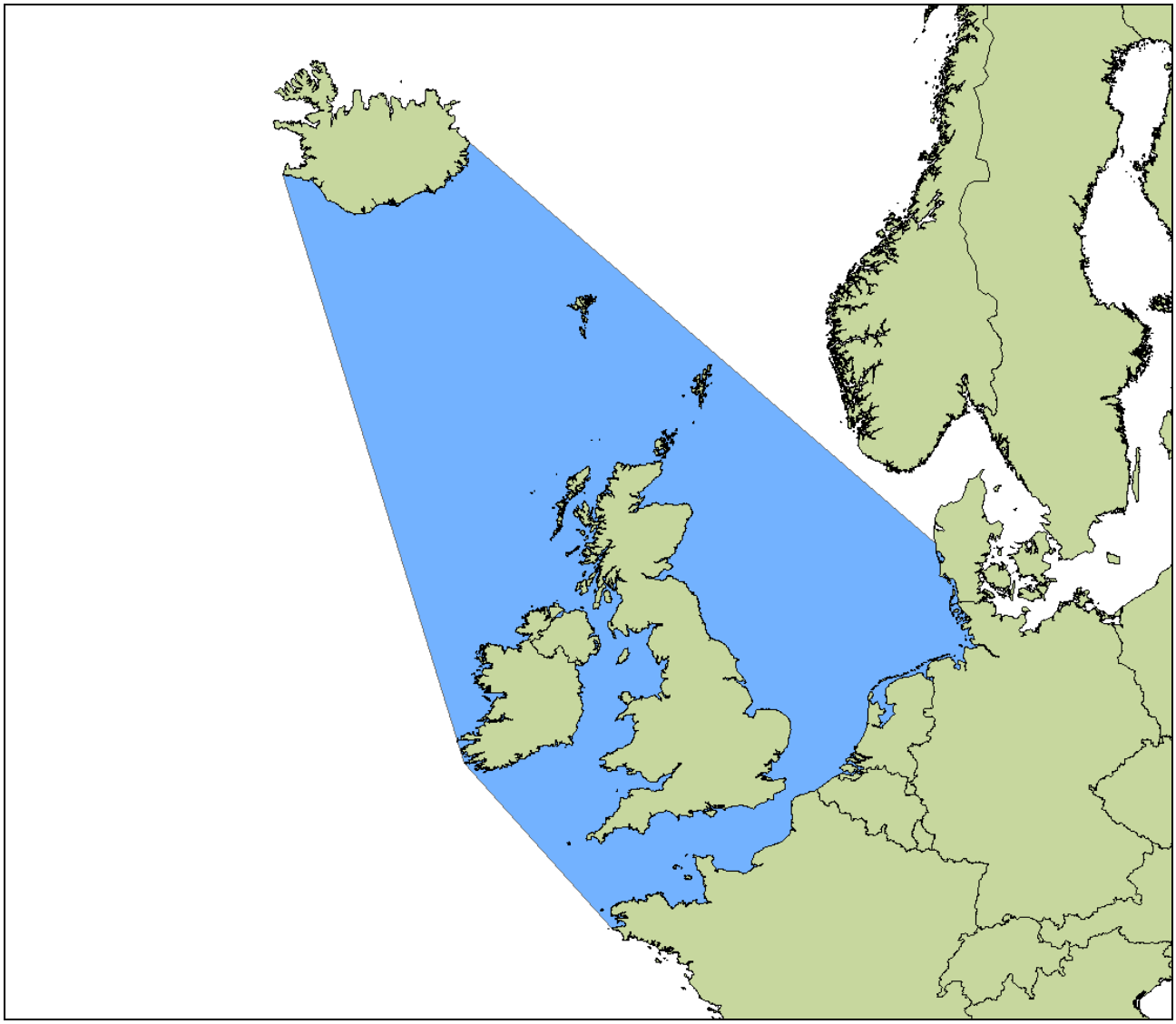
A very small number of Wood Sandpipers breed in northern Scotland and the three SPAs probably contain the entire UK breeding population. These birds winter in West Africa and thus must migrate across UK waters during spring (April-May) and autumn (late June to August), at which time a small number of passage birds also occur. However, the numbers migrating across the UK are insignificant in terms of the international population and thus this species is a very low priority for further work.

Redshank *Tringa totanus*

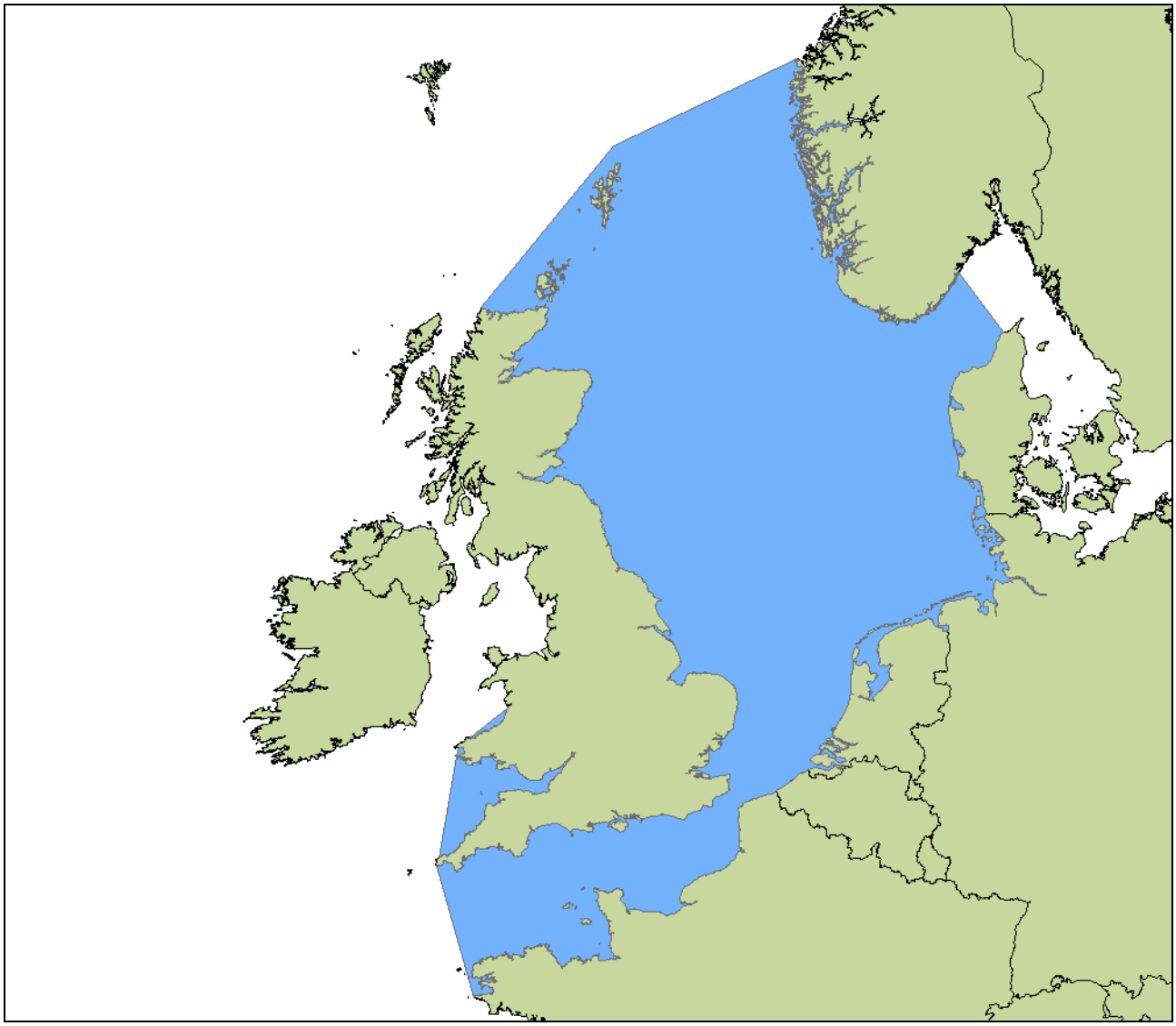
Redshank *Tringa totanus*	
SPA Species?	Yes (breeding and non-breeding populations)
SPA Sites	Breeding season 4 sites (Western Isles, Norfolk) Non-breeding 36 sites in various coastal areas
Population Size (UK/GB)	38,800 pairs in UK (breeding) 120,000 individuals in GB (non-breeding))
Population Size (Ireland)	31,090 (non-breeding)
Population Size (International)	95,000-135,000 (*britannica* Britain & Ireland breeding) 150,000-400,000 (*robusta* Iceland & Faeroes breeding) 200,000-300,000 (*totanus* N Europe breeding)
Percentage of international population in GB & Ireland	100% of *britannica* population (breeding) 18-34% of three populations combined (non-breeding)



The blue area on this map shows the predicted migration zone potentially used by Redshank of the *britannica* race.



The blue area on this map shows the predicted migration zone potentially used by Redshank of the *robusta* race that visit Britain and Ireland during the non-breeding season.

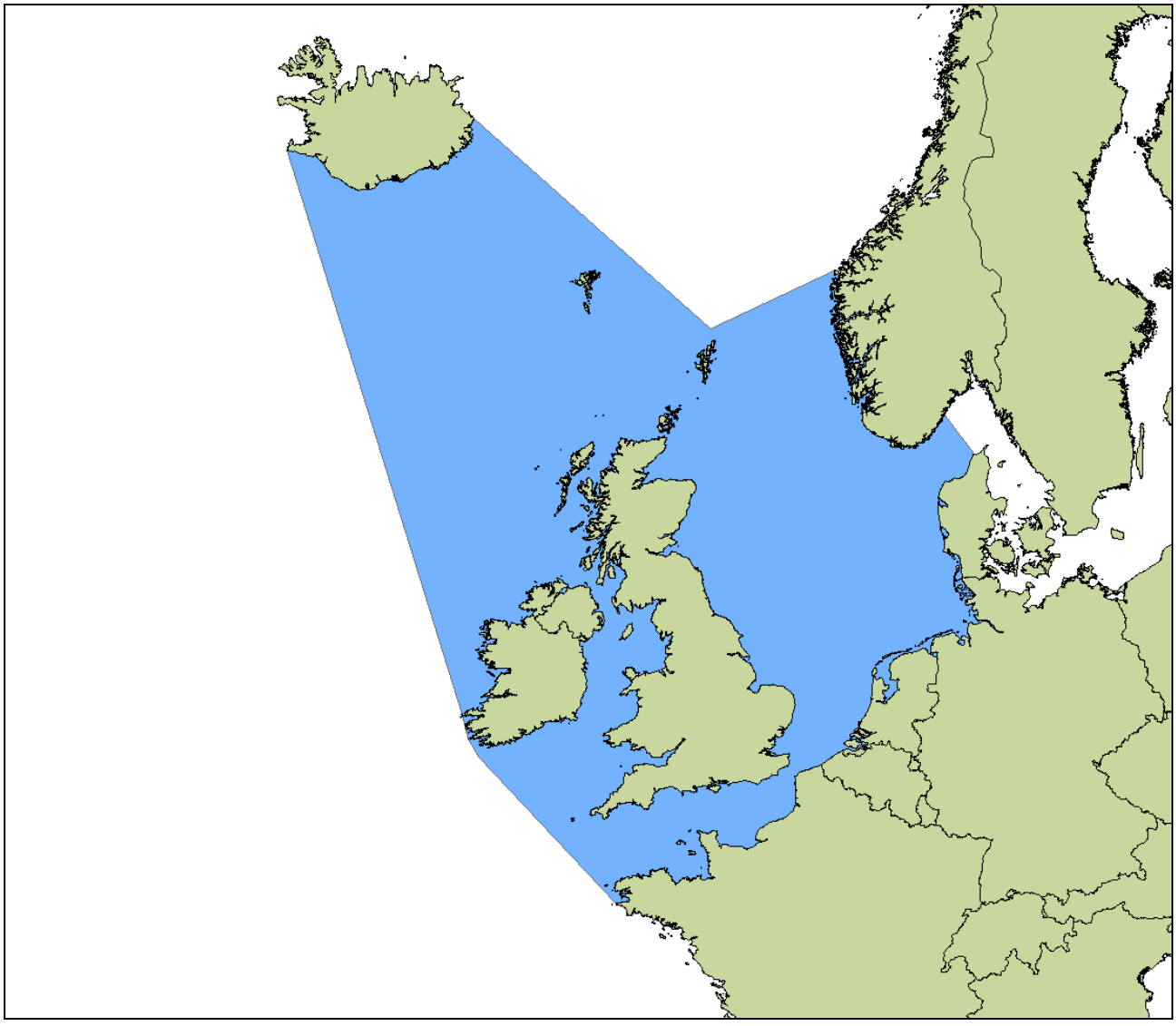


The blue area on this map shows the predicted migration zone potentially used by Redshank of the *totanus* race that visit Britain during the non-breeding season.

Three Redshank populations overlap in the UK in winter. Most of the *totanus* East Atlantic population winters outside the UK, but a large proportion of the other two populations (*britannica* and *robusta*) winter in the UK. A large number of *robusta* Redshank migrate from Iceland to the British Isles in autumn (late June to August), arriving at sites on all coasts so potentially migrating across most UK waters, and return in March and April. The majority of the *robusta* population (150,000 – 400,000 birds) probably migrates across UK waters at this time (Wernham *et al* 2002). Some *britannica* Redshank leave the UK during the non-breeding season, but a large proportion remains in the UK. Redshank from all three populations may cross UK waters to NW France or coastal areas around the North Sea, mainly during peak migration times (Wernham *et al*. 2002). Further research would be valuable to improve understanding of exact migration routes and this is a high priority for all races, but especially for *robusta* due to the large proportion of this population that migrates across UK waters. In the meantime, we suggest assuming that 100% of the *robusta* population (150,000 – 400,000 birds) migrates across the route shown in the map for this race, assuming that up to half of the British-breeding population (38,800 individuals (assuming individuals=pairs x2)) might migrate across the route shown in the *britannica* map, and assuming that up to 25,000 *totanus* Redshank (one tenth of the total population, as the vast majority of this population winters outside the UK) might migrate to Britain across the route shown in the *totanus* map.

Turnstone *Arenaria interpres*

Turnstone *Arenaria interpres*	
SPA Species?	Yes (non-breeding population)
SPA Sites	13 sites in coastal areas around the UK
Population Size (GB)	48,000
Population Size (Ireland)	11,810
Population Size (International)	100,000-200,000 (NE Canada & Greenland breeding) 45,000-120,000 (Northern Europe breeding)
Percentage of international population in GB & Ireland	30-60% of NE Canada/Greenland population Or 19-41% of two populations combined



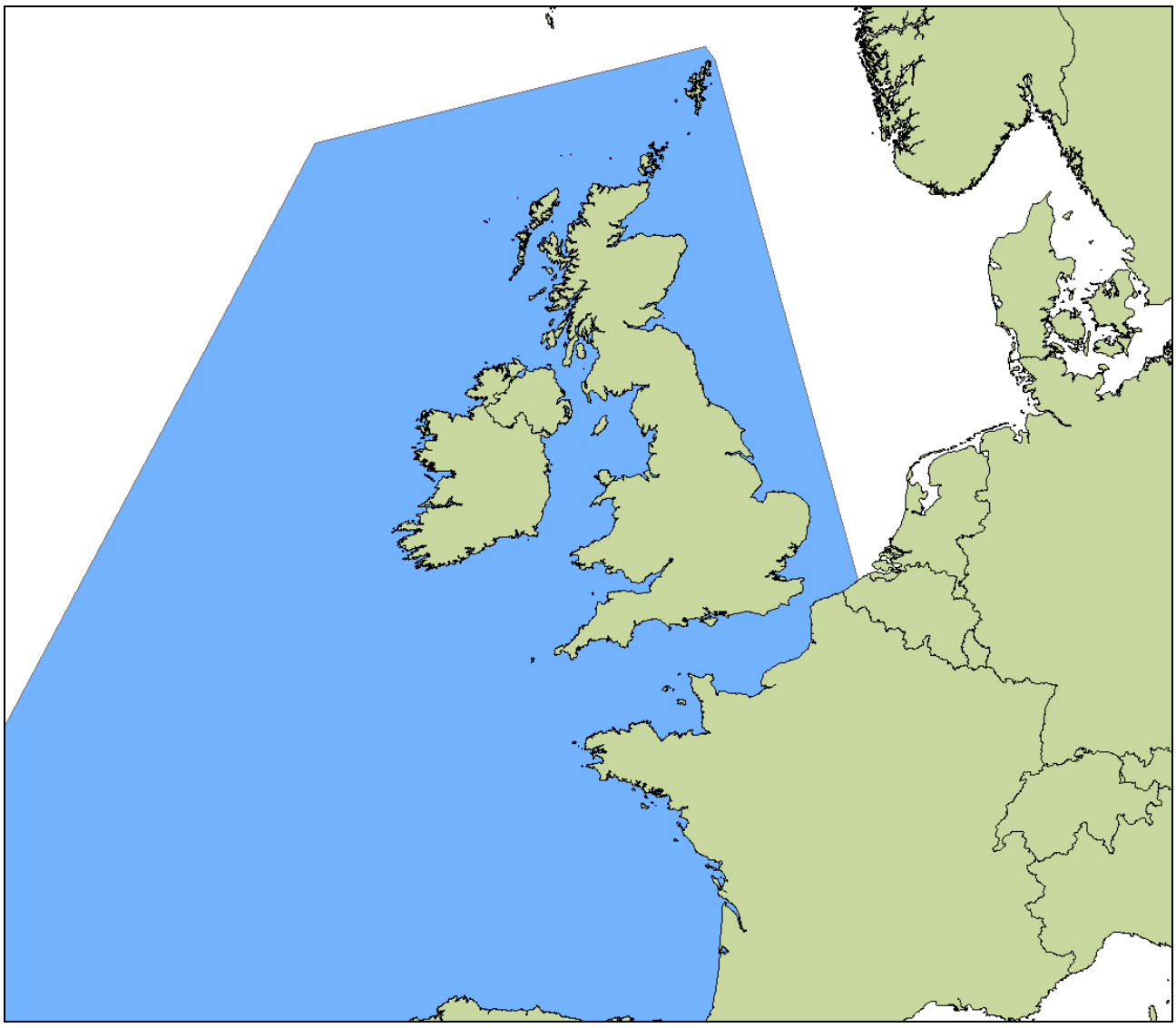
The blue area on this map shows the predicted migration zone potentially used by Turnstone that migrate to Britain and Ireland during the non-breeding season.

Turnstone that winter in the UK migrate from breeding grounds in northern Greenland and arctic Canada with a smaller number from Scandinavia. Birds from Greenland and Canada migrate via Iceland to the UK, arriving in autumn between late July and September, and some return from late February but the majority of spring migration occurs in April and May (Wernham *et al*. 2002). Smaller numbers of birds cross the North Sea to or from Scandinavia at similar times. Many Turnstone spend the whole winter in Britain but

there are also large numbers of passage birds that continue their migrations to sites further south in continental Europe or Africa, and many of these birds probably migrate via the English Channel. These migration patterns, and the fact that Turnstone are widespread around the UK coast, mean that Turnstone migration routes could potentially pass across any parts of UK waters. It is unclear whether Turnstone migrate on a broad front across UK waters or whether certain areas have higher densities of migrating birds, and further research could improve our understanding of this aspect of Turnstone migration and reduce the risk to consenting posed by the current lack of information regarding where these birds cross the sea.

Red-necked Phalarope *Phalaropus lobatus*

Red-necked Phalarope *Phalaropus lobatus*	
SPA Species?	Yes (breeding population)
SPA Sites	1 site (Fetlar)
Population Size (UK)	16 males
Population Size (International)	>1,000,000 (NW Eurasia)
Percentage of international population in UK	0.003%

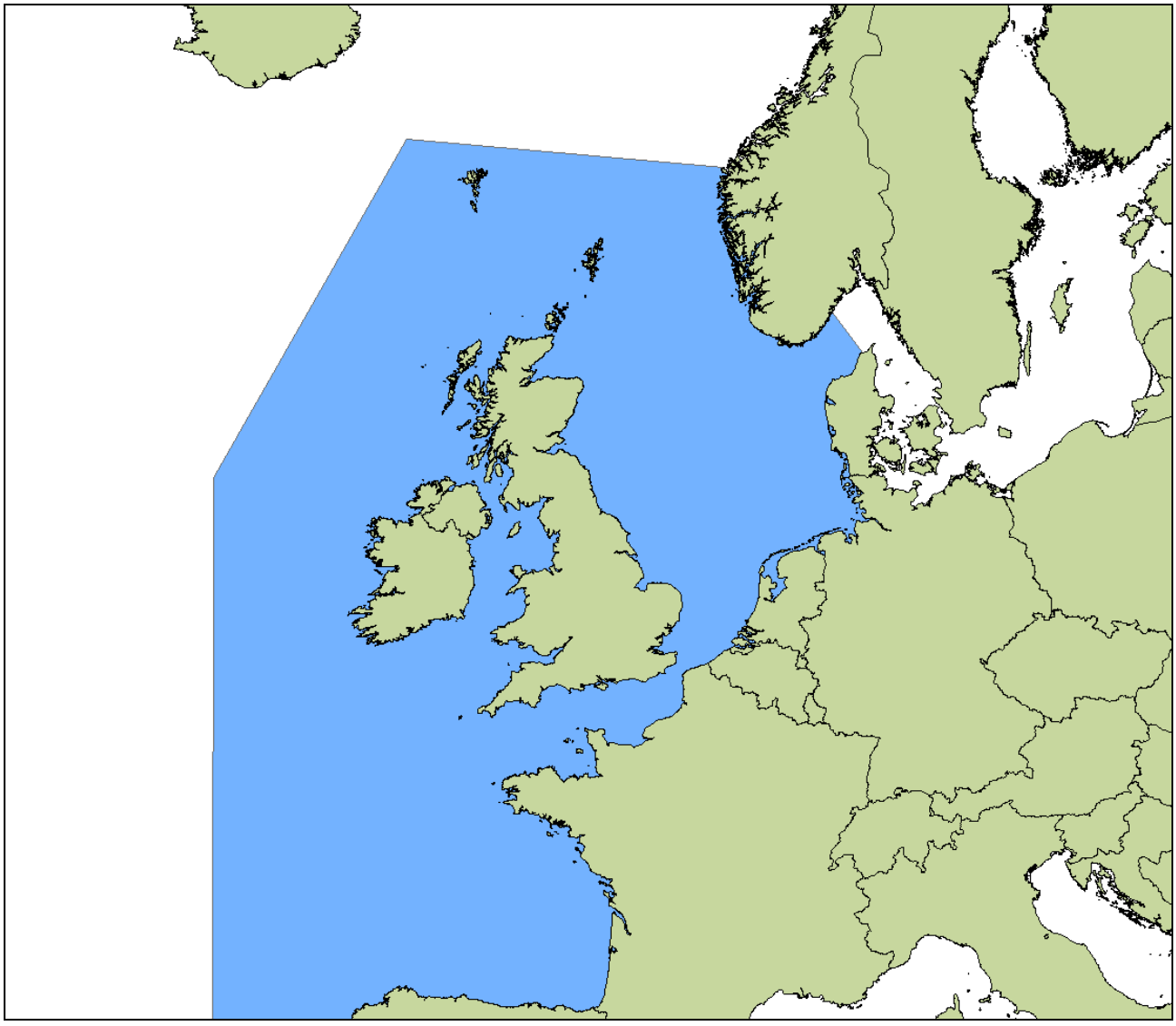


The blue area on this map shows the predicted migration zone potentially used by Red-necked Phalaropes that breed in the Fetlar SPA. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south and west.

A small number of Red-necked Phalaropes breed in Britain and Ireland and will pass across UK waters on migration to or from pelagic wintering areas. Spring passage occurs between mid-May and early June, mainly via the east coast, and autumn passage is from late June until September, again mainly via the east coast but some birds also occur in the west. As the numbers of birds of this species that migrate across UK waters is very small and represents a tiny fraction of the international population, passage migration of this species is not a priority for further research. The migration of breeding birds from the Fetlar SPA is unlikely to pose a risk to consenting in assessments for offshore wind farms.

Arctic Skua *Stercorarius parasiticus*

Arctic Skua *Stercorarius parasiticus*	
SPA Species?	Yes (breeding population)
SPA Sites	7 sites in Shetland and Orkney Isles
Population Size (UK)	2,136 breeding pairs
Population Size (International)	40,000-140,000 breeding pairs (Europe)
Percentage of international population in UK	1.5-5%

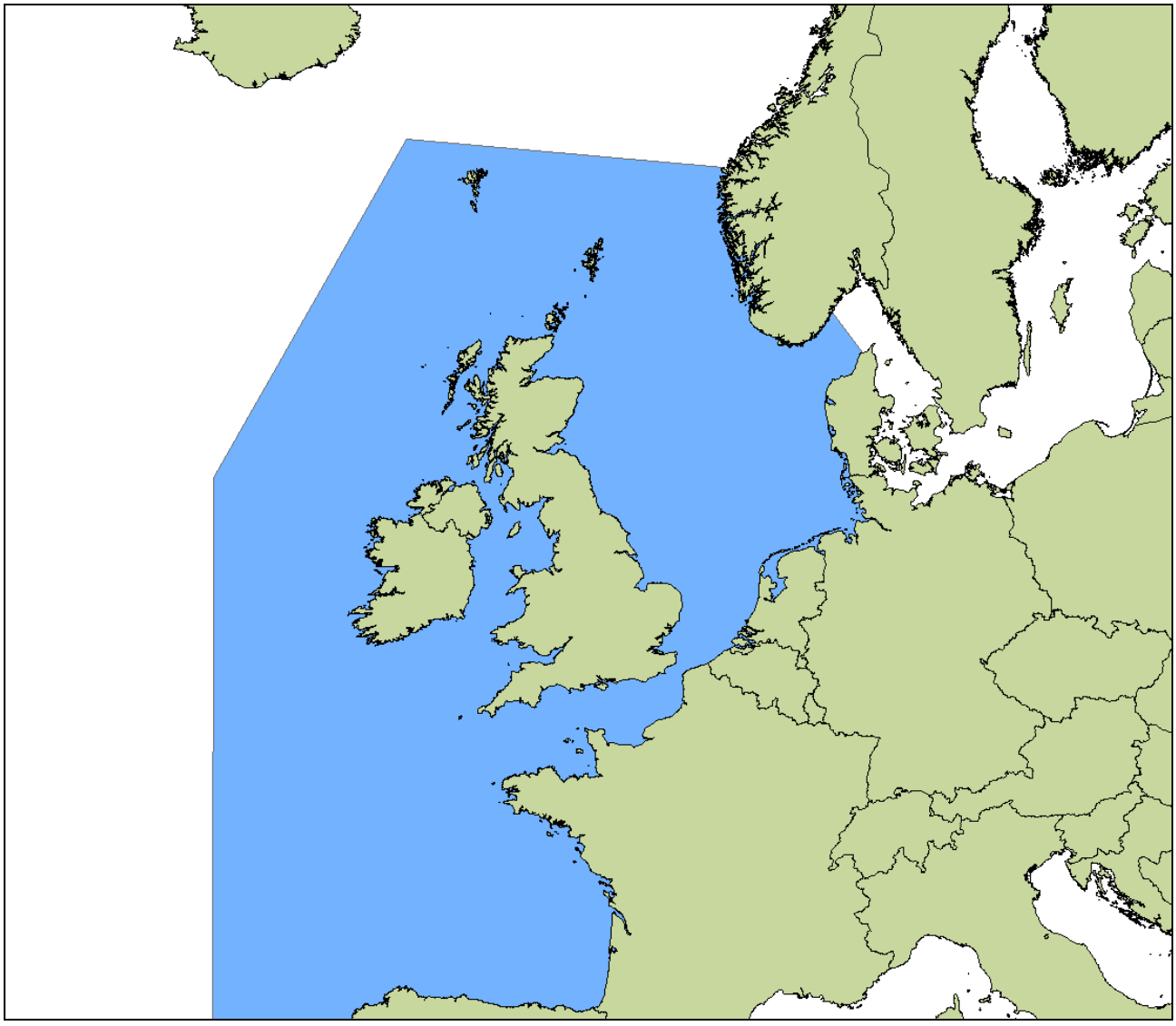


The blue area on this map shows the predicted migration zone potentially used by Arctic Skuas. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south and west.

A small number of Arctic Skuas breed in northern Scotland, which is at the southern edge of the breeding range. On leaving breeding sites in August, most of these birds probably follow a migration route through the North Sea (where migration peaks in August and September) and English Channel and then down the coasts of Europe and Africa, though some may cross the Atlantic to South American wintering grounds (Wernham *et al*. 2002). They tend to migrate and winter along coasts, and the birds that migrate along the coasts of Britain and Ireland comprise both UK-breeding birds and those that breed in the north of Europe (Wernham *et al*. 2002).

Great Skua *Stercorarius skua*

Great Skua *Stercorarius skua*	
SPA Species?	Yes (breeding population)
SPA Sites	9 sites on northern and northwest Scottish islands
Population Size (UK)	9,634 breeding pairs
Population Size (International)	16,000 breeding pairs
Percentage of international population in UK	60%



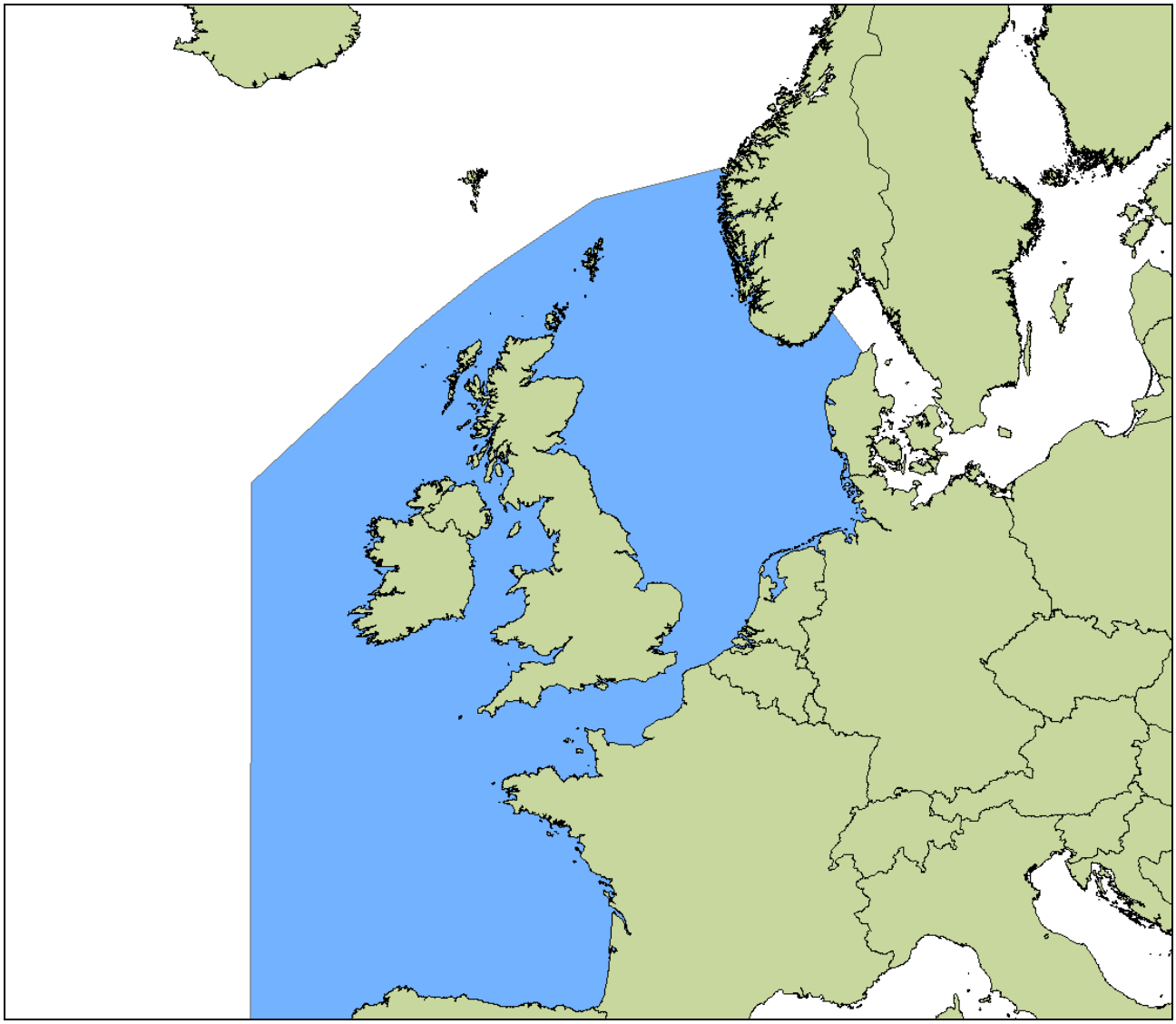
The blue area on this map shows the predicted migration zone potentially used by Great Skuas. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south and west.

Great Skuas breed at a few sites on islands to the north of Britain and migrate to wintering sites off the coasts of southern Europe. Birds from west coast colonies probably migrate down the west coast of Britain and Ireland, while those from colonies in the Orkney and Shetland Isles probably migrate via the North Sea before returning northward around the north coast of Scotland, and then heading south along the west coast and into the Atlantic. Immature birds that have visited colonies but not bred tend to migrate away from colonies in June and July, while breeding adults and juvenile birds leave colonies mainly in August, but with some remaining until October. Peak numbers on migration are in September in the North Sea and October to the west of Britain and Ireland. Great Skuas tend to avoid coasts when on migration, except

during periods of bad weather. Birds migrate slowly and may stay in areas with a good food supply for some time during migration. Spring migration peaks during March and April (Wernham *et al*. 2002). A number of tracking studies have recently been conducted, and are on-going, on Great Skuas, and data from these studies would be extremely valuable in improving understanding of the migration routes and flight heights of these birds, and thus reducing the consenting risk posed by the current gaps in knowledge.

Kittiwake *Rissa tridactyla*

Kittiwake *Rissa tridactyla*	
SPA Species?	Yes (breeding population)
SPA Sites	33 sites around UK, concentrated in Scotland
Population Size (UK)	379,892 breeding pairs
Population Size (International)	6,600,000 (E. Atlantic breeding)
Percentage of international population in UK	12%



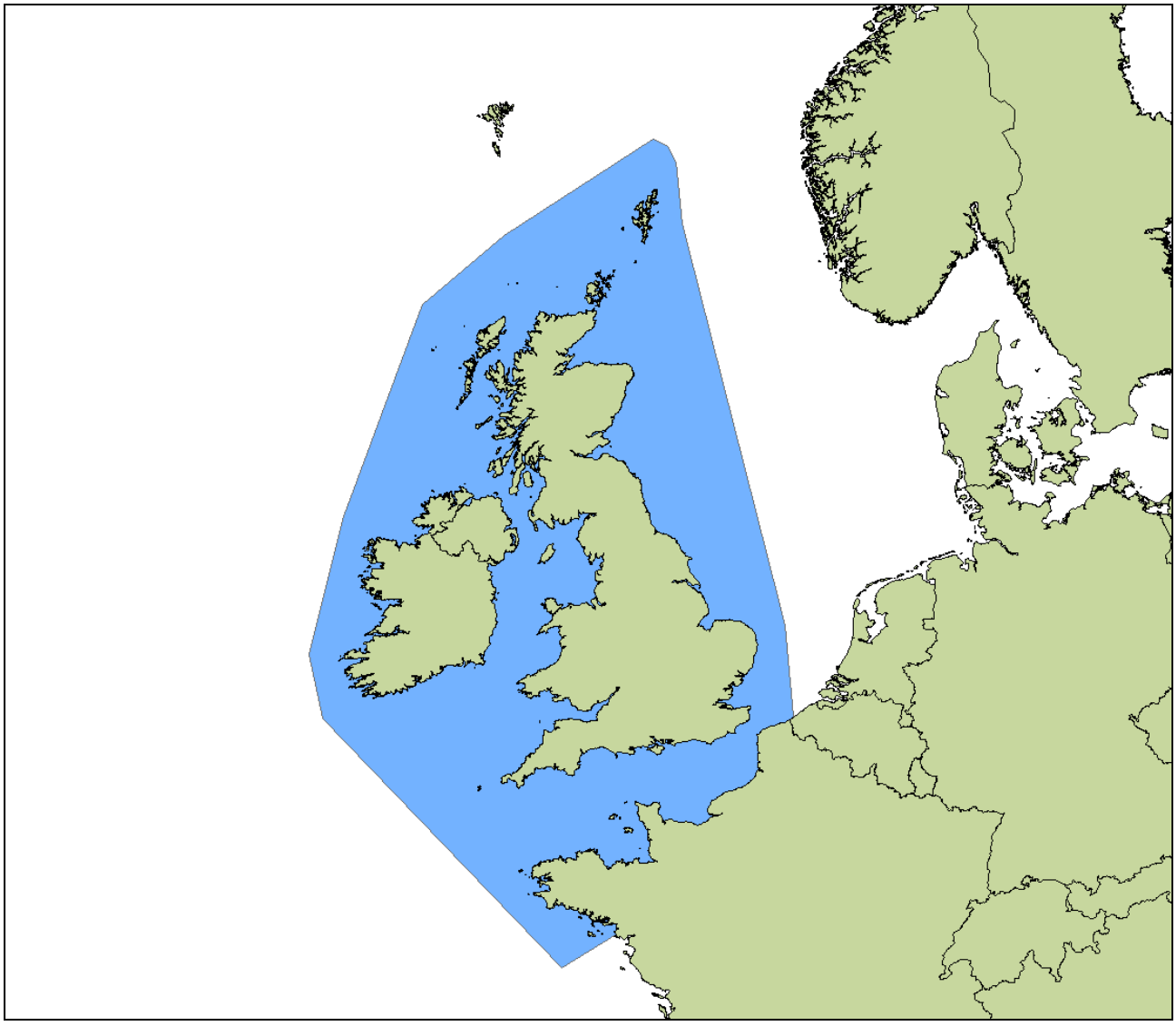
The blue area on this map shows the predicted migration zone potentially used by Kittiwakes that breed in the UK. Note that this only indicates likely directions of movement out of UK waters; birds may go well beyond the limits shown on this map, particularly to the south and west.

Kittiwakes that breed in the UK migrate to pelagic wintering grounds, either heading to the northwest Atlantic off Greenland and Newfoundland, to the mid-Atlantic, or heading to wintering sites in the east Atlantic off European coasts, sometimes via the North Sea. This means they can migrate in all directions past all coasts of Britain and Ireland Their distribution outside the breeding season is probably partly dependent on weather conditions and food supplies, and there can be large movements especially along North Sea coasts in response to certain weather conditions. A number of tracking studies have been carried out at breeding sites around Britain and Ireland in recent years, or are on-going. Data from these studies

will be valuable in improving understanding of the migration routes taken by birds from different SPA populations.

Black-headed Gull *Chroicocephalus ridibundus*

Black-headed Gull *Chroicocephalus ridibundus*	
SPA Species?	Yes (breeding population)
SPA Sites	4 sites in England and Northern Ireland
Population Size (UK)	138,014 breeding pairs
	2,200,000 (non-breeding individuals)
Population Size (International)	3,700,000-4,800,000 (W & C Europe breeding)
Percentage of international population in UK	6-7% (breeding)

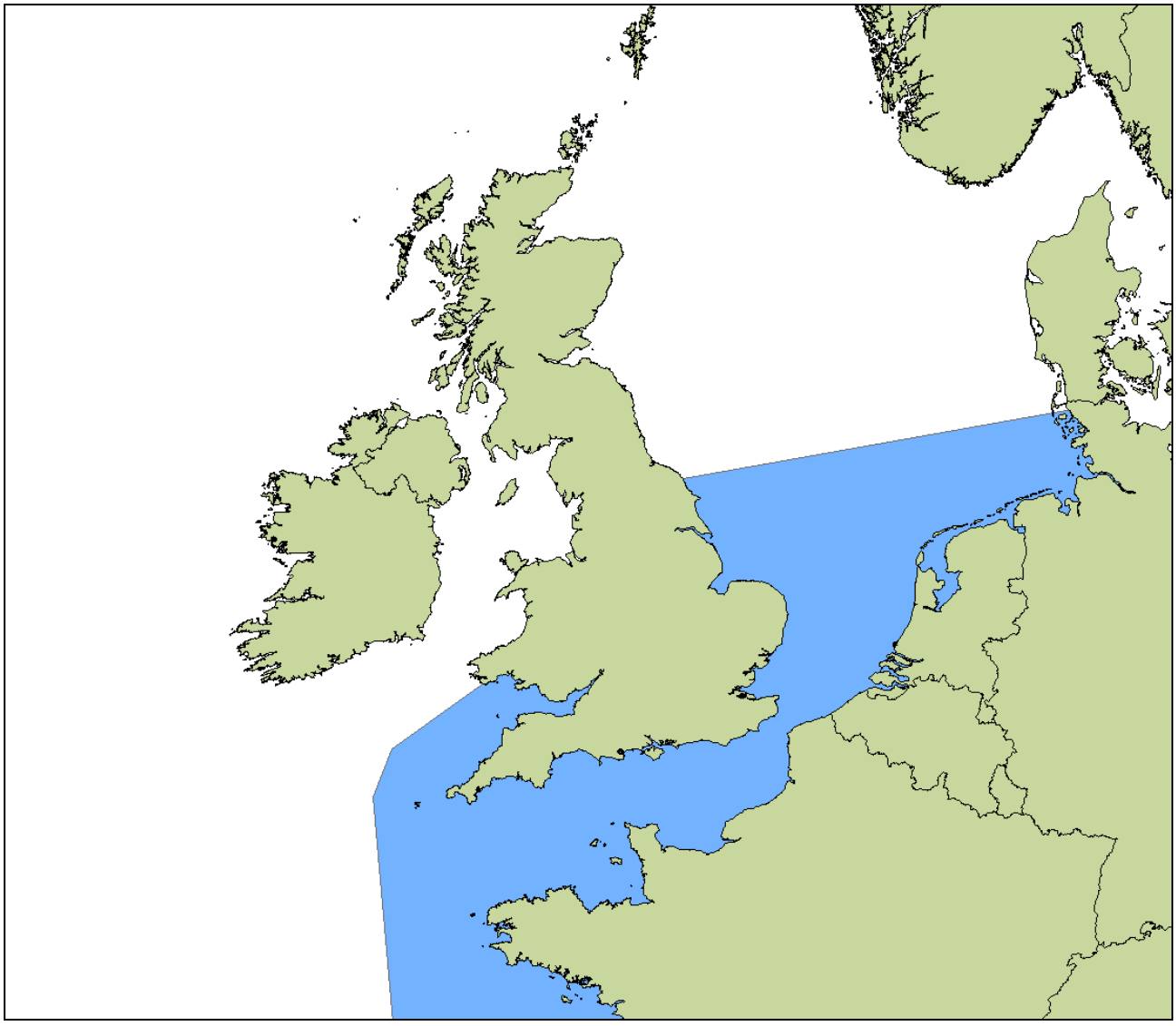


The blue area on this map shows the predicted migration zone potentially used by Black-headed Gulls that breed in the UK.

Most Black-headed Gulls that breed in the UK remain in Britain or Ireland during the winter, but a small proportion migrate southwards to wintering sites in France and Iberia (probably mostly crossing the English Channel), and some move across the Irish Sea between Britain and Ireland (Wernham *et al*. 2002). Quantifying the numbers of British-breeding birds that make these movements is difficult. A much larger number of Black-headed Gulls also migrates to the UK in the winter, from breeding sites in northern and eastern parts of continental Europe, along with some from Iceland, but there are no UK SPAs for the non-breeding population and so they are not considered here.

Mediterranean Gull *Larus melanocephalus*

Mediterranean Gull *Larus melanocephalus*	
SPA Species?	Yes (breeding)
SPA Sites	5 sites in south-east England
Population Size (UK)	110 breeding pairs 1,800 (non-breeding individuals)
Population Size (International)	50,000-120,000
Percentage of international population in UK	0.2-0.4% (breeding)

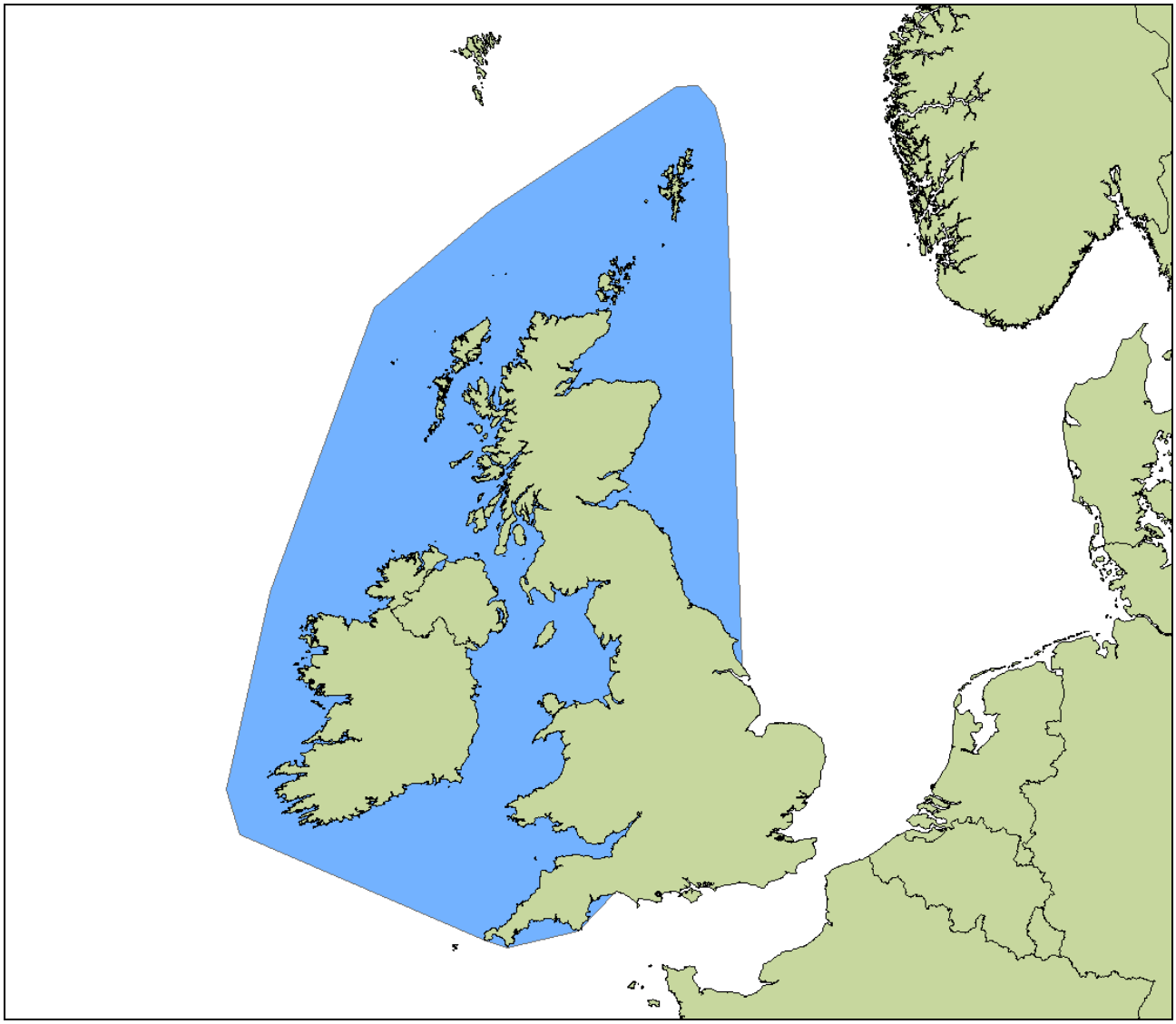


The blue area on this map shows the predicted migration zone potentially used by Mediterranean Gulls.

A very small number of Mediterranean Gulls breed in the UK, which is at the north-western limit of their breeding range. The wintering sites of birds breeding in the UK are not well known, but they are likely to winter around the English Channel or southern North Sea, close to breeding colonies. The map shows the extent of known movements between southern Britain and elsewhere. The migration of breeding Mediterranean Gulls from UK SPA populations is most likely to be of concern at proposed offshore wind farm sites close to the SPAs for this species in southern England.

Common Gull *Larus canus*

Common Gull *Larus canus*	
SPA Species?	Yes (breeding population)
SPA Sites	3 sites in Northern Ireland and Scotland
Population Size (UK)	48,720 breeding pairs 700,000 (non-breeding individuals)
Population Size (International)	1,200,000-2,250,000 (*canus*)
Percentage of international population in UK	4-8% (breeding) 15-29% (non-breeding)

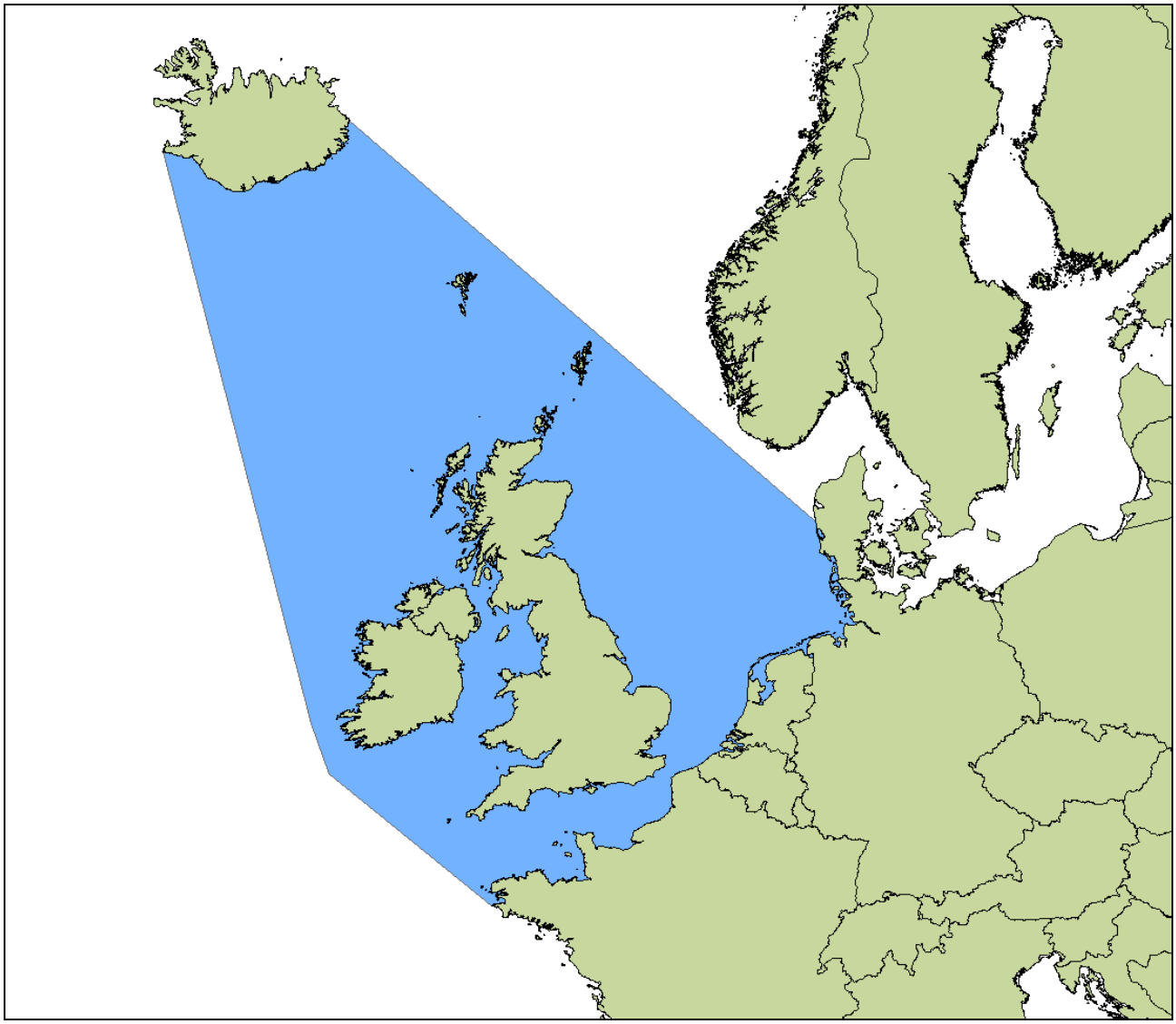


The blue area on this map shows the predicted migration zone potentially used by Common Gulls breeding in the UK.

Common Gulls breeding in Britain and Ireland are partial migrants, with some being fairly sedentary while others move in a south or south-westerly direction from breeding sites, but with most (except for a very small number of juveniles) remaining within Britain and Ireland (Wernham *et al.* 2002). These birds are joined in winter by a large influx of birds from Scandinavia and northern parts of continental Europe, with ringing recoveries suggesting that these birds cross the North Sea anywhere between Kent and Shetland. However, as there are no SPAs designated for wintering Common Gulls these are not considered further here.

Lesser Black-backed Gull *Larus fuscus*

Lesser Black-backed Gull *Larus fuscus*	
SPA Species?	Yes (breeding population)
SPA Sites	10 sites around the UK
Population Size (UK)	110,101 breeding pairs 120,000 (non-breeding individuals)
Population Size (International)	530,000-570,000 (*graellsii*)
Percentage of international population in UK	39-42%



The blue area on this map shows the predicted migration zone potentially used by Lesser Black-backed Gulls that breed at UK SPA sites.

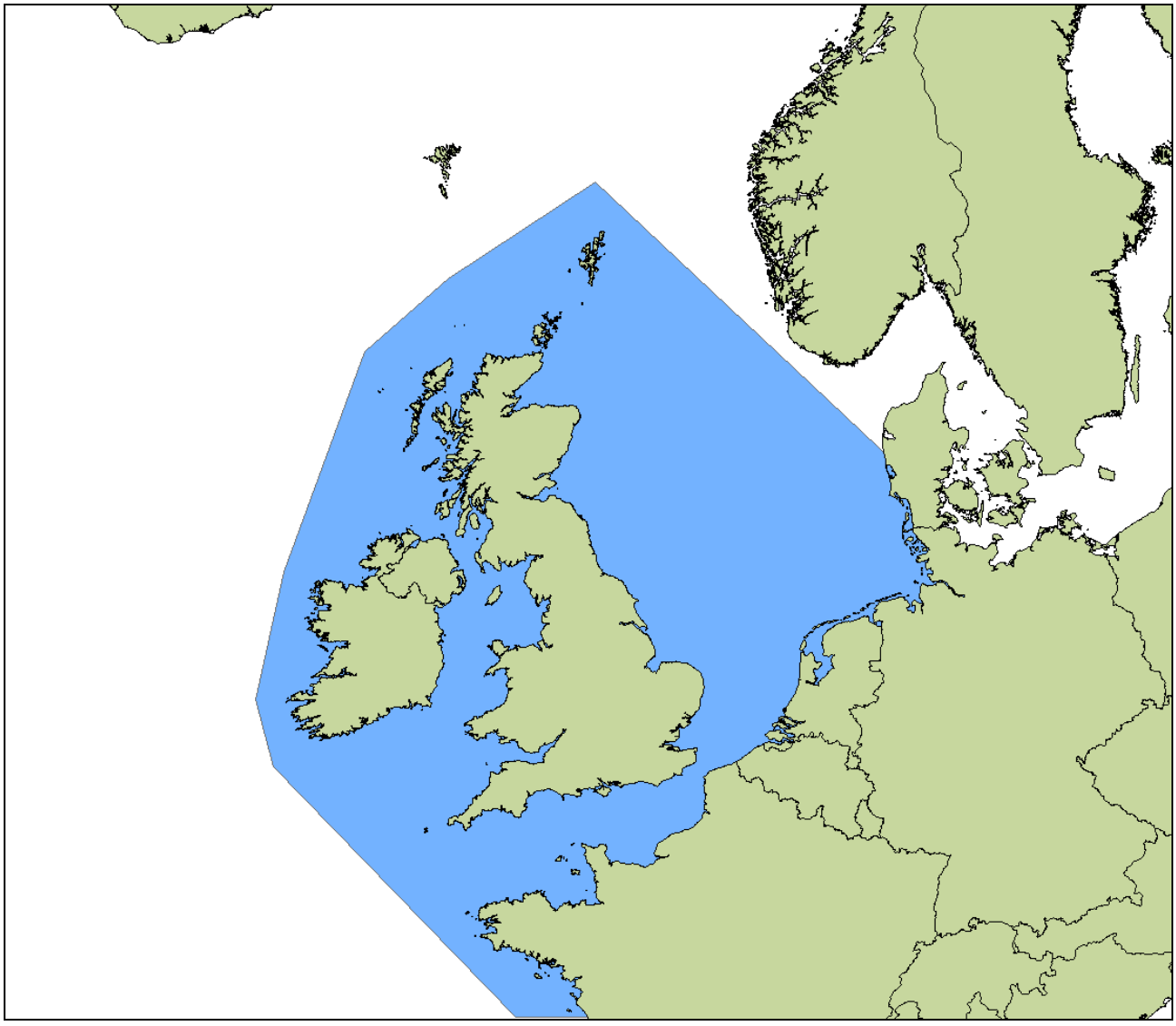
A large proportion of the *graellsii* race of Lesser Black-backed Gull breeds in Britain and Ireland. The majority of these birds move out of the UK to the south or south-west in winter, migrating along the western coast of Europe to wintering sites on the coasts of Iberia and north-west Africa, although some stay in Britain. Many of these birds have been the subject of long-term colour-ringing schemes so their destinations are relatively well known; however there is less information about the precise routes taken to reach them. Recent and on-going work using GPS tracking has provided more detailed information regarding the migration routes of a small sample of birds, and data from these studies may be of use in

assessments. The systems used in these tracking studies also record the altitude of birds therefore providing information that can be used to estimate the flight heights of migrating Lesser Black-backed Gulls.

In addition to British-breeding birds, a large number of birds from other populations visit the UK during the non-breeding season, migrating from Iceland or, in larger numbers, across the North Sea from Scandinavia. However, as there are no SPAs designated for non-breeding Lesser Black-backed Gulls these are not considered further here.

Herring Gull *Larus argentatus*

Herring Gull *Larus argentatus*	
SPA Species?	Yes (breeding population)
SPA Sites	12 sites around coasts of England, Scotland and Northern Ireland
Population Size (UK)	139,309 breeding pairs
	730,000 (non-breeding individuals)
Population Size (International)	990,000-1,050,000 (*argenteus*)
Percentage of international population in UK	27-28% (breeding)



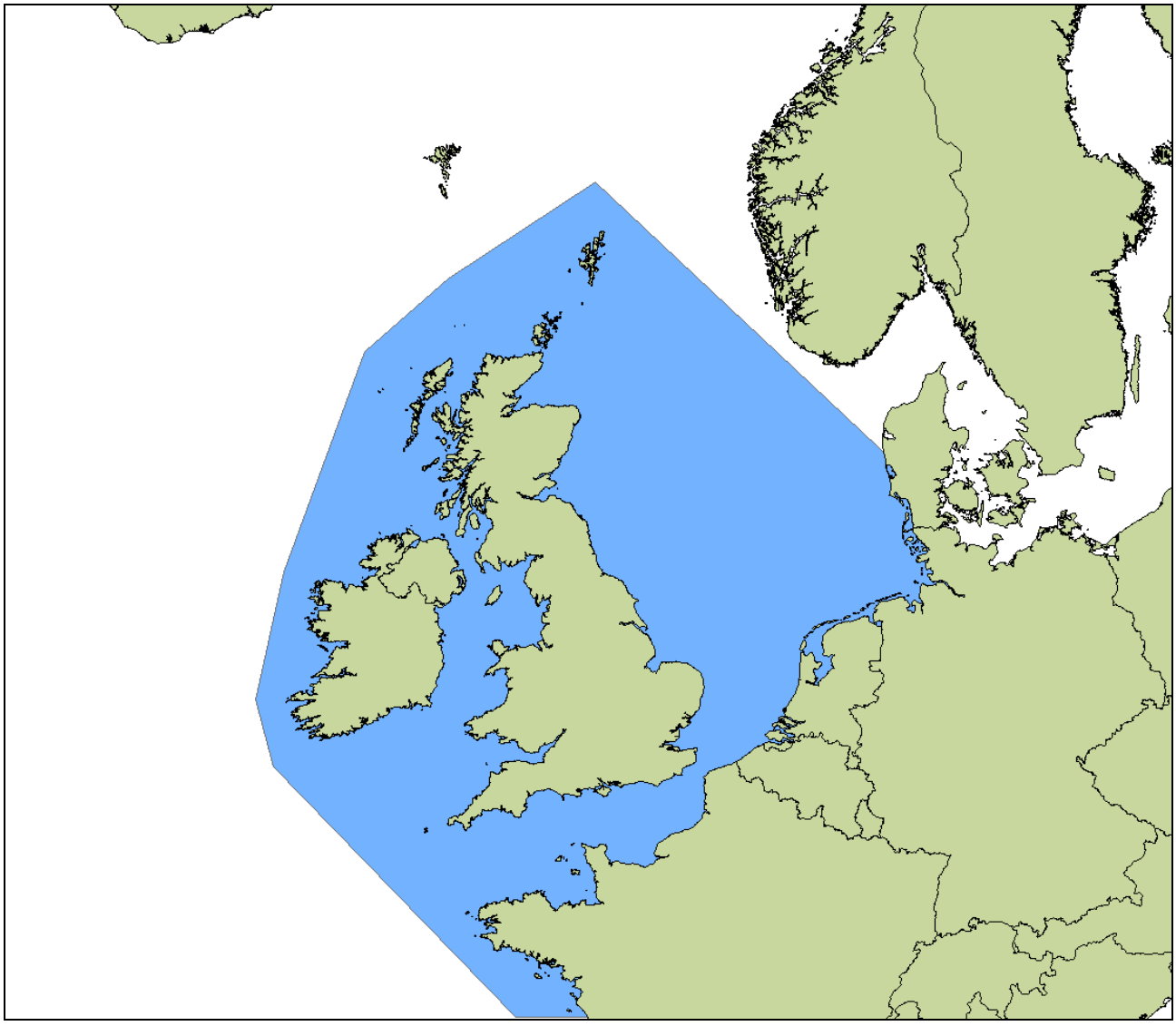
The blue area on this map shows the predicted migration zone potentially used by Herring Gulls that breed at UK SPA sites.

Herring Gulls that breed in Britain and Ireland are largely sedentary or only make small within-country movements between breeding and wintering sites. However, some of these birds make sea crossings between Britain and Ireland or between Britain and the near-continent (Wernham *et al*. 2002), crossing the areas shown in the map above. For the purposes of assessment a precautionary assumption might be that between 10% and 25% of the British and Irish breeding population might migrate across the routes shown in the map above.

In winter, there is an influx of birds from breeding sites around the coasts of north-western continental Europe and Scandinavia, migrating across the North Sea from Shetland to Kent and the English Channel. However, as there are no SPAs for non-breeding Herring Gulls, these birds are not considered further here and this route is not shown on the map.

Great Black-backed Gull *Larus marinus*

Great Black-backed Gull *Larus marinus*	
SPA Species?	Yes (breeding population)
SPA Sites	6 sites in northern Scotland and Isles of Scilly
Population Size (UK)	17,160 breeding pairs
	76,000 (non-breeding individuals)
Population Size (International)	330,000-540,000 (NE Atlantic)
Percentage of international population in UK	6-10%



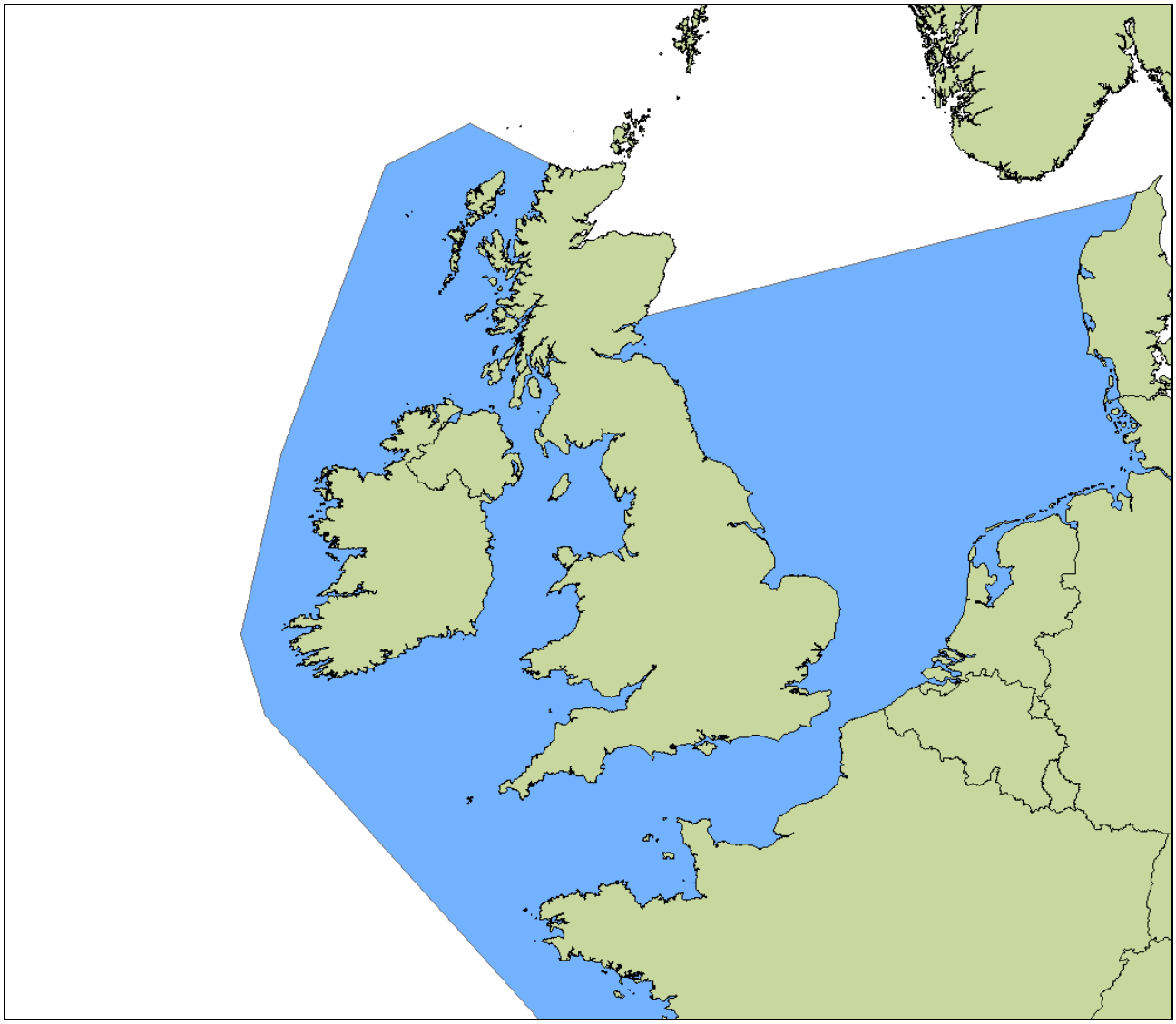
The blue area on this map shows the predicted migration zone potentially used by Great Black-backed Gulls that breed at UK SPA sites.

Great Black-backed Gulls that breed in Britain and Ireland are largely sedentary or only make small within-country movements between breeding and wintering sites. However, some of these birds make sea crossings between Britain and Ireland or between Britain and the continental Europe (Wernham *et al*. 2002), crossing the areas shown in the map above. For the purposes of assessment a precautionary assumption might be that between 10% and 25% of the British and Irish breeding population might migrate across the routes shown in the map above.

In winter, there is an influx of birds, mainly from breeding sites around the coasts of Scandinavia, migrating across the North Sea from Shetland to Kent. However, as there are no SPAs for non-breeding Great Black-backed Gulls, these birds are not considered further here and this route is not shown on the map.

Little Tern *Sternula albifrons*

Little Tern *Sternula albifrons*	
SPA Species?	Yes (breeding population)
SPA Sites	27 coastal sites around Britain
Population Size (UK)	1,947 breeding pairs
Population Size (International)	16,500-22,600 (*albifrons* Europe N of Mediterranean)
Percentage of international population in UK	17-24%

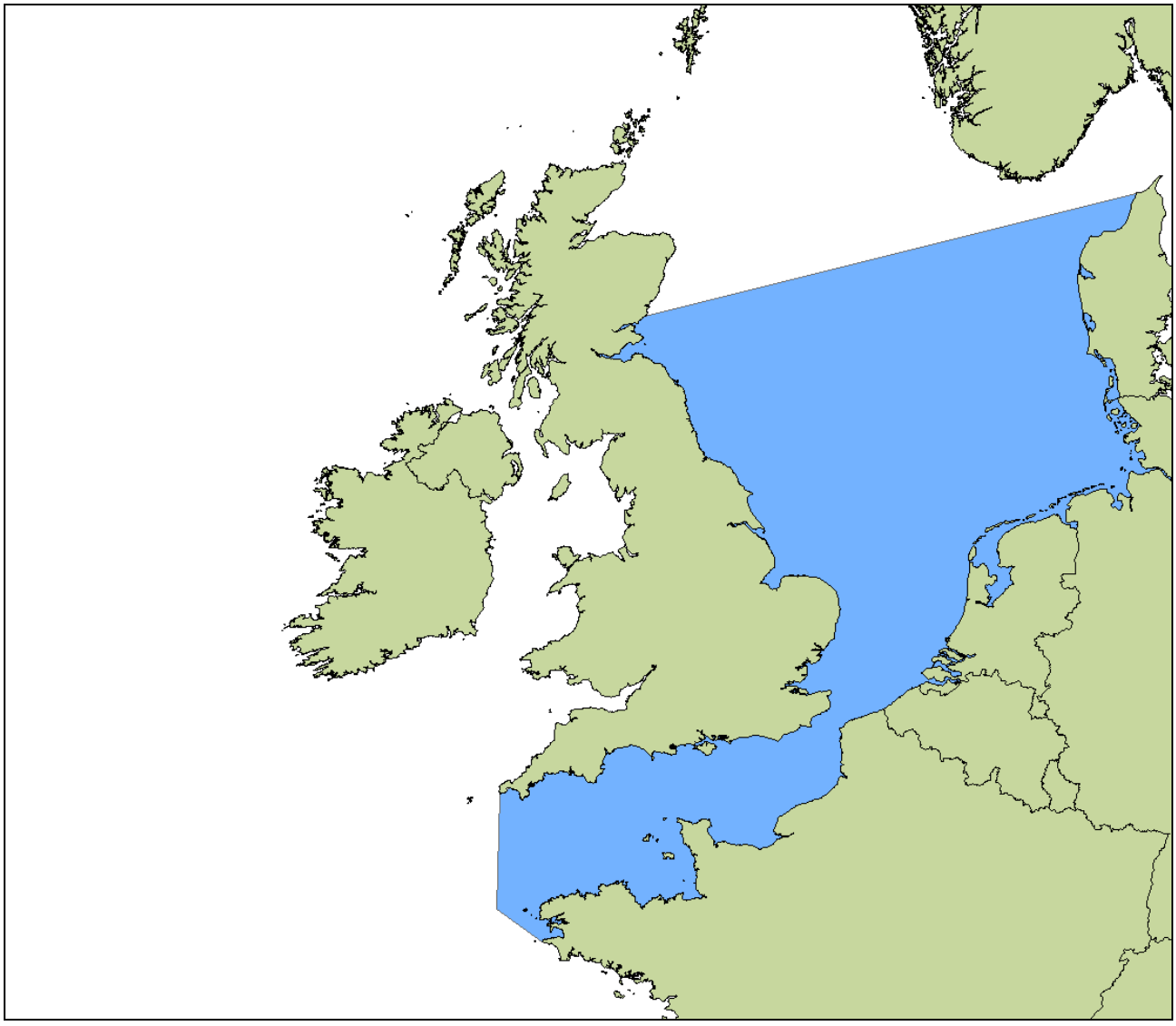


The blue area on this map shows the predicted migration zone potentially used by Little Terns that breed at UK SPA sites.

All Little Terns that breed in the UK migrate to and from wintering sites off western Africa, probably via the western coasts of Europe, leaving the UK along the routes shown in the map above. After the breeding season, birds may migrate directly towards wintering sites, or some may go via staging sites on the coast of the Netherlands in August (Wernham *et al*. 2002). The precise routes taken by this species, and the timing of its migration, are relatively poorly understood.

Black Tern *Childonias niger*

Black Tern *Childonias niger*	
SPA Species?	No but Annex 1
SPA Sites	None
Population Size (UK)	Unknown
Population Size (International)	500,000-1,000,000 (*niger*)
Percentage of international population in UK	Unknown

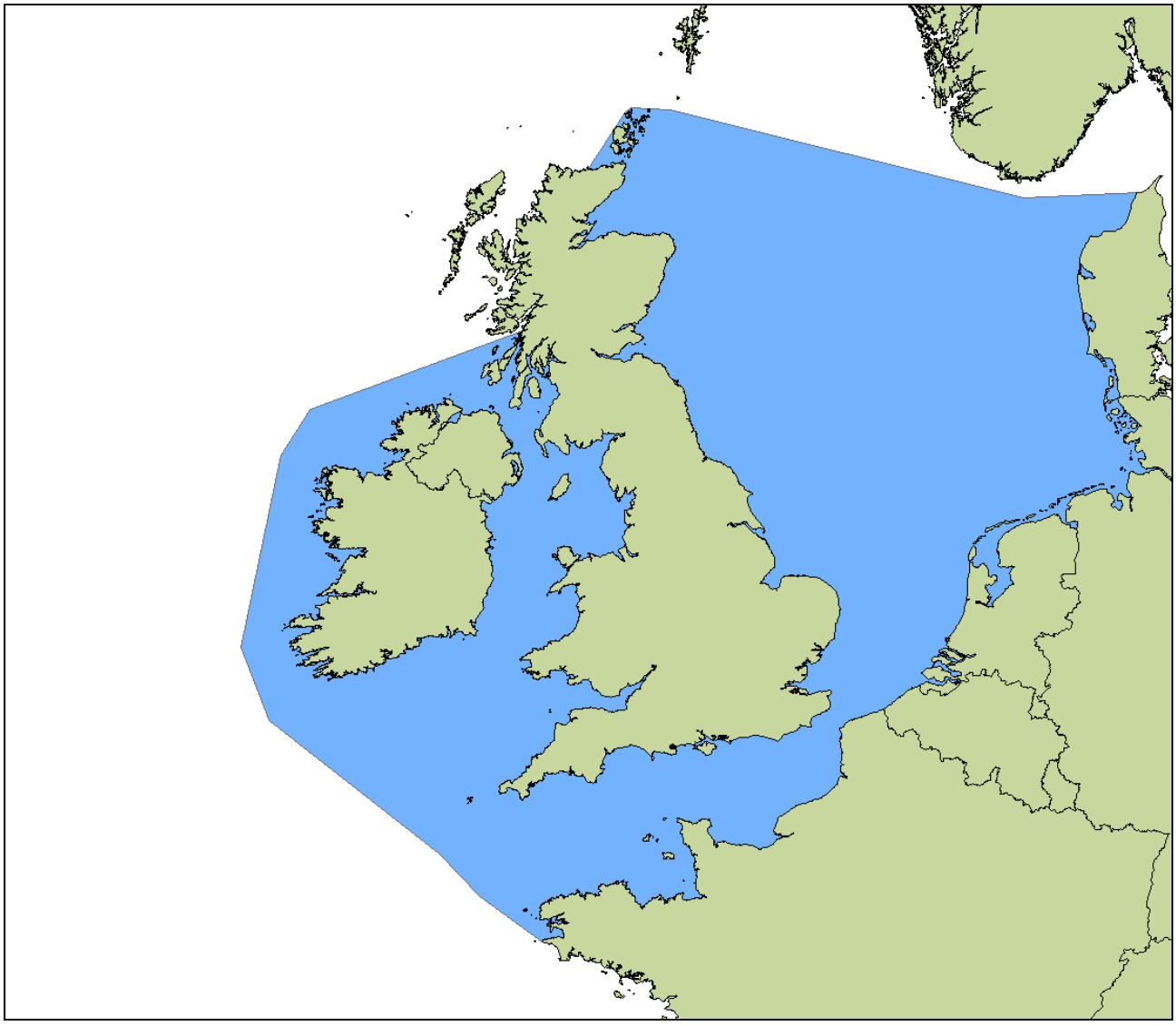


The blue area on this map shows the predicted migration zone potentially used by Black Terns that migrate via UK waters.

Black Terns are not designated features of any UK SPAs and do not either breed or winter in the UK, but they are an Annex 1 species and significant numbers occur in UK waters on passage migration (between breeding sites in continental Europe and wintering sites on the coast of West Africa), especially during periods of easterly wind in spring and autumn. The numbers passing through UK waters, and the routes taken, are poorly understood.

Sandwich Tern *Sterna sandvicensis*

Sandwich Tern *Sterna sandvicensis*	
SPA Species?	Yes (breeding and passage populations)
SPA Sites	16 coastal sites around the UK (breeding)
	3 sites (passage)
Population Size (UK)	12,490 breeding pairs
Population Size (International)	166,000-171,000 (*sandvicensis* W. Europe)
Percentage of international population in UK	15%

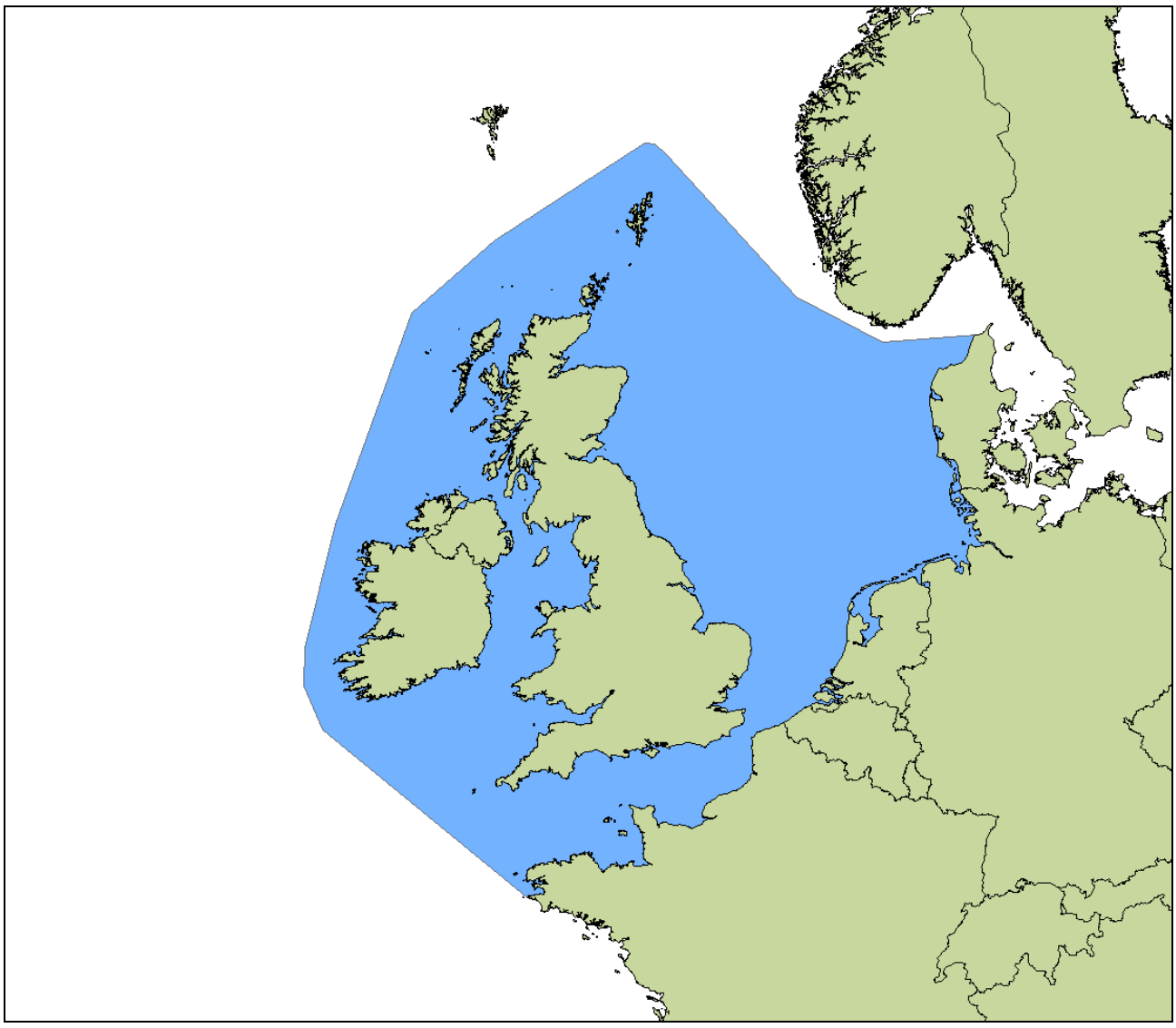


The blue area on this map shows the predicted migration zone potentially used by Sandwich Terns that breed at UK SPA sites or travel via UK SPAs on passage migration.

SPAs are designated for both the breeding and passage population of Sandwich Terns in the UK, which spend the winter in West Africa. After the breeding season, birds disperse around the coasts of Britain and Ireland and across the North Sea to the Netherlands and Denmark in late-June, July and August (Wernham *et al*. 2002). Return migration occurs between March and May and is more direct than in autumn, with many fewer birds going via the eastern North Sea. Around 42,000 birds are thought to pass through the UK on migration.

Common Tern *Sterna hirundo*

Common Tern *Sterna hirundo*	
SPA Species?	Yes (breeding population)
SPA Sites	22 sites around the UK
Population Size (UK)	11,838 breeding pairs
Population Size (International)	160,000-200,000 (*hirundo* S & W Europe)
Percentage of international population in UK	12-15%

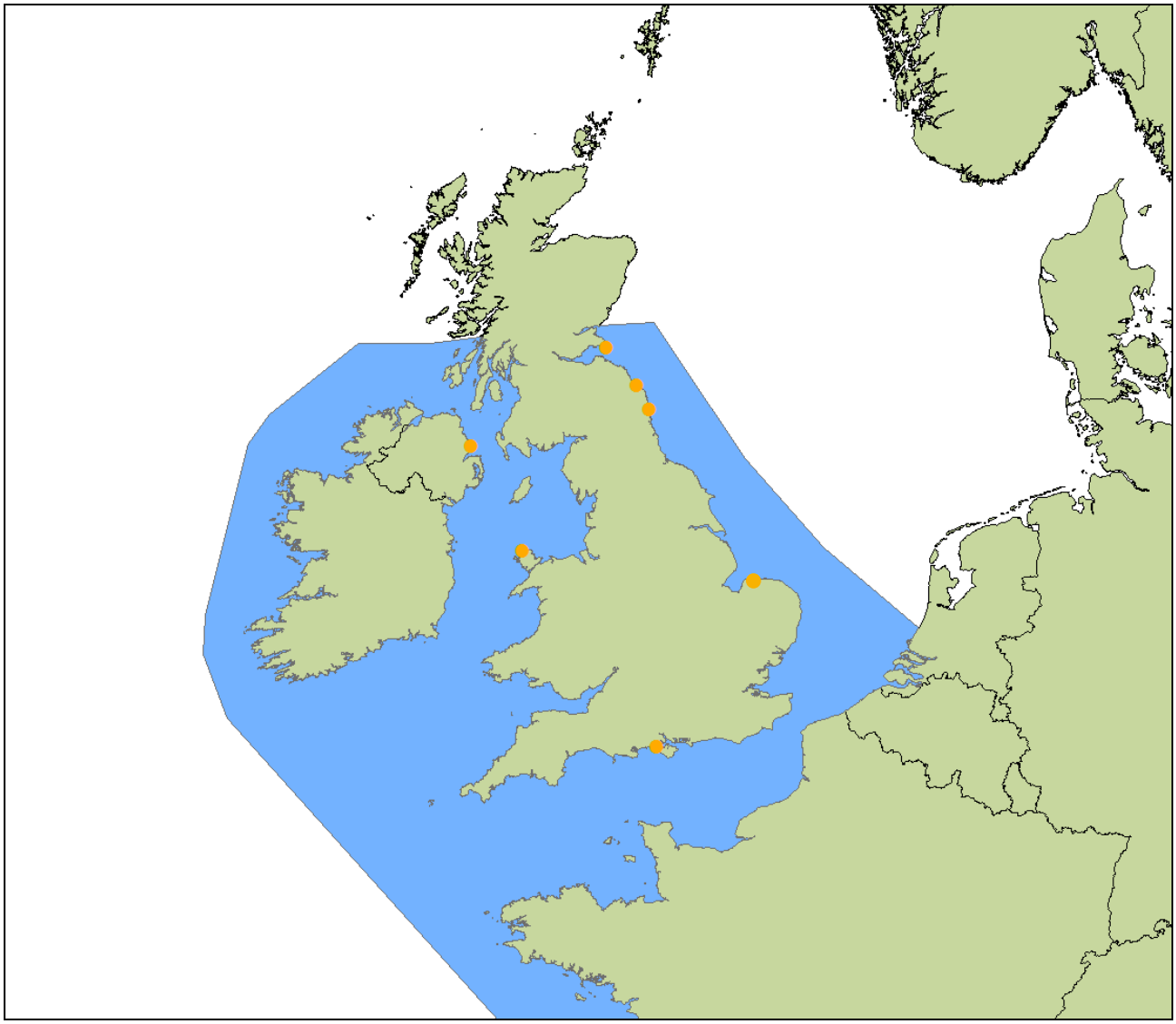


The blue area on this map shows the predicted migration zone potentially used by Common Terns that breed at UK SPA sites.

Common Terns breeding in the UK migrate via the western coasts of Europe to wintering grounds on the west coast of Africa. Post-fledging dispersal of juveniles occurs between July and October, with adults migrating mainly between August and October. They return to breeding sites in Britain and Ireland during April and May (Wernham *et al*. 2002). In addition to the native breeding population, many Common Terns from populations that breed in northern mainland Europe migrate via the UK on passage. However, as no SPAs are designated for non-breeding Common Terns these birds are not considered here and their migration routes are not shown on the map.

Roseate Tern *Sterna dougallii*

Roseate Tern *Sterna dougallii*	
SPA Species?	Yes (breeding population)
SPA Sites	7 sites around the UK coast
Population Size (UK)	56 breeding pairs
Population Size (International)	5,400-5,700 (*dougallii* W. Europe)
Percentage of international population in GB	2%

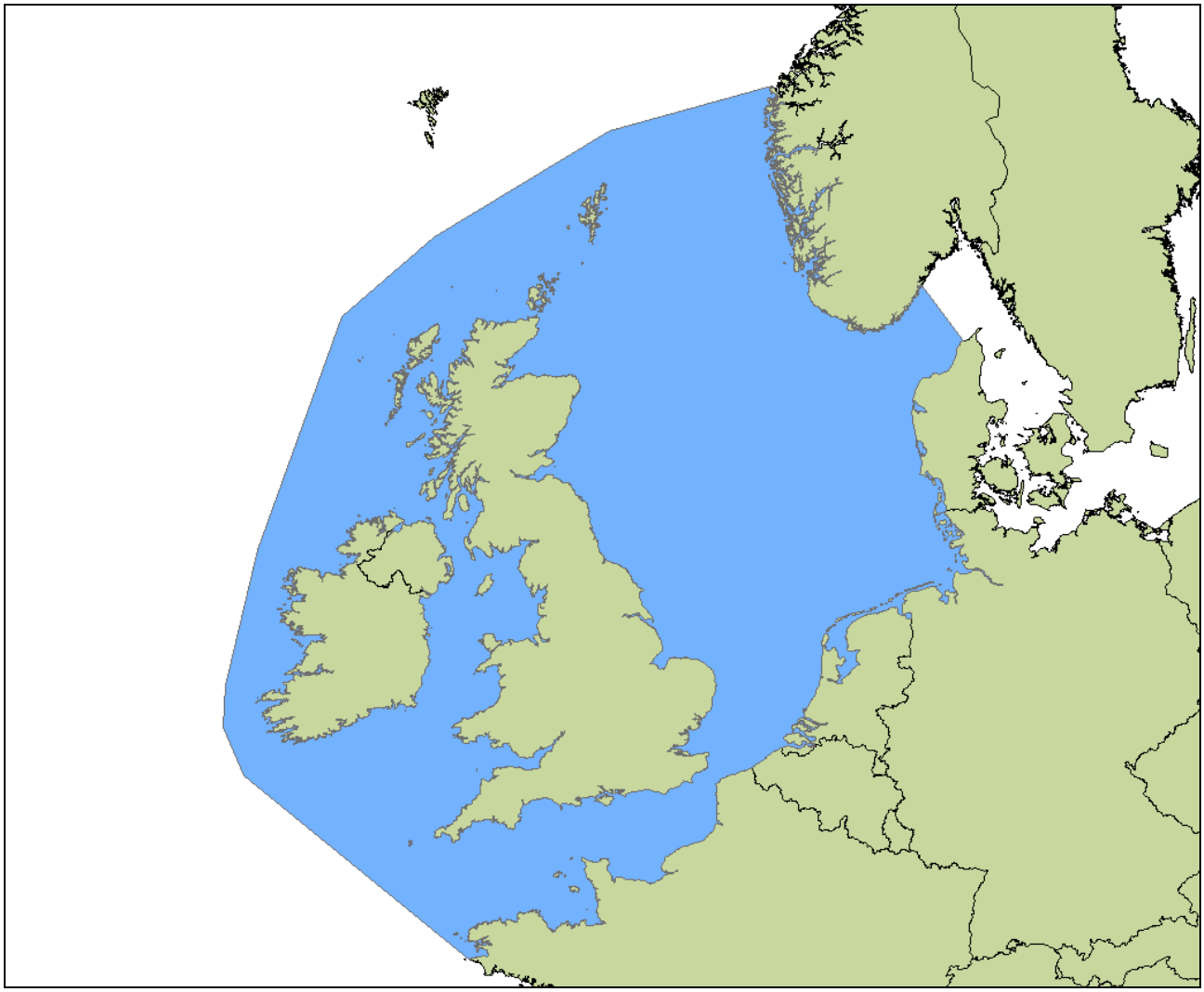


The blue area on this map shows the predicted migration zone potentially used by Roseate Terns that breed at UK SPA sites, while orange dots show the locations of these SPAs.

Only a small number of Roseate Terns breed in the UK and the majority of the population breeds in the 7 SPAs for which this species is designated (Stroud *et al*. 2001). As with other tern species, Roseate Terns migrate southwards in the non-breeding season, via the western coasts of Europe to wintering sites on the west coast of Africa. They arrive on colonies from May to July and depart in August to staging sites, with many birds from colonies around the Irish Sea congregating in Dublin Bay before onward southerly migration during September and October.

Arctic Tern *Sterna paradisaea*

Arctic Tern *Sterna paradisaea*	
SPA Species?	Yes (breeding population)
SPA Sites	17 coastal sites, most in the Northern Isles
Population Size (UK)	53,388 breeding pairs
Population Size (International)	>1,000,000 (W. Eurasia)
Percentage of international population in UK	<11%

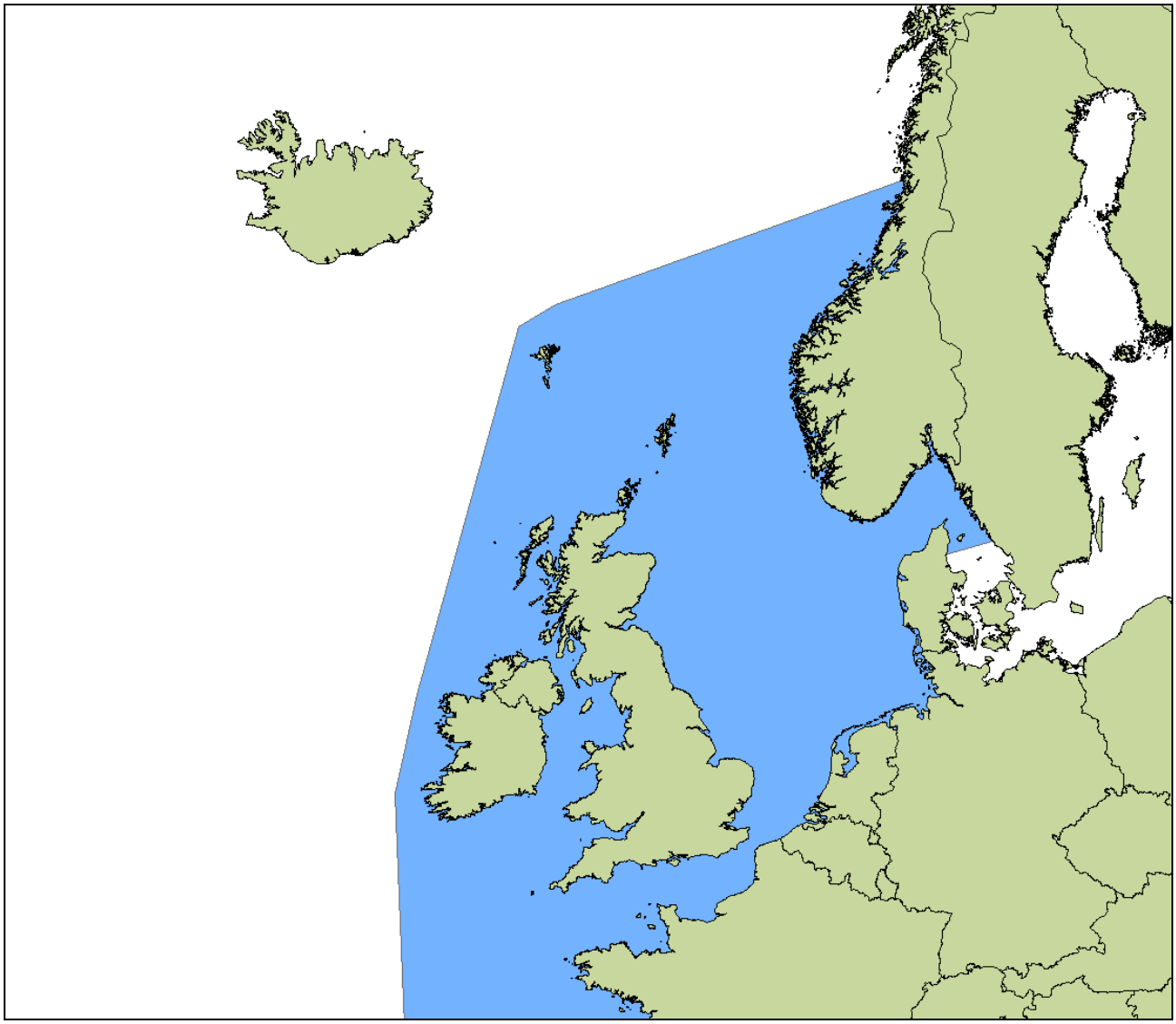


The blue area on this map shows the predicted migration zone potentially used by Arctic Terns that breed at UK SPA sites.

Britain and Ireland is at the southern edge of the breeding range of this species, and colonies are concentrated in the north of the country. Following breeding, birds migrate southwards, probably mainly offshore, via the coast of western and southern Africa to wintering sites around the Antarctic. A similar route is followed on return migration in spring. Birds are occasionally observed to migrate over land in the UK, perhaps in response to adverse conditions. Some juveniles make post-fledging movements across the North Sea before migrating southwards. Passage migration of birds that breed outside the UK is not shown here, as there are no SPAs designated for non-breeding birds.

Guillemot *Uria aalge*

Guillemot *Uria aalge*	
SPA Species?	Yes (breeding population)
SPA Sites	34 coastal sites around the UK
Population Size (UK)	1,420,900 breeding individuals
Population Size (International)	2,000,000-2,700,000 breeding pairs (Europe)
Percentage of international population in UK	26-36%

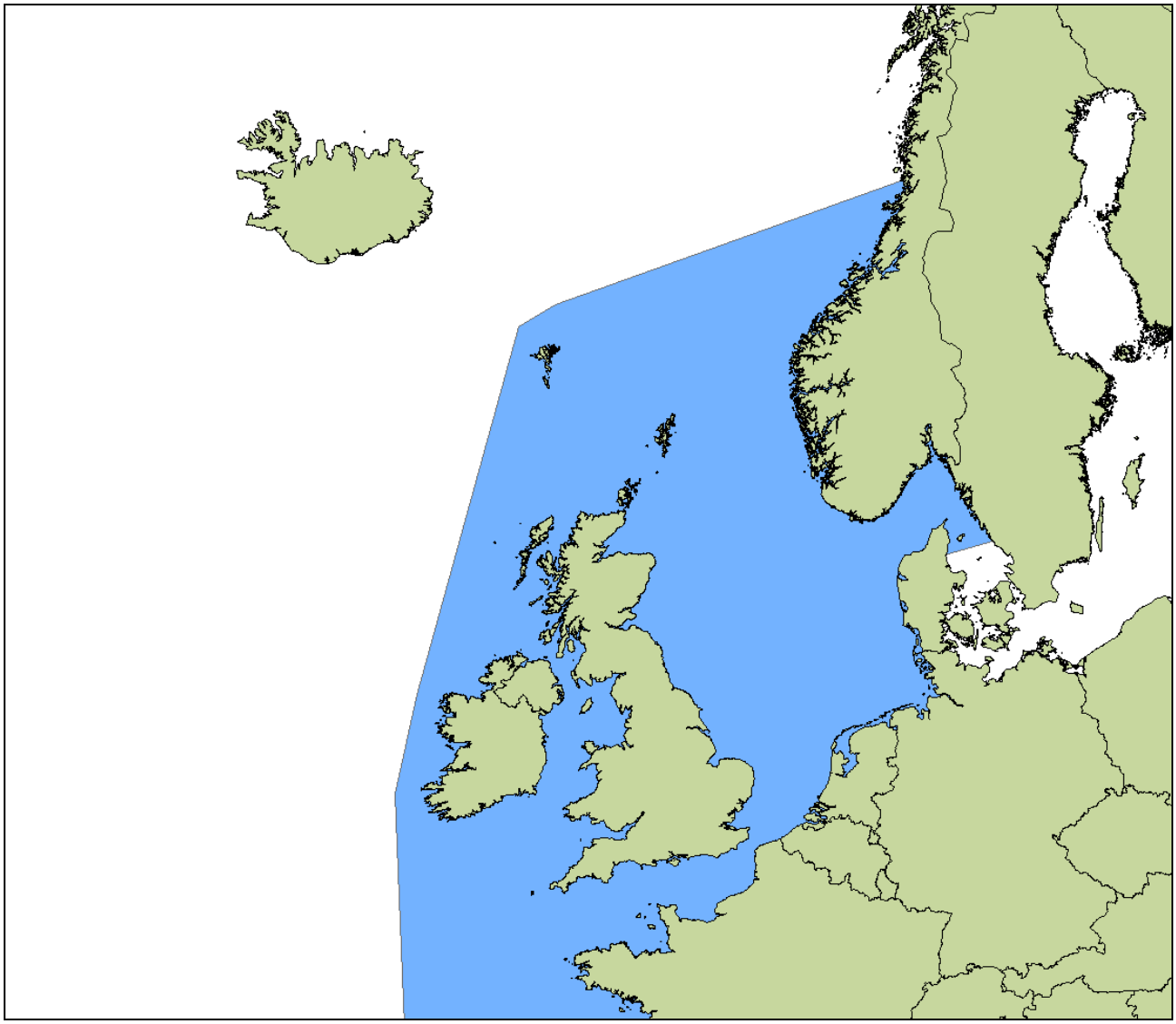


The blue area on this map shows the predicted dispersive zones potentially used by Guillemots that breed at UK SPA sites.

Guillemots are dispersive rather than migratory, with the birds breeding at sites around Britain and Ireland dispersing to the surrounding seas during the non-breeding season. In addition to the areas shown on the map, some birds may also disperse as far north as Iceland or as far south as Gibraltar, but they tend to avoid deep oceanic areas and stick to the continental shelf (Wernham *et al*. 2002). The presence of this species in proposed wind farm development zones at different times of year is probably better assessed using boat- and aerial-survey data. Information from a number of recent and on-going tracking studies will provide useful insight into the dispersal of birds from particular colonies.

Razorbill *Alca torda*

Razorbill *Alca torda*	
SPA Species?	Yes (breeding population)
SPA Sites	19 sites around UK coasts, most in Scotland
Population Size (UK)	188,576 breeding individuals
Population Size (International)	430,000-770,000 breeding pairs (Europe)
Percentage of international population in UK	12-22%



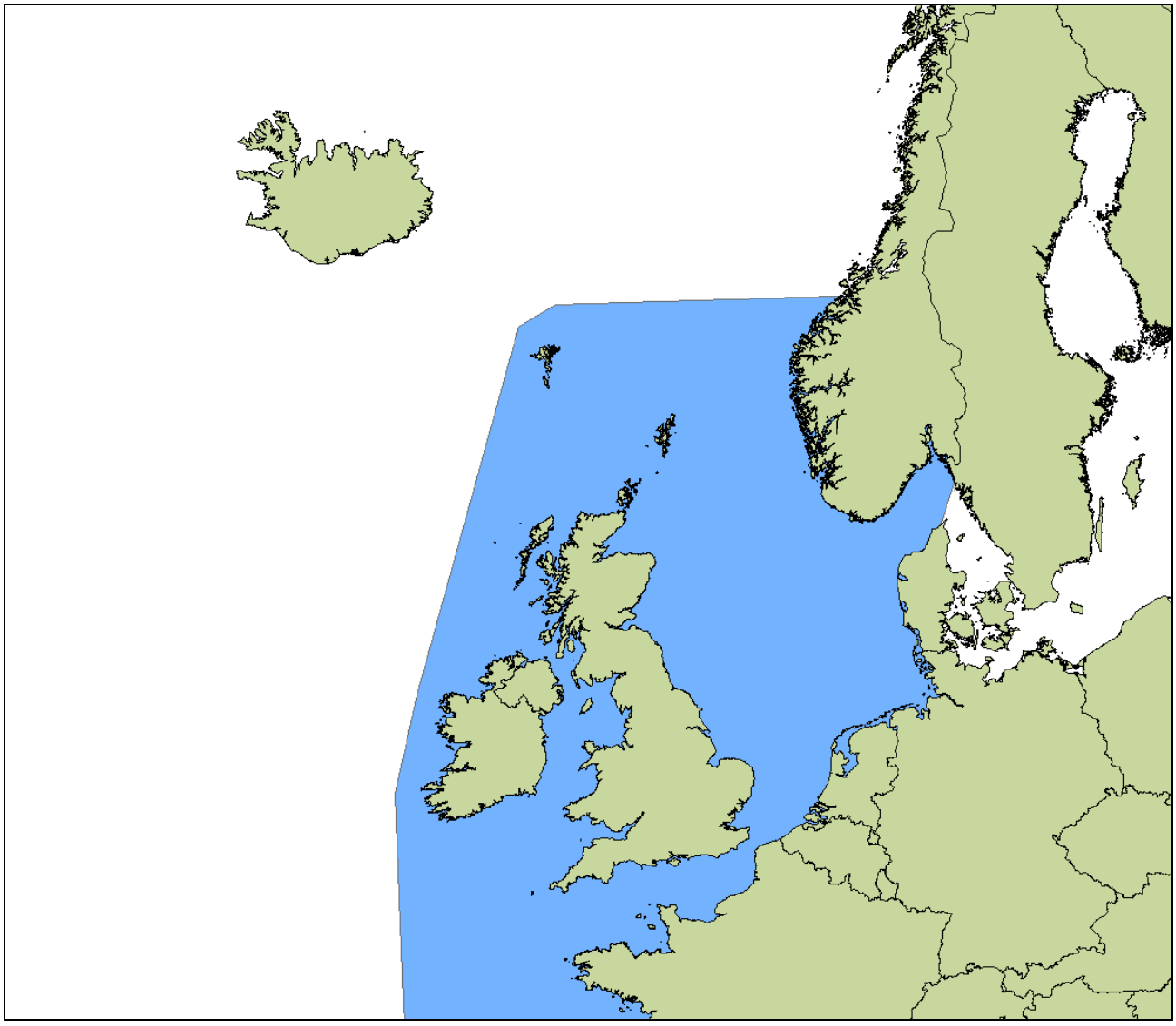
The blue area on this map shows the predicted migration zone potentially used by Razorbills that breed at UK SPA sites.

Razorbills that breed in the UK generally migrate in a southerly direction following the breeding season, to wintering sites along the Atlantic coasts of France, Iberia and Morocco or in the Mediterranean Sea. They are thought to remain relatively close to breeding sites until October, when the main southward migration begins, and continues through the winter. Some birds disperse to sites all around the North Sea coasts (including up to Norway) prior to southward migration. Return migration occurs between March and June. There are thought to be regional differences in dispersal and migratory behaviour, and these are detailed in Wernham *et al*. (2002). A number of recent and on-going tracking studies may significantly improve our understanding of Razorbill movements and it may be valuable for such data to be consulted as part of assessments for offshore wind farms in order to reduce the consenting risk posed by current gaps in

knowledge of this species' movements. Birds that breed outside the UK are not considered here as they are not UK SPA features.

Puffin *Fratercula arctica*

Puffin *Fratercula arctica*	
SPA Species?	Yes (breeding population)
SPA Sites	21 sites around UK coasts, most in Scotland
Population Size (UK)	579,189 breeding pairs
Population Size (International)	5,700,000-7,300,000 (Europe)
Percentage of international population in UK	8-10%

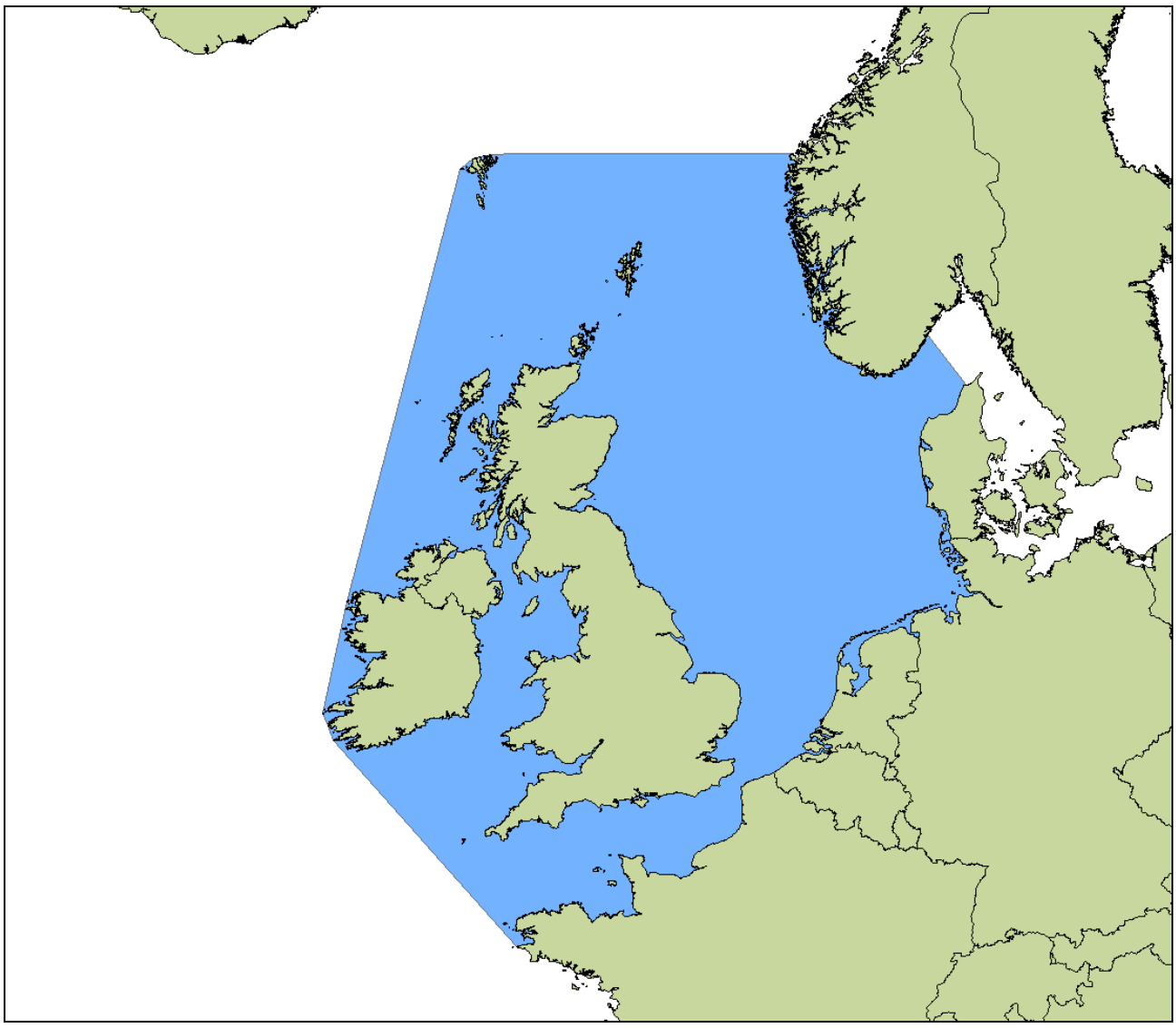


The blue area on this map shows the predicted migration zone potentially used by Puffins that breed at UK SPA sites.

The movements of Puffins away from breeding colonies are poorly understood, however it is thought that they may be dispersive rather than following particular migratory routes, with the birds breeding at sites around Britain and Ireland dispersing very widely to sites as far afield as Norway, Newfoundland and the Canary Islands during the non-breeding season (Wernham *et al*. 2002). The map shows movements through the waters around the UK but dispersal is actually over a much wider area than shown. The presence of this species in proposed wind farm development zones at different times of year is probably better assessed using boat- and aerial-survey data.

Short-eared Owl *Asio flammeus*

Short-eared Owl *Asio flammeus*	
SPA Species?	Yes (breeding population)
SPA Sites	6 sites in Scotland, Wales and northern England
Population Size (UK)	1,000-3,500 pairs
Population Size (International)	58,000-180,000 pairs
Percentage of international population in UK	2%



The blue area on this map shows the predicted migration zone potentially used by UK Short-eared Owl populations.

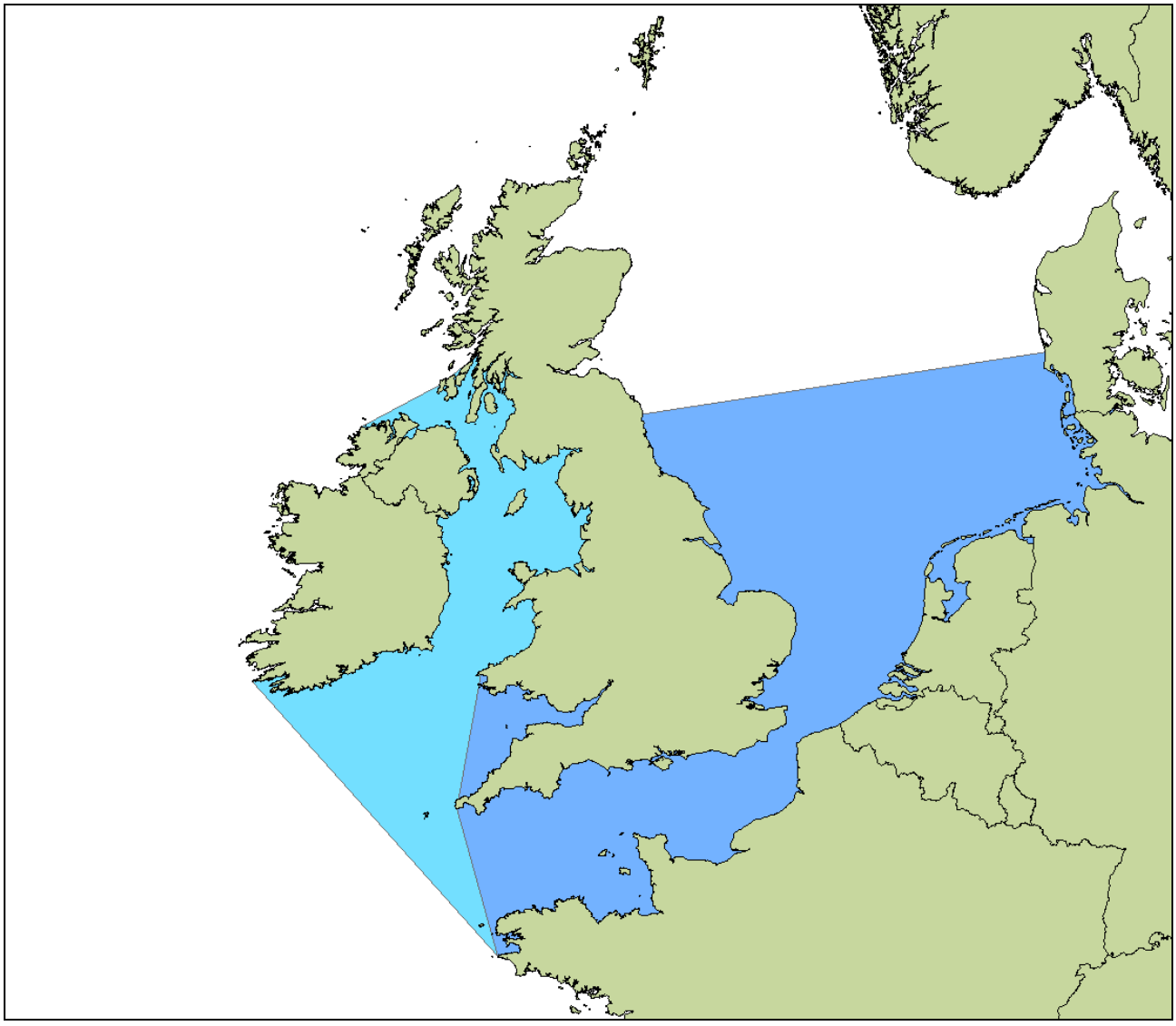
Short-eared Owls are probably the most migratory of all regularly occurring owl species in the UK and they are thought to move in a nomadic fashion in response to food supply (Wernham *et al*. 2002). As the migratory movements of this species are partially determined by fluctuating food supplies, such that migratory behaviour varies from year to year, the likelihood of collision with wind turbines would vary accordingly. A large proportion of ringing recoveries (14%) involve overseas movements, and these data suggest that Short-eared Owls will migrate across almost all parts of the UK's waters, with movements throughout the North Sea, English Channel, Irish Sea and off the north coast of Scotland towards the Faroe Islands. Juvenile dispersal occurs mainly between August and November, with birds moving in all directions and continuing to wander throughout their first winter. Irish Sea crossings occur in November and again in

spring as the species occurs mainly in winter in Ireland. Similarly, birds from Scandinavia and the Low Countries cross the North Sea to the UK mainly in autumn (late August to November) arriving throughout the eastern parts of the UK. Birds from the UK also cross the Channel towards France and Spain in autumn. There are relatively small numbers of Short-eared Owl ringing recoveries and thus migration routes and timing are relatively poorly understood. It would be useful to understand more about the movement patterns of this species.

Nightjar *Caprimulgus europaeus*

Nightjar *Caprimulgus europaeus*	
SPA Species?	Yes (breeding population)
SPA Sites	10 sites in south and east England
Population Size (UK)	4,600 males[1]
Population Size (International)	470,000-1,000,000 pairs
Percentage of international population in UK	0.6%

[1]Breeding population size from Conway *et al*. 2007.



The darker blue area on this map shows the predicted migration zone potentially used by Nightjars breeding in Britain and Ireland. A very small number of birds migrate to Ireland during the breeding season, and the predicted area encompassing their migration route is shown in pale blue. However, this route is not relevant to UK SPA populations of Nightjar.

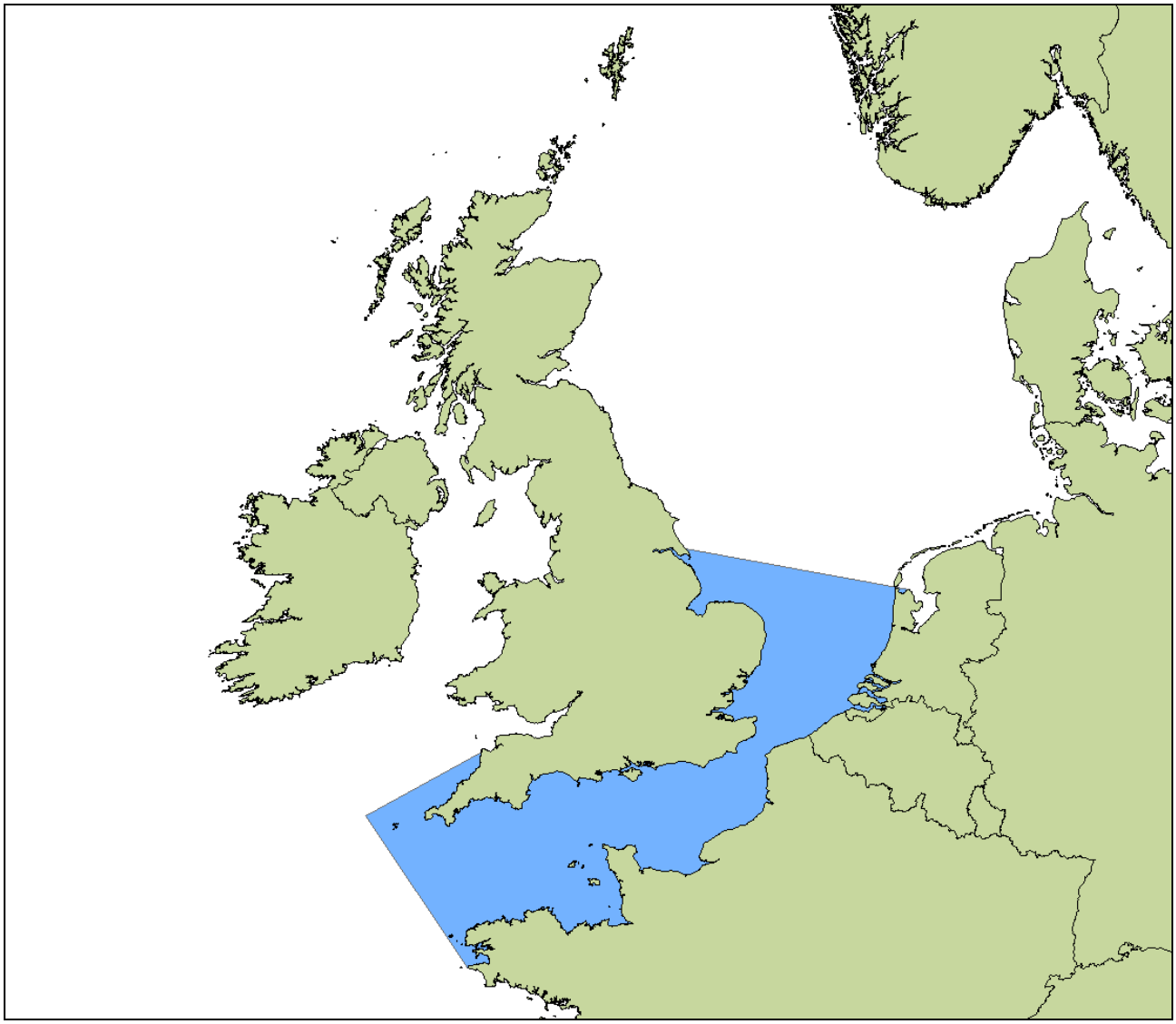
Nightjars are summer visitors to the UK, with the entire UK population migrating into the UK from the south in spring, and returning in autumn. It is likely that the majority of migration is concentrated in the English Channel and southern North Sea, especially given that the species' UK range is concentrated in south and east England. However, nightjars do occur throughout much of the country, so it is likely that a small number of birds might migrate across other parts of UK waters. Birds generally arrive in the UK during May, while autumn migration occurs mainly in August and September, but with some birds departing the UK

from late July through to October or November (Wernham *et al*. 2002). Little is known about the exact migration routes of Nightjars across UK waters, and as it is an SPA species, further research to better understand these routes, especially in the south and east of England, would be useful. Assuming an equal sex ratio, it can be assumed that 9,200 birds cross the dark blue area in spring en-route to UK breeding sites, and that these would be supplemented by juvenile birds in autumn.

Woodlark *Lullula arborea*

Woodlark *Lullula arborea*	
SPA Species?	Yes (breeding population)
SPA Sites	7 sites in south and east England
Population Size (UK)	3,064 territories[1]
Population Size (International)	1,300,000-3,300,000pairs
Percentage of international population in UK	0.1%

[1]Population size from Conway *et al.* 2009



The blue area on this map shows the predicted migration zone potentially used by Woodlarks that breed in the UK.

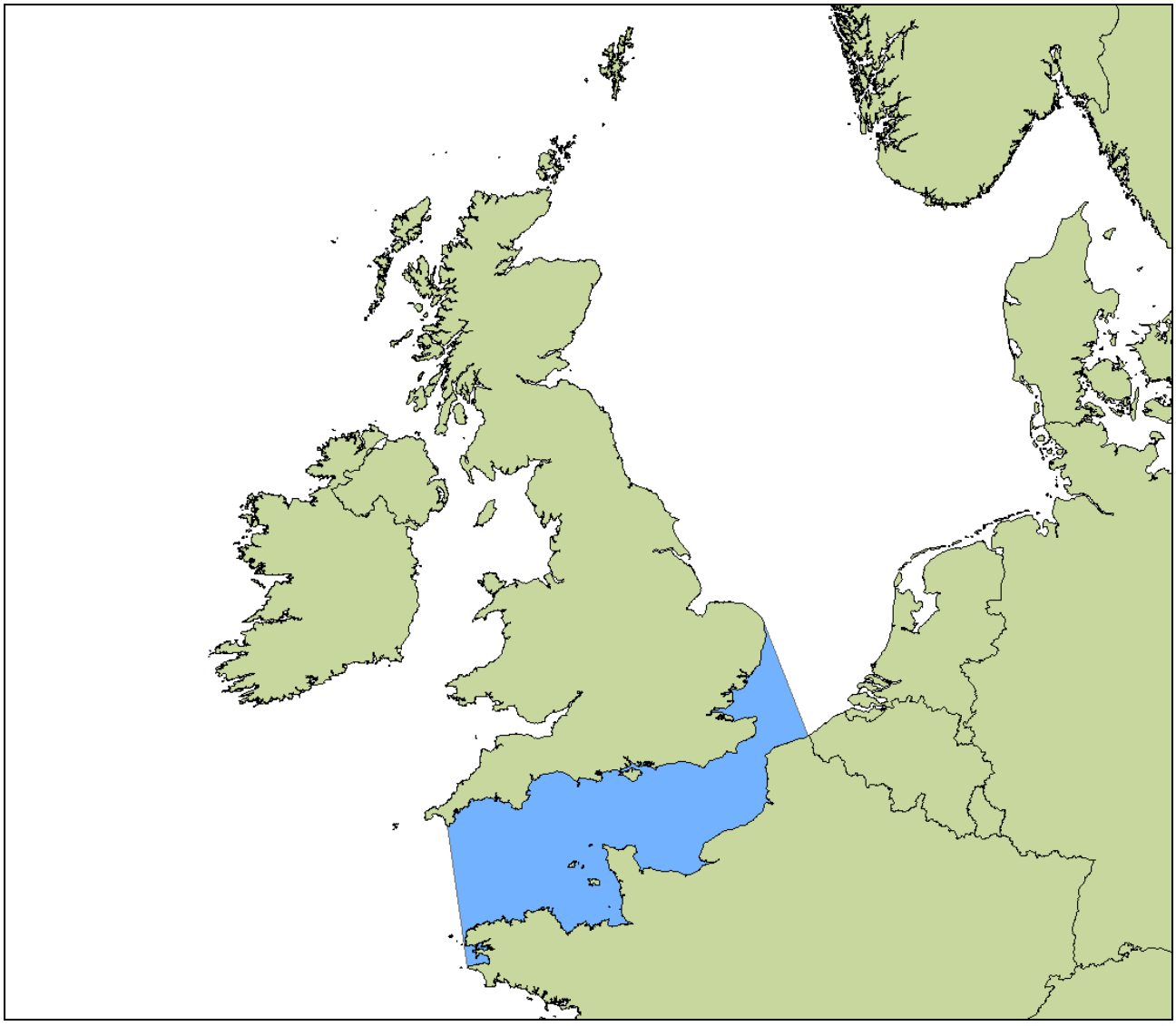
Woodlark is a partial migrant, but despite significant colour-ringing since the 1980s in some of its core UK breeding areas, little is understood about its migratory movements. It is recorded as an occasional passage migrant at sites all around the UK from Shetland to the Scillies, but many of these records probably do not relate to the breeding population from the seven SPAs in south and east England. There is one record of a bird from the Breckland population in the Netherlands in October, and there are a handful of records of Breckland-breeding birds from Kent, Devon and the Scillies in autumn, indicating that birds might move across the Channel. However, the proportion of the population involved in such movements is poorly understood. Populations in the south of the UK appear to be largely resident, but those from the Brecks or

further north appear to be partially migratory, although in recent years there have been a number of sightings in winter on arable land in East Anglia suggesting that more birds might now overwinter in the area (Atkinson 2001, Dunmore 2006, Wright *et al*. 2009, Conway *et al.* 2009). Although Woodlark is an SPA species in the UK, as the numbers migrating across UK waters are probably fairly low it is not a priority for further research at this time, nor is it a key species for consideration in assessments for offshore wind farms. If this species is to be considered in any assessment, a precautionary assumption would be that all birds from the Brecks, Minsmere-Walberswick and Sandlings SPAs potentially migrate across the blue area of the map, and assume that up to 25% of birds from other SPAs migrate across the same route. This is likely to over-estimate the numbers of migrating birds, but is precautionary.

Dartford Warbler *Sylvia undata*

Dartford Warbler *Sylvia undata*	
SPA Species?	Yes
SPA Sites	6 in Southern England
Population Size (UK)	2,878-3591 males[1]
Population Size (International)	1,900,000-3,700,000 pairs
Percentage of international population in UK	0.1%

[1]Population size from Wotton *et al.* 2009



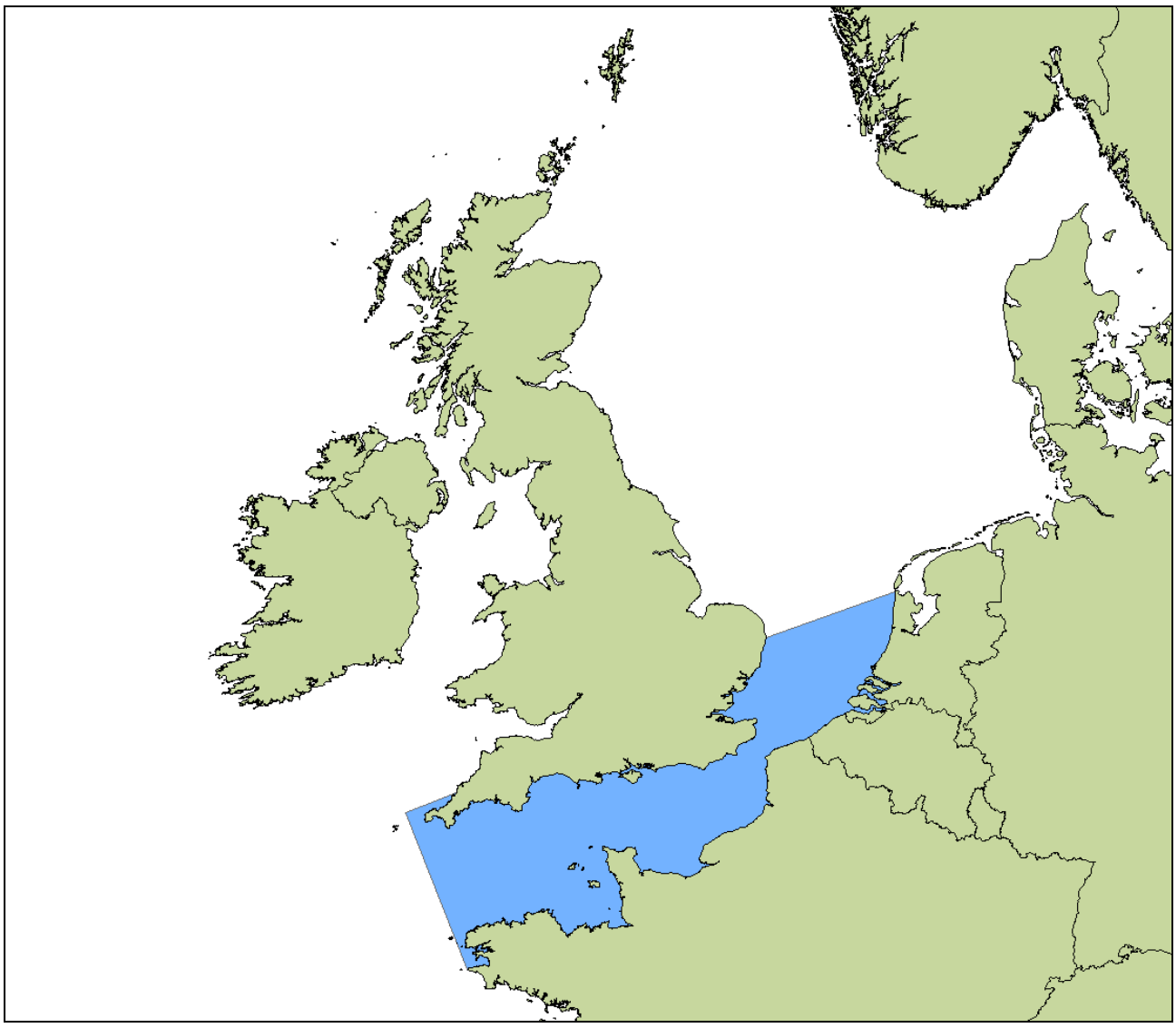
The blue area on this map shows the predicted migration zone potentially used by Dartford Warblers that breed at UK SPA sites.

The Dartford Warbler is a largely sedentary species. However, a limited number of birds do migrate, and this dispersal proved sufficient to re-establish a breeding population at sites in England following local extinction due to harsh weather (Wotton *et al.* 2009). In the UK, the majority of movements relate to movements within the UK, although there is some evidence of inter-change with birds from France (Wernham *et al*. 2002). As migratory movements are limited, and only a small proportion of the international population occur within the UK, further research into the movements of this species should be a low priority as it is unlikely to pose a risk to consenting for offshore wind farms. If it is deemed necessary to assess the migratory movements of Dartford Warblers in any assessment, a precautionary

assumption that up to 10% of the UK population might migrate across the route shown in the map above could be made.

Aquatic Warbler *Acrocephalus paludicola*

Aquatic Warbler *Acrocephalus paludicola*	
SPA Species?	Yes
SPA Sites	3, on the South Coast of England
Population Size (UK)	33 individuals (autumn passage)
Population Size (International)	12,000-20,000 pairs
Percentage of international population in UK	0.1%



The blue area on this map shows the predicted migration zone potentially used by Aquatic Warblers that breed at UK SPA sites.

Aquatic Warblers occur in the UK as a rare breeding bird and passage migrant. Breeding is now largely confined to Eastern Europe, particularly around the Baltic region. Following the end of the breeding season, birds travel on passage through western and southern Europe, passing through Germany, Switzerland, Southern England, France and Spain, before arriving on their wintering grounds in West Africa. Whilst the Aquatic Warbler is a feature of 3 UK SPAs, these were designated for breeding populations, the current status of which is in doubt. As only a small proportion of the international population of this species occurs within the UK, further research in to the movements of this species should be a low priority and it is unlikely to pose a risk to consenting for any offshore wind farm. If it is deemed necessary to make an

assessment of the movements of this species, it could be assumed that the entire UK population (currently estimated at 33 individuals) migrates across the route shown in the map above.

Flight heights and fall events

The main ways of tracking flight heights, as reported in the literature, are through observations (including moon-watching and deployment of ceilometer beams at night), use of radar, infrared and thermal imaging and recording of vocalisations (Liechti *et al*. 1995; Williams *et al*. 2001; Desholm 2005; Burger & Shaffer 2008; Walls *et al.* 2009; Langston 2010; Newton 2010). Tags, including satellite transmitters, geolocators and GPS, are increasingly being employed to examine migratory behaviour. Although this technology is providing unprecedented detail on the movements of a number of species, it is only currently available for larger birds, as the tags are too heavy for use on small species (Newton 2010). Moreover, most tags do not provide information on flight altitude, and tagging can be very expensive. Information on fall events is generally obtained from observations of birds' arrival (e.g. North Sea Bird Club 2011) and through ringing data (Wernham *et al*. 2002).

Wildfowl

Several species of swan and goose are thought to be vulnerable to collision with wind turbines due to the height at which they fly (Langston 2010; Griffin *et al.* 2011), although collision is less of a concern for ducks (Langston 2010), in particular diving ducks (Dirksen *et al.* 2000) and seaducks (Desholm & Kahlert 2005). A recent study using satellite transmitters to study Whooper Swan movements found that this species flies at low altitudes over water (9 m ± 16.2 near the coast, and 32 m ± 55 on passage between Britain and Iceland), underlining their vulnerability to turbine collisions (Griffin *et al* 2010). Further details of studies of flight altitudes in wildfowl can be found in tables 1 & 2.

Unlike passerines, which are thought to migrate on a broad front, wildfowl typically migrate along narrow corridors known as flyways (Pennycuick 1999; Wernham *et al*. 2002; Newton 2010), meaning that wind farms situated away from these routes may be less likely to pose a threat to these species. Wildfowl species may migrate by day and by night (Pennycuick 1999; Griffin *et al*. 2010; Newton 2010), but have been observed flying lower after dark (Newton 2010) and are therefore potentially more vulnerable to collisions at this time.

Wildfowl are less prone to falls and wrecks (high number of dead/dying birds washed ashore) than passerines and waders because of their ability to alight on water, and as such reports of falls in these species are rare (Lensink *et al.* 1999). However, alighting on the water when poor weather hits during migration will any cause birds that are flying above turbine height to reduce their flight altitude; it therefore could be risky if it occurs when birds are passing a wind farm.

Seabirds and seaducks

A detailed review of flight altitude in seabirds and seaducks and collision risk therein can be found in Cook *et al*. 2012. This work concludes that gulls are at greatest risk of turbine collisions due to flight height, broadly echoing the findings of other studies (e.g. Garthe & Hüppop 2004; Langston 2010). However, much of the information on seabird and seaduck flight altitudes with respect to turbine collision risk has been gathered by observations in wind farms (Garthe & Hüppop 2004). While this is valuable, it does not discern between individuals that are resident at breeding colonies and those that are on passage. Indeed, the few reports of flight heights of seabirds and seaducks on migration suggest that some species fly far above turbine height (e.g. Alerstam *et al*. 1999). Like wildfowl, seabirds can land at sea and are thus less susceptible to falls than passerines and raptors. However, seabird wrecks (high numbers of dead/dying birds washed ashore) are reported in bad weather.

Raptors and Owls

Raptors migrate by day, as they require warm temperatures to produce the thermals and updrafts they need to generate lift for soaring flight (Newton 2010). The absence of thermals over water causes raptors to congregate at short sea-crossings and migrate across sea in narrow corridors to minimize time engaged in energetically expensive flapping flight (Newton 2010). Raptors also lose height as they cross water and fly low before they regain land (Newton 2010), making them potentially vulnerable to collisions with

offshore structures at this time. Owls migrate mainly at night (though there is also some migration during the daytime), but have good nocturnal vision (Martin 1986), such that turbine avoidance might not pose a threat to them (for a review of how different species might perceive wind turbines, see Martin 2011), although particular species have been observed to fly at low altitudes before dawn (Duffy & Kerlinger 1992), suggesting that they might face an increased risk of collisions at this time.

Waders

Many wader species for which there was available information were observed flying at heights which exposed them to collision risk with wind turbines (van der Winden *et al*. 1997; Banks *et al*. 2005), while migration routes suggested that individuals might come into contact with wind farms, as they cross areas where they exist or are proposed, such as the North Sea, Irish Sea and Bristol Channel (Wernham *et al*. 2002). However, like wildfowl, many waders also migrate along flyways (Davidson *et al*. 1995), so wind turbines positioned outside these areas would pose a reduced risk of collision. Certain species of wader migrate by night, during which time they fly at lower altitudes than during the day (Newton 2010). There are, however, studies in which wader flight height over sea has far exceeded that of any wind turbines constructed for proposed (Alerstam *et al*. 1990; Alerstam & Gudmundsson 1999), suggesting again that in certain areas waders might not be at risk of collision (see also tables 1 & 2). Although waders' capacity to swim at sea is limited, reports of falls in species of this group are rare (Lensink *et al*. 1999).

Passerines

The migration patterns of passerines and near passerines, particularly far offshore, can be difficult to discern as individuals are small and hard to spot in a marine environment (Blew *et al*. 2008). Furthermore, passerines may migrate at night and during conditions of poor visibility (Blew *et al*. 2008; Newton 2010), rendering many individuals invisible through telescopes (Desholm *et al*. 2006; Hüppop *et al*. 2006). Even under conditions of good visibility, it is difficult to accurately see passerines at distances of greater than 300 m (Blew *et al*. 2008). Passerine migration has been studied with other tools, including radar, acoustic recordings and thermal imaging (e.g. Zehnder *et al*. 2001; Hüppop *et al*. 2006). However, such tools do not reliably allow identification to species level (Zaugg *et al*. 2008; Schmaljohann *et al*. 2008b). Several studies have indicated that passerines are vulnerable to collisions with turbines and other offshore structures such as oil rigs, especially when visibility is poor (Blew *et al*. 2008; Newton 2010) and birds are attracted to illuminated offshore obstacles (Hüppop *et al*. 2006). Although migrating passerines may fly higher than turbine height (Blew *et al*. 2008; Newton 2010), they have been observed flying at altitudes at which they would be vulnerable to collision in several studies (e.g. Desholm 2005), especially at night and in foggy conditions (Blew *et al*. 2008; Newton 2010) (see also tables 1 & 2 for studies of passerine flight altitude). There is also evidence that passerines are attracted to, and killed by collision with, offshore structures (especially those that are lit) under poor climatic conditions (Percival 2001; Blew *et al*. 2008; Newton 2010).

The literature contains sporadic reports of fall events. Falls are often noted by bird observatories (see Lensink *et al*. 1999), but it is not clear whether these are relevant to the construction of offshore wind turbines, which may be a great distance from land, at which point birds might be flying high above the turbines. Although falls can be associated with poor weather, they also occur when conditions are ideal for migration, indicating that in these instances, bird may fly at high altitudes until shortly before coming into land (Lensink *et al*. 1999). More relevant reports of falls are perhaps those contained in literature produced by the North Sea Bird Club (NSBC), as these records concern birds arriving on offshore structures such as oil rigs. However, records in NSBC report frequently describe birds that are exhausted or dead, and as such these individuals seem unlikely to make landfall regardless of the presence of offshore wind turbines. There are, however, reports of falls of living birds. For example, approximately 5000 Redwing were observed on Buchan A oil platform on 28th October 2009 (North Sea Bird Club 2011). However, records are not always as precise, instead describing birds in "tens" or "hundreds" and in regions such as the "South sector".

DISCUSSION & RECOMMENDATIONS

Very many bird species migrate across UK waters, but for the majority of species we have little knowledge of exact migration routes. Flight height ranges, and variability in flight height, during migration are also poorly understood, and for most species we have no data regarding flight altitudes for individuals migrating over the sea around the UK.

For a small number of migratory bird species, migratory pathways are well understood and well defined (for example some swan and goose species). However, when assessing risks to most other migrant species, a broad front of migration between breeding and non-breeding sites is often assumed. There is some evidence that this assumption is not accurate for certain species, especially those that migrate by day, as many follow geographical landmarks and are likely to cross narrower areas of sea from headlands (Wernham *et al.* 2002, Newton 2010), while some waterbirds and raptors migrate between specific staging sites and so are likely to be concentrated along particular routes (Newton 2010). However, as there is no quantifiable information regarding the migration routes of most bird species at sea, an assumption of a broad front migration should continue to apply in assessments, except for species where evidence is available to show otherwise.

Unfortunately, even if a broad front migration is assumed, assessing risks to migrants is not simple. Many species fly over UK waters along more than one migratory pathway, and where this occurs, the numbers travelling along different routes and the breadth of the front occupied by each migratory pathway, is often very unclear and near impossible to quantify based on existing data. Furthermore, migrants passing through multiple wind farms should also be considered as having higher risk of collision.

Guidance for assessment of migration in HRAs/EIAs based on current knowledge

The migratory bird species to be considered in the impact assessment for a particular development should be agreed with the relevant statutory nature conservation bodies, but this process could be guided by using the maps of migratory routes provided for each species in this report. This will allow the identification of SPA bird species whose migratory routes potentially overlap with the proposed wind farm footprint.

For dispersive seabird species (including Fulmar, Manx Shearwater, petrels and auks) that do not make a single pass migration, the guidance below is probably not the best way to assess risks to their populations from proposed wind farm developments, and we suggest that existing methods using boat and aerial survey data (with perhaps additional survey effort during key periods of migration/movement) are likely to provide a better approach. Seabirds whose migration routes tend to follow coastlines but at some distance offshore, often with foraging en-route rather than a direct migration (including skuas, gulls and terns) are also not well assessed using this method, though a similar method could be developed using migration routes that run parallel to coastlines, and with some assumptions about time spent foraging.

For each non-seabird species being considered in the assessment, the following basic stages should be followed:

Stage 1. Estimate the number of individuals that will fly across the footprint of the wind farm during a single migration season (at any height).

Stage 2. Estimate the proportion of migrating individuals of that species that will fly at a height where they may encounter the turbine blades, and multiply this by the number flying across the footprint (from stage 1) to estimate the number of birds potentially at risk of collision.

Stage 3. Feed this number (from stage 2) into a collision risk assessment to estimate collision mortality. A slight adjustment to the usual method would be required to allow the feed in of numbers of birds passing through the wind farm rather than a bird density (this will be agreed with Bill Band and added to the Band (2011) guidance).

Stage 4. Repeat this process for the return migration season, or simply multiply the collision mortality by two to estimate annual collision mortality if there are no known differences between spring and

autumn migration. This stage will not be necessary if the return migration is known to be via a different route that does not encompass the wind farm (though this is only likely for a very small number of species).

Stage 5. Assign the estimated collision mortality to particular SPA populations.

This guidance deals primarily with the first two stages in the above list, as guidance on methods for collision risk assessment is provided elsewhere (e.g. Band 2011, Cook *et al*. 2011), and guidance on assigning mortality to particular SPA populations should be agreed with the relevant statutory body.

STAGE 1: Estimate the number of individuals that will fly across the footprint of the wind farm during a single migration season

Several possible methods could be used to estimate the number of individuals that will fly across the footprint of a wind farm during each migration season.

Method 1:
In a small number of cases, there may be sufficient data from boat or aerial surveys of the wind farm to generate population estimates for some migratory species. This is particularly likely for seabirds that exhibit a gradual dispersal from breeding sites rather than a direct flight point-to-point migration. If this is done, it is important that turnover in the population is recognised. This means that any population estimate must not simply estimate the number of birds using the site at any one time, but instead aim to quantify the total number of birds flying across the site during the entire migration period. The calculation of population estimates from boat surveys is covered elsewhere and so will not be described in detail here. However, it is important that these population estimates are multiplied by the length of the migration season combined with estimates of the time individual birds spend in the area to estimate the total birds passing the site. They should be presented with an estimate of uncertainty, such as 95% confidence limits.

Method 2:
For some species, there may be sufficient data from tracking studies to make an estimate (with confidence limits to account for uncertainty) of the proportion of the population likely to cross the wind farm footprint during an average migration season. However, it is important to note that the majority of tracking studies will involve a relatively small number of individuals marked at a relatively small number of sites over a relatively small number of years, and therefore may not offer a complete picture of the migration routes of the population as a whole over many years. We therefore suggest that method 3 or 4 below is also used for species that have been the subject of tracking studies, to allow a comparison.

Method 3:
In the majority of cases there will not be sufficient survey or tracking data and so estimates of the number of individuals that will fly across the wind farm must rely on published information. In this case the following steps should be followed:

1. Use the map provided in this report to estimate the proportion of the migratory population of each species that will cross the footprint of the wind farm in question, based on the size of the wind farm footprint relative to the width of the migration zone. One method for doing this is given in the excel tool “SOSS migrant assessment” that accompanies this report. Full instructions and explanation of its rationale are given in Annex 1. This approach assumes straight-line migration, and that the start- and end-points of birds’ migration routes are uniformly distributed along the coastline, neither of which is realistic. It is unclear how much these assumptions may differ from reality and the effect this may have on estimates. A more advanced modelling approach, that also assumes straight-line migration but takes this further to provide a partitioning of effects to specific protected sites with a statistical estimate of confidence, has been developed independently by APEM and is described briefly in “Method 4” below. The map for each species’ migration route should be modified if new information is available to refine the migration route presented here.

2. Multiply the proportion of the population that will cross the wind farm footprint (from point 1) by the total size of the migrating population (given in the species account) to estimate the number of birds crossing the wind farm. [Note that this assumes that birds are evenly distributed across the migratory front, which is highly unlikely. Also notice that migrants follow great circles to move between two points over a spherical surface (Alerstam 1990)]. In some cases, the numbers of birds migrating across different parts of the migration route (e.g. North Sea, Irish Sea, English Channel) may be known, in which case these numbers can be used instead of the total population size. For species where SPAs are designated for passage populations (e.g. Sanderling, Whimbrel, Ruff), the size of the population based on maximum counts will significantly underestimate the total number of birds passing through the site, due to turnover. In the absence of a proper estimate of turnover rates we suggest multiplying the population size based on maximum counts by three for species with SPAs designated for passage populations, to account for turnover (this is an arbitrary value based on expert judgement, assuming a 30 day migration period, that individual birds stay for about 10 days each, and a constant rate of turnover – this is unlikely to be accurate but given the many other assumptions in the assessment of risks to migrating birds this inaccuracy is unimportant).
3. In order to account for the fact that birds are extremely unlikely to be evenly distributed across the migratory front (but we do not know whether or not high concentrations cross the wind farm footprint), that some species may follow great circle routes rather than straight lines, and that migratory routes will vary greatly due to weather, alternative calculations should be performed making the assumption that birds could be at a higher or lower than average density where they cross the wind farm. To do this, multiply the estimate from point 2 by 2, 4, 0.5 and 0.25 to give a range of possible values. All of these values should be presented in assessments to give a range of possibilities for consideration in the absence of detailed data. Our review demonstrated that detailed data are not currently available for the majority of migratory bird species.

Method 4:
Alternative methods for estimating the number of individuals that will migrate across the wind farm footprint may be possible, for example using a randomised simulation modelling approach such as that recently developed independently by APEM. This sort of advanced modelling approach will allow a more robust estimate of confidence/uncertainty in results to be produced and allows the partitioning of effects to specific protected sites. Such methods still make a number of unrealistic assumptions, including that birds migrate along straight lines, and it is unclear how much such assumptions may affect results. These approaches should follow the maps provided in this report to define the overall width of the migratory front, unless new information becomes available to refine the maps. Such methods should be agreed with the relevant statutory nature conservation bodies, and outputs should always be presented as a range of possible values to account for uncertainty.

STAGE 2: Estimate the proportion of migrating individuals of that species that will fly at a height where they may encounter the turbine blades

Again, there are a number of methods by which the proportion of individuals might be estimated, as described below. Note that whichever method is used to estimate the proportion of individuals flying at turbine height, the range of uncertainty from stage 1 (above) should be captured by feeding the range of outputs from stage 1 through the calculations in stage 2 to give several outputs.

Method 1:
For species where there are suitable flight height data available (e.g. from tracking studies that record altitude such as those conducted on Whooper Swans, or radar), these should be used to calculate the proportion of birds at turbine height, with 95% confidence limits. The mean proportion and upper and lower confidence limits should all be applied to the estimates from Stage 1 to give a range of estimates of the numbers of birds that could pass through the wind farm during each migration season at turbine

height. If flight height data indicate that birds fly at different height ranges in spring and autumn, separate estimates should be calculated for each season. Note that if flight height data are not available for the species, but there are data for more than one closely related species that show similar flight height patterns (e.g. other goose species), these could be applied to the species in question.

Method 2:
If there are data available to measure the weather conditions during which species fly at turbine height, and other data to demonstrate that they do not fly at turbine height except in certain weather conditions, an estimate could be made of the proportion of days in autumn/spring with those weather conditions, and assume that is the proportion of birds that would be at turbine height. At present, there is insufficient evidence from published studies to allow such a quantification of the conditions when birds may or may not be at risk height (though there is some information about how birds alter their flight elevations in response to weather conditions). However, such evidence may become available in the future, enabling this method to be used.

Method 3:
For species where there is no good information about flight height ranges available (for either the species in question or closely related species, see Tables 1 & 2), precautionary assumptions on the proportions of birds potentially flying at turbine height, by species group, are given in Table 3.

STAGE 3 – 5: Assigning mortality to particular SPA populations

Once estimates have been made of the number of individual birds likely to pass through the wind farm at a height where they may encounter turbines, a collision risk assessment may be carried out following established methods (e.g. Band 2011) to give estimates of annual collision mortality. A slight adjustment to the usual method would be required to allow the feed in of numbers of birds passing through the wind farm rather than a bird density (this will be agreed with Bill Band and added to the Band (2011) guidance). Again, the range of uncertainty in estimates of the numbers of birds should be fed through into the collision risk assessment to give a range of outputs that account for this uncertainty. There is then the question of assigning the estimated collision mortality to particular SPAs. This could be done in a number of ways, and should be agreed with the relevant statutory nature conservation body.

- All mortality could be assigned to the single nearest SPA population.
- The total mortality could be distributed evenly between all UK SPA populations (i.e. all SPA populations lose the same percentage of birds).
- The total mortality could be distributed between UK SPA populations based on a weighting according to distance from the wind farm in question (i.e. the majority assigned to the nearest SPAs or any other SPA in turn).
- As a precautionary approach, all mortality could be assigned to each SPA in turn.
- A modelling approach such as the randomised simulation modelling currently being conducted by APEM could be used.

Recommendations for further work

For future offshore wind farm developments (i.e. those where survey work has not already begun), the guidelines outlined above could potentially be used before survey work begins to identify any migrant bird species potentially at risk, such that appropriate survey modifications can be made to improve the accuracy with which their timing and scale of movement are recorded – for example by additional survey effort, the deployment of radar or by implementing tracking studies on the species of concern.

It would be useful to apply the guidelines in this report to assessing cumulative risks to all bird species covered by this report from all existing and proposed Round 3 and Scottish Territorial Waters wind farm sites, as well as those in other countries. By making precautionary assumptions about the maximum numbers of turbines at each proposed site, and following the precautionary guidance in this report, it may be possible to scope out any species for which there is unlikely to be a cumulative risk even when these precautionary assumptions are made. This would be of benefit to the industry if some species could be scoped out from further assessment for individual projects.

We suggest that further generic, collaborative (rather than just project-specific) work, such as tracking and/or radar studies, would be valuable to gain a better overall understanding of the migration routes and flight height ranges of some key bird species. Existing data on colour-ringing studies, BirdTrack information and tagging studies could be collated to obtain further detailed information on movements of at least some species. For species-specific studies using any of these approaches, we suggest the following order of priority:

1. SPA species that are part of species groups for which no tracking studies that quantify flight height ranges during migration have been conducted, for example waders (large waders such as Oystercatcher or Curlew would be best as other species are too small for tags that record altitude) and ducks. Choosing example species that follow similar routes to other species would be valuable and could provide insight into the likely flight height behaviours of other species in the group. Combining tracking on a small number of birds with colour-ringing of many additional birds from the same sites (to increase knowledge of the proportion of birds going to different destinations, therefore making it easier to see how the tracking data from a small number of birds might apply to the wider population) would significantly increase the value of the work for relatively little additional cost.

2. Other SPA species where the entire international biogeographic population, subspecies or European population migrates across the waters around the British Isles (Pink-footed Goose, Greenland White-fronted Goose, Icelandic Greylag Goose, Greenland Barnacle Goose, Svalbard Barnacle Goose, Canadian Light-bellied Brent Goose, the British and Irish breeding population of *schinzii* Dunlin, passage populations of *schinzii* and *arctica* Dunlin and the Icelandic population of Black-tailed Godwit), and where initial assessment (using the methods and precautionary assumptions described in this report) suggests that there could be a significant impact on the population from proposed wind farm developments.
3. SPA species where more than 50% of the international biogeographic, subspecies or European population migrates across the waters around the British Isles (Whooper Swan, Knot and the Icelandic population of Redshank), and where initial assessment (using the methods and precautionary assumptions described in this report) suggests that there could be a significant impact on the population from proposed wind farm developments.
4. SPA species where between 25 and 49% of the international biogeographic, subspecies or European population migrates across the waters around the British Isles (Bewick's Swan, Dark-bellied Brent Goose, Svalbard Light-bellied Brent Goose, Wigeon, Gadwall, Teal, Pintail, Shoveler, Oystercatcher, Ringed Plover, wintering *alpina* Dunlin, Bar-tailed Godwit, Curlew, Redshank and Turnstone), and where initial assessment (using the methods and precautionary assumptions described in this report) suggests that there could be a significant impact on the population from proposed wind farm developments.

For larger species, such as wildfowl, seabirds, raptors and some larger waders, tracking studies using tags that record altitude and location on a regular basis (for example those incorporating GPS technology) would be particularly valuable. However, due to cost, tracking studies can only follow a very small number of individuals thus may not give an accurate picture of the migration route of the population as a whole, especially for species which are widespread and have a range of different movement patterns. Tracking studies would therefore be most beneficial for species whose distributions are concentrated in a small number of sites or areas, and where the majority (or a significant proportion) of the population is thought to follow similar migration routes, for instance by travelling along narrow flyways (e.g. swans, geese, raptors and some waders). A key limitation of tracking studies is that they only record the movements of a few individuals, and therefore quantification of the total numbers of birds moving along similar routes may remain problematic, especially where individuals have been tagged at a limited number of sites and there is uncertainty as to whether birds from other sites use similar migration routes. Combining tracking with radar studies could allow quantification of the numbers of birds passing across particular areas (especially proposed wind farm development sites) and would be extremely valuable. Alternatively, combining tracking on a small number of birds with colour-ringing of much larger numbers from the same populations could also significantly increase the value of the outputs of tracking studies at very little additional cost.

There may be some data available from existing tracking studies that have recorded routes and/or altitudes of migrating birds over the sea, but where data have not been analysed with assessing over-sea migration in mind. It may therefore be possible to gain additional information on over-sea migration routes and flight heights by analysing such data through collaboration with organisations who have conducted these studies. A first step would be to contact those conducting existing studies to find out whether such data are available.

For species with less defined migration routes, for example passerines that are largely thought to migrate on a broad front, radar placed at particular locations (for example North Sea oil platforms) could provide information on flight heights and migration intensity. Weather radar could also be used to study migration (e.g. Dokter *et al*. 2011), and there is potential to use such data from across nations to model the spatial and temporal patterns in numbers of migrants in relation to weather patterns. Such an approach could be used to determine numbers of migrants for use in collision risk models and also has the potential to inform strategies to implement shut downs to mitigate against the risk of collisions by avian migrants (e.g. Kube

2011). Again, this type of approach may be best organised as a generic or collaborative project across the industry, rather than being conducted by individual developers.

It would be valuable to conduct an analysis of data from the BirdTrack survey (organised by BTO, RSPB, Birdwatch Ireland and the SOC), that records bird sightings and counts throughout Britain and Ireland at all times of year. This could allow an assessment of the timing of arrival of all bird species at different locations around the UK, an assessment of where the highest concentrations of arrivals are for different species, and how this varies between years. Although this would still not allow the assessment of over-sea migration routes, it would give valuable information about where birds arrive in the UK, which would help to refine our understanding of likely migratory routes. It is important to note that BirdTrack sightings are not necessarily arrivals from migration, but spatio-temporal modelling of data on sightings of migratory species from BirdTrack (controlling for survey effort) could allow arrival densities in different locations to be estimated.

Many species have been the subject of long-running colour-marking studies. Analyses of these data for key species of concern (where available) could improve our understanding of their migratory movements and thus reduce some of the current gaps in knowledge. There may also be significant new information available if up-to-date data from regular ringing studies were analysed, with a focus on understanding over-sea migration routes.

BENEFITS TO CONSENTING

This report provides guidance on the assessment of the numbers of migrating birds likely to pass through proposed offshore wind farm developments, feeding these numbers into a collision risk model to calculate mortality estimates, and apportioning this mortality to specific SPA populations. Agreeing this guidance with statutory nature conservation bodies, developers, consultants and other stakeholders will have a significant benefit to consenting as there has previously been no agreement on how to assess likely rates of collision mortality for migrating birds. This lack of agreement previously posed a significant consenting risk. It is important to note that this guidance does not address whether the predicted mortality results in a likely significant effect, and if so, whether the level of additional mortality to an SPA population affects the integrity of the site (assessed against the conservation objectives established for the SPA).

We have developed a tool that simplifies the process of estimating the numbers of migrating birds of each species likely to cross the footprint of a proposed wind farm, significantly reducing the work required to do this as part of impact assessments.

There are still many gaps in our understanding of the routes and flight heights of most migratory bird species, and these gaps in knowledge can also pose a risk to consenting if an overly-precautionary stance is adopted. Here we suggest pragmatic solutions to allow an assessment of risk to migrating birds that accounts for these gaps, acknowledges uncertainty, and adopts a reasonable degree of precaution.

We have made recommendations for further work that could address some of the remaining gaps in knowledge and further reduce the consenting risk posed by our current lack of understanding of the precise migration routes, timings and flight heights of birds migrating to and from Britain and Ireland. As a first step, it would be beneficial to use the guidance developed in this report to assess the cumulative risk to each bird species from all existing and proposed wind farms around the UK, in order to prioritise and target any further work for risky species, and refine the list of species likely to be of concern in impact assessments.

REFERENCES

Able, K.P. & Gauthreaux, J.R. 1975. Quantification of nocturnal passerine migration with a portable ceilometer. *Condor* **77:** 92-96.

Alerstam, T. 1990. *Bird Migration.* Cambridge University Press, Cambridge.

Alerstam, T., Gudmundsson, G.A., Jönsson, P.E., Karlsson, J. & Linström, Å. 1990. Orientation, migration routes and flight behaviour of Knots, Turnstones and Brant Geese departing from Iceland in spring. *Arctic* **43:** 201-214.

Alerstam, T. & Gudmundsson, G.A. 1999. Migration patterns of tundra birds: tracking radar observations along the Northeast Passage. *Arctic* **52:** 346-371.

Atkinson, P. 2001. Woodlarks' winter harbour. *BTO News* **234:** 5.

Atkinson, P.W., Delany, S., Clark, J.A., Diagana, C.H., Feu, C. du, Fielder, W., Fransson, T., Gaulthier-Clerc, M., Grantham, M., Gschwerg, M., Hagemeijer, W., Helmink, J., Johnson, A., Khomenko, S., Martakis, G., Overdijk, O., Robinson, R.A., Solokha, A., Spina, F., Sylla, S.I., Veen, J. & Visser, D. 2006. *Urgent preliminary assessment of ornithological data relevant to the spread of Avian Influenza in Europe*. Report to the European Commission, Study Contract No. 07010401/2005/425926/MAR/B4. Wetlands International & Euring.

Baker, H., Stroud, D.A., Aebischer, N.J., Cranswick, P.A., Gregory, R.D., McSorley, C.A., Noble, D.G. & Rehfisch, M.M. 2006. Population estimates of birds in Great Britain and the United Kingdom. *British Birds* **99:** 25-44.

Band, B. 2011. *Using a collision risk model to assess bird collision risks for offshore windfarms*. Report to Strategic Ornithological Support Services.

Beekman J., Berthold, P., Nowak, E. & Querner, U. 1996. Implementation of satellite tracking in studying the migration of Anatidae: an overview and a case study. In Birkhan, M., van Vessem, J., Havet, P., Madsen, B., Troillet, B. & Moser, M. (eds) *Proceedings of the Anatidae 2000 Conference, Strasbourg, France, 5-9 December 1994*. *Gibier Faune Sauvage* **13:** 157-176.

Beekman J.H., Nolet, B.A. & Klaassen, M. 2002. Skipping swans: fuelling rates and wind conditions determine differential use of migratory stopover sites of Bewick's Swans *Cygnus bewickii*. In Both, C. & Piersma, T. (eds) *The avian calendar: exploring biological hurdles in the annual cycle. Proceeding of the 3rd Conference of the European Ornithologists Union, Groningen, August 2001. Ardea* **90 special issue:** 437-460.

Birdlife International 2004. *Birds in Europe: population estimates, trends and conservation status*. Birdlife International, Cambridge, UK.

Blew, J., Hoffman, M., Nehls, G. & Hennig, V. 2008. *Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms Horns Rev, North Sea, and Nysted, Baltic Sea, in Denmark Part I: Birds.* Universität Hamburg and BioConsult SH Report.

Boere, G.C. 1976. The significance of the Dutch Waddenzee in the annual life cycle of arctic, subarctic and boreal waders. Part I. The function as a moulting area. *Ardea* **64:** 210-291.

Bruderer, B., Underhill, L. G. & Liechti, F. 1995. Altitude choice of night migrants in a desert area predicted by meteorological factors. *Ibis* **137:** 44-55.

Burger, A.E. & Shaffer, S.A. 2008. Application of tracking and data-logging technology in research and conservation of seabirds. *The Auk* **125:** 253-264.

Clausen, P., Madsen, J., Percival, S.M., O'Connor, D. & Anderson, G.Q.A. 1998. Population development and changes in winter site use by the Svalbard Light-bellied Brent Goose, *Branta bernicla hrota* 1980-1994. *Biological Conservation* **84:** 157-165.

Conway, G., Wotton, S., Henderson, I., Langston, R., Drewitt, A. & Currie, F. 2007. Status and distribution of European Nightjars *Caprimulgus europaeus* in the UK in 2004. *Bird Study* **54:** 98–111.

Conway, G.J., Burton, N.H.K., Handschuh, M. & Austin, G.E. 2008 *UK population estimates from the 2007 Breeding Little Ringed Plover and Ringed Plover Surveys*. BTO Research Report 510. BTO, Thetford.

Conway, G., Wotton, S., Henderson, I., Eaton, M., Drewitt, A. & Spence, J. 2009. The status of breeding Woodlarks *Lullula arborea* in Britain in 2006. *Bird Study* **56**: 310-325.

Cook, A.S.C.P, Johnston, A., Wright, L.J. & Burton, N.H.K. 2012. *Strategic Ornithological Support Services Project SOSS-02: A review of flight heights and avoidance rates in birds in relation to offshore wind farms.* Draft BTO Research Report.

Cooper, B.A. & Ritchie, R.J. 1995. The altitude of bird migration in east-central Alaska: a radar and visual study. *Journal of Field Ornithology* **66:** 590-608.

Crowe, O., Austin, G.E., Colhoun, K., Cranswick, P.A., Kershaw, M. & Musgrove, A.J. 2008. Estimates and trends of waterbird numbers wintering in Ireland, 1994/95 to 2003/04. *Bird Study* **55:** 66-77.

Davidson, N.C., Rothwell, P.I. & Pienkowski, M.W. 1995. Towards a flyway conservation strategy for waders. *Wader Study Group Bulletin* **77:** 70-81.

Day, R.H., Rose, J.R., Prichard, A.K., Blaha, R.J. & Cooper, B.A. 2004. Environmental effects on the fall migration of eiders at Barrow, Alaska. *Marine Ornithology* **32:** 13-24.

Denny, M.J.H., Clausen, P., Percival, S.M., Anderson, G.Q.A., Koffijberg, K. & Robinson, J.A. 2004. *Light-bellied Brent Goose Branta bernicla hrota (East Atlantic population) in Svalbard, Greenland, Franz Josef Land, Norway, Denmark, the Netherlands and Britain 1960/61 – 2000/01*. Waterbird Review Series, The Wildfowl & Wetlands Trust/Joint Nature Conservation Committee, Slimbridge.

Desholm, M. 2005. *TADS investigations of avian collision risk at Nysted offshore wind farm, autumn 2004.* Report commissioned by Energi 2.

Desholm, M., and Kahlert, J. 2005. Avian collision risk at an offshore wind farm. *Biology Letters* **1:** 296– 29

Desholm, M., Fox, A.D., Beasley, P.D.L. & Kahlert, J. 2006. Remote techniques for counting and estimating the number of bird–wind turbine collisions at sea: a review. *Ibis* **148:** 76-89.

Devort, M., Trolliet, B. & Veiga, J. 1988. Sur la migration postnuptiale de la Tourterelle des bois (*Streptopelia turtur turtur*) en Gironde. *Gibier Faune Sauvage* **5:** 61-70.

Dirksen, S., Spaans, A.L. & van der Winden, J. 2000. Studies on Nocturnal Flight Paths and Altitudes of Waterbirds in Relation to Wind Turbines: A Review of Current Research in the Netherlands. In Proceedings of the National Avian-Wind Power Planning Meeting III, San Diego, California, May 2000. Prepared for the National Wind Coordinating Committee. Ontario: LGL Ltd.

Dokter, A.M., Liechti, F., Stark, H., Delobbe, L., Tabary, P. & Holleman, I. 2011. Bird migration flight altitudes studied by a network of operational weather radars. *Journal of the Royal Society Interface* **8:** 30-43.

Dolbeer, R.A. 2006. Height distribution of birds recorded by collisions with civil aircraft. *Journal of Wildlife Management* **70:** 1345-1350.

Duffy, K. & Kerlinger, P. 1992. Autumn owl migration at Cape May Point, New Jersey. *Wilson Bulletin* **104:** 312-320.

Dunmore, G. 2006. Systematic list: Woodlark. *Transactions of the Norfolk and Norwich Naturalists' Society*, **39:** 208.

Elkins, N. 1983. *Weather and bird behaviour*. T & AD Poyser Ltd, Calton.

Erni, B., Liechti, F. & Bruderer, B. 2005. The role of wind in passerine autumn migration between Europe and Africa. *Behavioral Ecology* **16:** 732-740.

Gagnon, F., Ibarzabal, J., Savard, J.-P.L., Vaillancourt, P., Bélisle, M. & Francis, C.M. 2011. Weather effects on autumn nocturnal migration of passerines on opposite shores of the St. Lawrence Estuary. *Auk* **128:** 99-112.

Garthe, S. & Hüppop, O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. *Journal of Applied Ecology* **41:** 724-734.

Gibbons D.W., Reid J.B. & Chapman R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.* T & A D Poyser, London.

Green, M. 2004. Flying with the wind – spring migration of Arctic-breeding waders and geese over South Sweden. *Ardea* **92:** 145-160.

Griffin, L., Rees, E. & Hughes, B. 2010a. *The Migration of Whooper Swans in Relation to Offshore Wind Farms*. WWT Final Report to COWRIE Ltd, WWT, Slimbridge.

Griffin, L., Rees, E. & Hughes, B. 2010b. Whooper Swan *Cygnus cygnus* migration in relation to offshore wind farms. *BOU Proceedings – Climate Change and Birds*. Available: http://www.bou.org.uk/bouprocnet/ccb/griffin-etal.pdf.

Griffin, L., Rees, E. & Hughes, B. 2011. Migration routes of Whooper Swans and geese in relation to wind farm footprints. WWT Final Report to DECC, WWT, Slimbridge.

Gudmundsson, G.A., Alerstam, T. & Larsson, B. 1992. Radar observations of northbound migration of the Arctic Tern *Sterna paradisaea*, at the Antarctic Peninsula. *Antarctic Science* **4:** 163-170.

Guilford, T. C., 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:** 1215-1223.

Gunnarsson, T.G., Gill, J.A., Atkinson, P.W., Gélinaud, G., Potts, P.M., Croger, R.E., Gudmundsson, G.A., Appleton, G.F. & Sutherland, W.J. 2006. Population-scale drivers of individual arrival times in migratory birds. *Journal of Animal Ecology* **75:** 1119-1127.

Harvey, P.V. & Riddiford, N. 1990. An uneven sex ratio of migrant Long-eared Owls. *Ringing and Migration* **11:** 131-135.

Holt, C.A., Austin, G.E., Calbrade, N.A., Mellan, H.J., Hearn, R.D., Stroud, D.A., Wotton, S.R. & Musgrove, A.J. 2012. *Waterbirds in the UK 2010/11: The Wetland Bird Survey*. BTO/RSPB/JNCC, Thetford.

Hüppop, O., Dierschke, J., Exo, K.M., Fredrich, E. & Hill, R. 2006. Bird migration studies and potential collision risk with offshore wind turbines. *Ibis* **148:** 90-109.

Jarry, G. 1995. Tourterelle des bois *Streptopelia turtur*. In Tucker, G.M. & Heath, M.F. *Birds in Europe: their conservation status. Conservation Series no. 3*. Birdlife International, Cambridge.

Kober, K., Webb, A., Win, I., Lewis, M., O'Brien, S., Wilson, L.J. & Reid, J.B. 2010. *An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs*. JNCC Report, Peterborough.

Komenda-Zehnder, S., Jenni, L. & Liechti, F. 2010. Do bird captures reflect migration intensity? Trapping numbers on an Alpine pass compared with radar counts. *Journal of Avian Biology* **41:** 434-444.

Krijgsveld, K.L., Lensink, R., Schekkerman, H., Wiersma, P., Poot, M.J.M., Meesters, E.H.W.G. & Dirksen, S. 2005. *Baseline studies of North Sea wind farms: fluxes, flight paths and altitudes of flying birds 2003-2004.* Bureau Waardenburg/Alterra/National Institute for Coastal and Marine Management.

Kube, J. 2011. *Options for mitigation of bird collisions at offshore wind farms: a European perspective*. In May, R. & Bevanger, K. (eds) Proceedings of the Conference on Wind energy and Wildlife impacts, 2-5 May 2011, Trondheim, Norway, p. 33. NINA Report 693. Norwegian Institute for Nature Research, Trondheim, Norway.

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

Lack, P. 1986. *The atlas of wintering birds in Britain and Ireland*. T & AD Poyser Ltd, Calton.

Langston, R.H.W. 2010. *Offshore wind farms and birds: Round 3 zones, extensions to Round 1 & Round 2 sites & Scottish Territorial Waters.* RSPB Research Report No. 39. The Lodge, Sandy, Bedfordshire, United Kingdom.

Laubek, B., Knudsen, H.L. & Ohtonen, A. 1998. Migration and winter range of Whooper Swans *Cygnus cygnus* breeding in different regions of Finland. In Laubek, B. (ed.) *The Northwest European Whooper Swan (Cygnus cygnus) population: ecological and management aspects of an expanding waterfowl population*, 1-33. PhD thesis, University of Aarhus, Denmark.

Lensink, R., Camphuysen, C.J., Jonkers, D.A., Leopold, M.F., Schekkerman, H. & Dirksen, S. 1999. *Falls of migrant birds, an analysis of current knowledge*. Bureau Waardenburg, Wageningen.

Leopold M.F., Camphuysen C.J., van Lieshout S.M.J., ter Braak C.J.F. & Dijkman E.M. 2004. *Baseline studies North Sea wind farms; Lot 5 marine birds in and around the future site nearshore windfarm (NSW).* Alterra-rapport 1047, Wageningen.

Liechti, F. & Bruderer, B. 1995. Quantification of nocturnal bird migration by moonwatching: comparison with radar and infrared observations. *Journal of Field Ornithology* **66:** 457-468.

Main, I.G. 1999. Overseas movements to and from Britain by Greenfinches *Carduelis chloris*. *Ringing and Migration* **19:** 191-199.

Martin, G.R. 1986. Sensory capacities and the nocturnal habit of owls (Strigiformes). *Ibis* **128:** 266-277.

Martin, G.R. 2011. Understanding bird collisions with man-made objects: a sensory ecology approach. *Ibis* **153:** 239-254.

Mitchell, C., Patterson, D., Boyer, P., Cunningham, P., McDonald, R., Meek, E., Okill, J.D. & Symonds, F. 2000. The summer status and distribution of Greylag Geese in north and west Scotland. *Scottish Birds* **21:** 69-77.

Musgrove, A.J., Austin, G.E., Hearn, R.D., Holt, C.A., Stroud, D.A. & Wotton, S.R. 2011. Over-winter population estimates of British waterbirds. *British Birds* **104:** 364-397.

Newton, N. 2010. *Bird migration*. Collins, London.

North Sea Bird Club. 2011. *Twenty-seventh annual report for the year 2009*. North Sea Bird Club.

Percival, S. 2001. *Assessment of the effects of offshore wind farms on birds*. ETSU W/13/00565/REP. Ecology Consulting, Durham, UK.

Perkins, S., Jones, A. & Allison, T. 2003. *Survey of tern activity within Nantucket Sound, Massachusetts, during pre-migratory fall staging*. Massachusetts Audobon Society, Lincoln, MA.

Plonczkier, P. & Simms, I.C. 2012. Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. *Journal of Applied Ecology* doi: 10.1111/j.1365-2664.2012.02181.x

Schmaljohann, H., Liechti, F. & Bruderer B. 2007. Songbird migration across the Sahara: the non-stop hypothesis rejected! *Proceedings of the Royal Society B* **274:** 735-739.

Schmaljohann, H., Bruderer, B. & Liechti, F. 2008a. Sustained bird flights occur at temperatures far beyond expected limits. *Animal Behaviour* **76:** 1133-1138.

Schmaljohann, H., Liechti, F., Bächler, E., Stauri, T. & Bruderer, B. 2008b. Quantification of bird migration by radar – a detection probability problem. *Ibis* **150:** 342-355.

Schmaljohann, H., Liechti, F. & Bruderer, B. 2009. Trans-Sahara migrants select flight altitudes to minimize energy costs rather than water loss. *Behavioural Ecology and Sociobiology* **63:** 1609-1619.

Shamoun-Baranes, J., Liechti, O., Yom-Tov, Y. & Leshem, Y. 2003. Using a convection model to predict altitudes of White Stork migration over central Israel. *Boundary-Layer Meterology* **107:** 673-681.

Shamoun-Baranes, J., van Loon, E., van Gasteren, H., van Belle, J., Bouten, W. and Buurma, L. S. 2006. A comparative analysis of the influence of weather on the flight altitudes of birds. *Bulletin of the American Meteorological Society* **87:** 47-61.

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

Stroud, D.A., Davidson, N.C., West, R., Scott, D.A., Haanstra, L., Thorup, O., Ganter, B. & Delany, S. (compilers) on behalf of the International Wader Study Group. 2004. Status of migratory wader populations in Africa and Western Eurasia in the 1990s. *International Wader Studies* **15:** 1-259.

van der Winden, J., Spaans, A.L., van den Bergh, L.M.J. & Dirksen, S. 1997. *Vogelhinder door windturbines. Landelijk onderzoekprogramma, deel 3: nachtelijke vlieghoogtemetingen van getijdentrek in het Deltagebied*.

Walls, R., Pendlebury, C., Budgey, R., Brookes, K. & Thompson, P. 2009. Revised best practice guidance for the use of remote techniques for ornithological monitoring at offshore windfarms. Published by COWRIE Ltd.

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

Wetlands International 2012. *Waterbird Population Estimates – Fifth Edition*. wpe.wetlands.org.

Williams, R.S.R. 1996. *Ecology and population dynamics of the Long-eared Owl* Asio otus. PhD Thesis, University of East Anglia.

Williams, T.C., Williams, J.M., Williams, P.G. & Stokstad, P. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. *Auk* **188:** 389-403.

Wotton, S., Conway, G., Eaton, M., Henderson, I. & Grice, P. 2006. The status of the Dartford Warbler in the UK and the Channel Islands in 2006. *British Birds* **102:** 230-246.

Wotton, S., Lodge, C., McIntyre, R., Schmitt, S., Gregory, R. & Brown, A. 2010. *Bittern Botaurus stellaris monitoring in the UK. Summary of the 2010 breeding season*. RSPB, Sandy. Available: http://www.rspb.org.uk/ourwork/projects/details/258718-annual-bittern-monitoring-.

Wright, L.J., Hoblyn, R.A., Green, R.E., Bowden, C.G.R., Mallord, J.W., Sutherland, W.J. & Dolman, P.M. 2009. Importance of climatic and environmental change in the demography of a multi-brooded passerine, the woodlark *Lullula arborea*. *Journal of Animal Ecology* **78:** 1191-1202.

Zaugg, S., Saporta, G., van Loon, E., Schmaljohann, S & Liechti, F. 2008. Automatic identification of bird targets with radar via patterns produced by wing flapping. *Journal of the Royal Society Interface* **5:** 1041-1053.

Zehnder, S., Åkesson, S., Liechti, F. & Bruderer, B. 2001. Nocturnal autumn bird migration at Falsterbo, South Sweden. *Journal of Avian Biology* **32:** 239-248.

Table 1. Published bird flight heights during migration. Heights are given in metres above ground level (m AGL). The location, season, conditions, technique used to measure flight height, and references are also given. Note that in the majority of studies the information presented will not allow estimation of the numbers of birds flying at heights where they may encounter wind turbines. This is because many in many cases the data are only sufficient to group birds into broad height bands (e.g. birds are at less than 4,000 m. But this means birds could be at altitudes 3999m or 0.5m, or anywhere in between). Other studies give a mean flight height but no estimate of the distribution of flight heights around this mean.

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Swans	≤300 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Whooper Swan	9±16.2	British coast	Spring & Autumn	Day & night	Satellite tag	Griffin *et al*. 2010
Whooper Swan	32±55	Between Britain and Iceland	Spring & Autumn	Day & night	Satellite tag	Griffin *et al*. 2010
Whooper Swan	74±123	Overland	Spring & Autumn	Day & night	Satellite tag	Griffin *et al*. 2010
Whooper Swan	68-324	Between Britain/ Ireland and Iceland	Spring	Day & night	PTT-100 satellite transmitters	Pennycuick *et al*. 1999
Whooper Swan	146-1856	Between Iceland and Britain/Ireland	Autumn	Day & night	PTT-100 satellite transmitters	Pennycuick *et al*. 1999
Geese	≤300 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Geese	64.2 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Pink-footed Geese	250-300	Lincolnshire coast	Autumn	Good visibility	Visual observation of flight heights (flock detection by radar)	Plonczkier & Simms 2012
Pink-footed Geese	100-150	Lincolnshire coast	Autumn	Poor visibility	Visual observation of flight heights (flock detection by radar)	Plonczkier & Simms 2012
Brant Geese	200-500	Sweden (departing over land)	Autumn	Afternoon/ evening	Observation	Alerstam *et al*. 1990
Brent Goose	506 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Brent Goose	<1000	Southern Sweden	Spring	Evening	Tracking radar	Green 2004
Ducks	≤150 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Pintail	238 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Common Eider	13.7±15	In wind farm, Nysted, Denmark	Autumn		TADS (infrared)	Desholm 2005
Common Eider	28.9±19.6	Outside wind farm, Nysted, Denmark	Autumn		TADS	Desholm 2005
King Eider	12.1±0.8	Barrow Spit, Alaska	Autumn	Day, good visibility	Observation	Day *et al*. 2004
King Eider	7.3±1.2	Barrow Spit, Alaska	Autumn	Headwind	Observation	Day *et al*. 2004
King Eider	14.4±1.2	Barrow Spit, Alaska	Autumn	Tailwind	Observation	Day *et al*. 2004
Steller's Eider	369 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Long-tailed Duck	428 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Common Scoter	4 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Cormorant	58.3 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
White Stork	488-1615 (max daily)	Israel (Coastal Plains, Judean and Samarian Mountains)	Spring		Airport surveillance radar/glider	Shamoun-Baranes *et al*. 2003
White Stork	488-1615 (max daily)	Israel (Coastal Plains, Judean and Samarian Mountains)	Spring		Airport surveillance radar/glider	Shamoun-Baranes *et al*. 2003
Raptors	≤150 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Sandhill Crane	30 – 300 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Shorebirds	<150 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Waders	1000-3000	Southern Sweden	Spring	Evening	Tracking radar	Green 2004
Small waders (Turnstone, Knot)	400-2000	Iceland (departing)	Spring	Afternoon/evening	Observation	Alerstam *et al*. 1990
Ruff	479 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Bar-tailed Godwit	61 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Bar-tailed Godwit	119 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Red-necked Phalarope	283 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Grey Phalarope	530 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Pomarine Skua	908 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Arctic skua	49 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Gulls	71 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Black-legged Kittiwake	294 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Herring Gull	208 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Terns	21 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Arctic Tern	522 (mean)	NE Passage, Arctic	Autumn		Tracking radar/observation	Alerstam & Gudmundsson 1999
Arctic Tern	30-60	Antarctica	Autumn		Marine navigation radar	Gudmundsson *et al*. 1992
Woodpigeon	210 (mean)	Horns Rev, Denmark	Spring & Autumn	Day & night	Radar	Petersen *et al*. 2005
Passerines	<30 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Day	Observations	Cooper & Ritchie 1995
Passerines	<1000 (mostly <500)	St Lawrence Estuary, Canada	Autumn	Night	Doppler radar	Gagnon *et al*. 2011
Passerines	2000-4000	Sahara, Mauritania	Spring	Night	Fixed-beam radar	Schmaljohann *et al*. 2007
Songbirds	mostly <1100 (but up to 3800)	Sahara, Mauritania	Autumn	Night	Fixed-beam radar	Schmaljohann *et al*. 2008
Songbirds	<1000	Sahara, Mauritania	Autumn	Night, tailwind	Radar	Schmaljohann *et al*. 2009
Passerines	<300	Appalachian Mountains, USA	Autumn	Night	Radar/ceilometers	Williams *et al*. 2001
Passerines	<2100 (mostly <300)	Falsterbo, Sweden	Autumn	Night	Infrared	Zehnder *et al*. 2001

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Thrush-sized passerines	<500	Georgia, USA	Spring & Autumn	Night	Radar, ceilometers	Able & Gauthreaux 1975
All	<4000	Arava Valley, Israel	Spring	Night	Tracking radar	Bruderer *et al*. 1995
All	<3000 (mostly <2000)	Arava Valley, Israel	Autumn	Night	Tracking radar	Bruderer *et al*. 1995
All	<500 (lower in Spring than Autumn)	CE Alaska, USA	Spring & Autumn	Night	Radar	Cooper & Ritchie 1995
All	<2300	Swiss Alps	Autumn	Night	Radar	Komenda-Zehnder *et al*. 2010
All	<1800	Swiss Alps	Autumn	Day	Radar	Komenda-Zehnder *et al*. 2010
All	<3600 (mostly <2200)	Israel	Spring	Night	Moon-watching/fixed-beam radar	Liechti & Bruderer 1995
All	<2000 (mostly <1200)	Israel	Autumn	Night	Moon-watching/fixed-beam radar	Liechti & Bruderer 1995

Table 2. Published bird flight heights at times of year other than during migration. These flight heights are presented for completeness, but it is important to note that they will not be applicable to migrating birds that will be behaving differently and may fly at different heights. Heights are given in metres above ground level (m AGL). The location, season, conditions, technique used to measure flight height, and references are also given. Note that in the majority of studies the information presented will not allow estimation of the numbers of birds flying at heights where they may encounter wind turbines. This is because many in many cases the data are only sufficient to group birds into broad height bands (e.g. birds are at less than 4,000 m. But this means birds could be at altitudes 3999m or 0.5m, or anywhere in between). Other studies give a mean flight height but no estimate of the distribution of flight heights around this mean.

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Geese & swans	35.2±37.1	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Non-sea ducks	34.8±32.8	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Sea ducks	18.5±19.0	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Common Eider	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Eider	<50	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Common Scoter	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Common Scoter	<50	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Velvet Scoter	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Divers	19.0±16.1	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Divers	<100	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Red-throated Diver	5-10	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Black-throated Diver	5-10	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Tubenoses	11.3±0	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Northern Fulmar	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Fulmar	<23	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Northern Gannet	10-20	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Gannets	25.6±15.8	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Gannet	>100 (but most <100)	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Cormorants	23.8±22.4	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Great Cormorant	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Great Cormorant	mostly <100	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Double-crested Cormorant	150	Nantucket Sound, MA	Autumn	Day	Observation (aerial)	Perkins *et al*. 2003
Grebes	11.3	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Great-crested Grebe	5-10	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Red-necked Grebe	5-10	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Raptors & owls	78.3±53.3	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Shorebirds	<150	USA	Year round		Aircraft collisions	Dolbeer 2006
Waders	28.6±45.4	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Skuas	16.2±11.9	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Arctic Skua	10- 20	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Great Skua	10- 20	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Gulls & terns	<1000	USA	Year round		Aircraft collisions	Dolbeer 2006
Gulls	36.8±33.3	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Black-legged Kittiwake	<50	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Black-legged Kittiwake	5-10	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Little, Black-headed, Common Gull	mostly <200	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Black-headed Gull	>100	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Black-headed Gull	<574.6 132±71.3 (soaring) 225.8±139.4 (flapping)	SE Netherlands			Tracking radar/video camera	Shamoun-Baranes *et al*. 2006
Little Gull	0- 5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Mew Gull	10- 20	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Herring, Lesser Black-backed, Great Black-backed Gull	mostly <200	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Lesser Black-backed Gull	20- 50	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Lesser Black-backed Gull	<737.7 174.8±138.5 (soaring) 298.3±152.85 (flapping)	SE Netherlands			Tracking radar/video camera	Shamoun-Baranes *et al*. 2006
Herring Gull	20- 50	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Great Black-backed Gull	10-20	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Terns	27.6±18.7	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Terns	150	Nantucket Sound, MA	Autumn	Day	Observation (aerial)	Perkins *et al*. 2003
Black Tern	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Sandwich Tern	10-20	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Sandwich Tern	mostly <50	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Common, Arctic Tern	<50	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004

Species	Height (m AGL)	Location	Season	Conditions	Technique	References
Common Tern	5- 10	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Arctic Tern	0- 5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Alcids	11.9±4.4	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Common Guillemot	0- 5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Guillemot	<50	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Razorbill	0-5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Razorbill	<25	Dutch North Sea	Year round	Day	Observation	Leopold *et al*. 2004
Atlantic Puffin	0- 5	German North Sea	Year round	Day	Observations	Garthe & Hüppop 2004
Songbirds	>300	Baltic/North Sea		Day	Radar/observation	Blew et al. 2008
Passerines	<1000	USA	Year round		Aircraft collisions	Dolbeer 2006
Thrushes	43	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004
Small passerines	<135	Dutch North Sea	Year round	Day	Radar	Krijgsveld *et al*. 2004

Table 3. Assumptions of the percentage of migrating birds potentially flying at turbine height, by species group, to be used in the absence of any other evidence regarding flight heights for the species in question (e.g. from site-specific survey data, or from tracking or radar studies). A range is given in brackets for each species group to suggest lower and upper limits to provide a range of estimates. These figures are based on expert judgement of the likely average height of birds in each group bearing in mind variation due to weather. Estimates draw on the published figures for recorded/estimated flight heights of birds during migration, detailed in Table 1, and on figures on proportion of migrating birds at turbine height that have been used in impact assessments. Upper limits follow a precautionary approach where there is uncertainty, bearing in mind that at offshore wind farm sites that are near coasts, birds may by close to the end of their migratory journey and therefore reducing their altitude as they approach land. Many groups have a very wide range due either to a lack of information or conflicting information from the range of studies available.

Species group	**Percentage of birds potentially at turbine height (20-200m), and range (in brackets)**
Swans	50% (10-90%). If available, use latest data on flight heights from tracking studies (e.g. Griffin *et al*. 2010a, b, 2011) to calculate proportion of time birds spend at turbine height when over the sea, and 95% confidence limits around these values.
Geese	30% (5-75%) (or use data from Griffin *et al*. 2011 or other tracking studies as described above)
Ducks	15% (0.1-60%) (except for Common Scoter use Cook *et al*. 2012: 1% (<0.1-17%))
Divers	2% (0.1-35%) For Red- and Black-throated use Cook *et al*. 2012 (Red-throated Diver 2% (<0.1-22.4%), Black-throated Diver 1% (<0.1-30.5%))
Seabirds	Variable. Use Cook *et al*. 2012, or information therein on closely related species for species not covered by Cook *et al*. 2012.
Bittern / Little Egret	50% (5-95%). This wide range is because of a lack of information.
Grebes	10% (1-40%)
Raptors	50% (25-100%)
Crakes	50% (5-95%)
Coot	50% (5-95%).
Waders	25% (5-75%)
Gulls	Cook *et al*. 2012 covers most gulls. For species not covered by that report, use 20% (0.5-60%), based on the average of gull species in Cook *et al*.
Terns	Use Cook *et al*. 2012 for Sandwich, common and Arctic terns. For other species, use 7% (0.1-35%), based on the average of tern species in Cook *et al*. 2012.
Owls & Nightjar	50% (10-95%)
Passerines	25% (5-75%)

ANNEX 1 – GUIDANCE FOR THE USE OF THE MIGRATION ASSESSMENT TOOL

This document describes the rationale behind, and use of, the Excel Workbook and accompanying GIS shapfile that together comprises the 'SOSS Migration Assessment Tool' (SOSSMAT). There is also an accompanying video demonstrating the use of SOSSMAT that can be found at:
http://www.youtube.com/watch?v=sTt0kODhuEE&feature=share&list=PLDmgiA5KPXHQzTfVshzj2OhuRX1Zxw015

RATIONALE

Connectivity Matrix

The connectivity matrix forms an integral part of the Excel Workbook that comprises the SOSSMAT. This has already been derived. Consequently no user action is required and thus the first two sections on Lines of connectivity and Species Specific connectivity are for information only.

Lines of connectivity

Using the Station Point wizard of ET Geowizards™ within ArcGIS™, station points were first generated along the coastlines of the UK and coastlines of countries with line of sight to the UK relevant to migratory birds.

The initial station points were automatically positioned at 10km intervals along the coastlines.

These were then rationalised through manual edits to ensure a relatively even distribution along the general coastline by removing points from clusters (such as those caused by the coastline following estuaries and fjords).

Station points were then allocated to categories representing contiguous stretches of coast or country, chosen to represent distinct coastal stretches between which direct sea-crossings could be plotted.

The grid references of all station points were then exported from ArcGIS.

Based on these locations, a matrix of start and end points was generated in the statistical software SAS™ for all possible straight line sea-crossings between each station point and all other station points (approx. 1,200,000 lines).

These were filtered to remove joins that would not be required for assessment of migration through off-shore wind farms, for example lines crossing land and lines within coastal stretches other than specific exceptions where those lines crossed significant offshore stretches of sea.

These start and end points were then imported back into GIS and the 'points to polyline' tool of ET Geowizards™ used to generate all possible direct line of sight sea crossings for migrants traveling across UK waters (251,599 lines of connectivity).

Species specific connectivity

The maps accompanying the species accounts from this report, depicting polygons encompassing the migration routes of individual species were then used to flag lines of connectivity on a species specific basis.

This was done using the 'select by location' dialogue to select all lines falling completely within each migration polygon. Note that for some species there are separate maps for breeding and passage populations - these were processed independently. Also where there are separate polygons distinguishing major migration paths from trivial or speculative migration paths only the former are considered.

Those lines falling completely within the migration polygon were coded '1' and all other lines coded '0' for the species in question. This forms the basis of the worksheet 'Connectivity Matrix' in the SOSSMAT. That worksheet is locked to prevent accidental changes.

ANALYSIS

Wind farm footprint

The ArcGIS shapefile provided 'ConnectivityLines.shp' contains the final selection of 251,599 lines of connectivity. Users will need to flag those lines of connectivity that cross the footprint(s) of the proposed wind farm and use the resulting table of attributes to populate the work sheet 'Footprints' in the SOSSMAT.

The SOSSMAT has the capacity to assess up to 10 wind farm footprints simultaneously so long as they are all situated in approximately the same offshore area. Separate copies of the SOSSMAT workbook should be used if wind farms involving different subsets of sea areas are being considered. Detailed instructions follow later in this document.

Relevant Sea-crossings

The SOSSMAT contains a worksheet 'Route Filter'. Each record represents a unique combination of start and end points associated with lines of connectivity of which there are 130 possibilities. Only cells colour coded 'green' are editable. Values in the field 'Retained for project(s)' are user defined (intuitive Y/N and not case sensitive) to determine which sea crossings will be used in the analysis. Detailed instructions follow later in this document.

Percentage of relevant population(s) using the sea crossing(s) in question that cross the wind farm footprint

Once the Footprint(s) and Route Filter worksheets have been populated, a value for percentage of the population crossing the relevant sea crossing that will pass over the wind farm footprint(s) will be automatically updated in the worksheet 'Results' of the SOSSMAT. These fields are colour coded 'blue' (columns F to O) and are not editable. The percentage is calculated as:

[The number of lines crossing the wind farm footprint, totally contained within the species migration corridor(s) and belong to a relevant sea crossing] / [The number of lines totally contained within the species migration corridor(s) and belong to a relevant sea crossing] %

Population size and Population Correction Factor

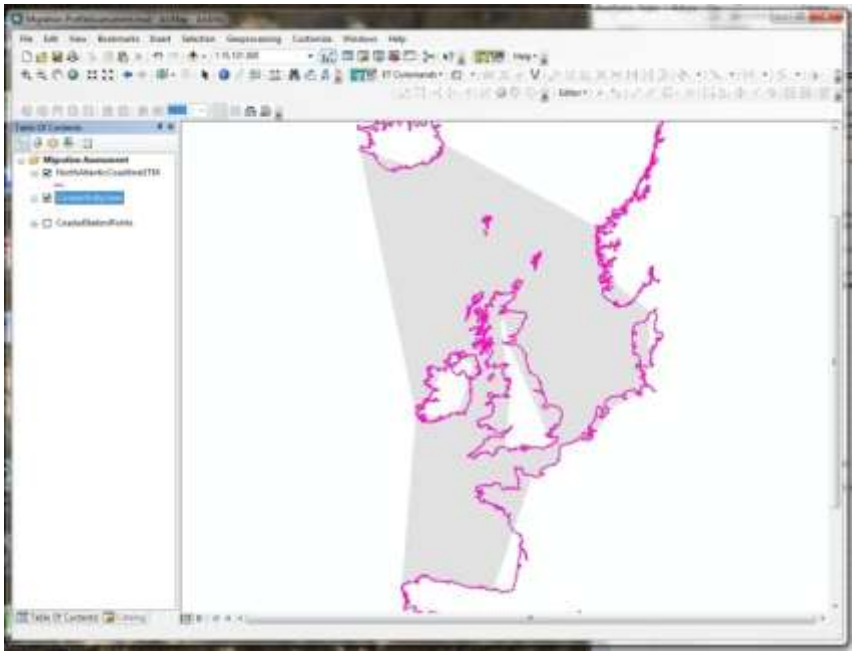
There are several other user fields in the worksheet 'Results' that allow users to take the next step in the analysis i.e. to estimate the actual number of birds that will cross the wind farm footprint(s). These cells are colour coded 'green' and are user editable. Two of these fields 'Population Size' (column C) and 'Population correction Factor' (column D) need to be populated by the user. Once populated, estimates for the number of individuals crossing the wind farm footprint will be automatically updated in the cells colour coded 'orange' (columns P to Y). Detailed instructions follow later in this document.

Detailed instructions for populating Footprints in the SOSSMAT

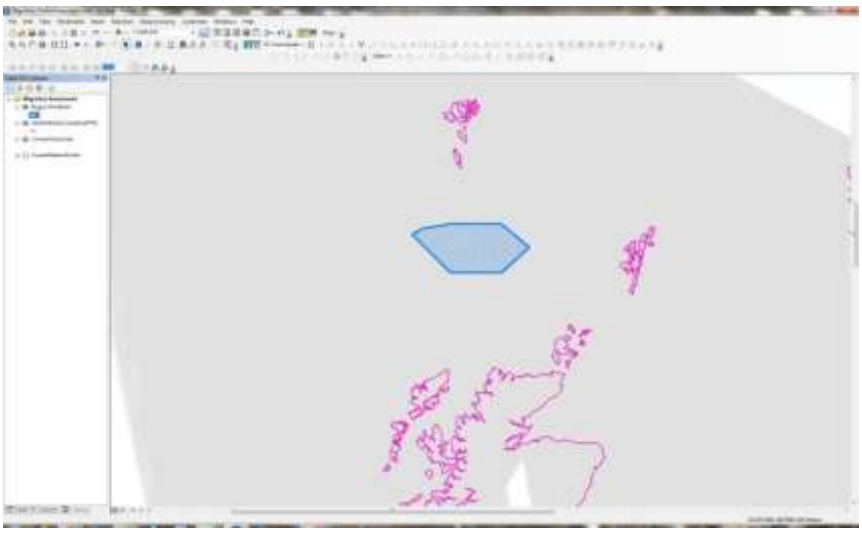
This involves a relatively straightforward GIS process. The instructions and screen shots that follow assume the use of ArcGIS™ 10. One shapefile is provided as an accompaniment to the SOSSMAT. The processes described below and ability to import the shapefile should be available in any mainstream GIS software.

The only two shapefiles required are the file 'ConnectivityLines.shp' provided with the SOSSMAT and a polygon file representing the footprint(s) of the wind farm under assessment. A European outline is reassuring but not required.

1) add the shapefile ConnectivityLines.shp to your GIS project. This shapefile contains 251599 potential lines of connectivity for all potential sea crossing involving UK waters. You probably want to un-tick the check-box to display these lines so as to speed up screen refreshes.



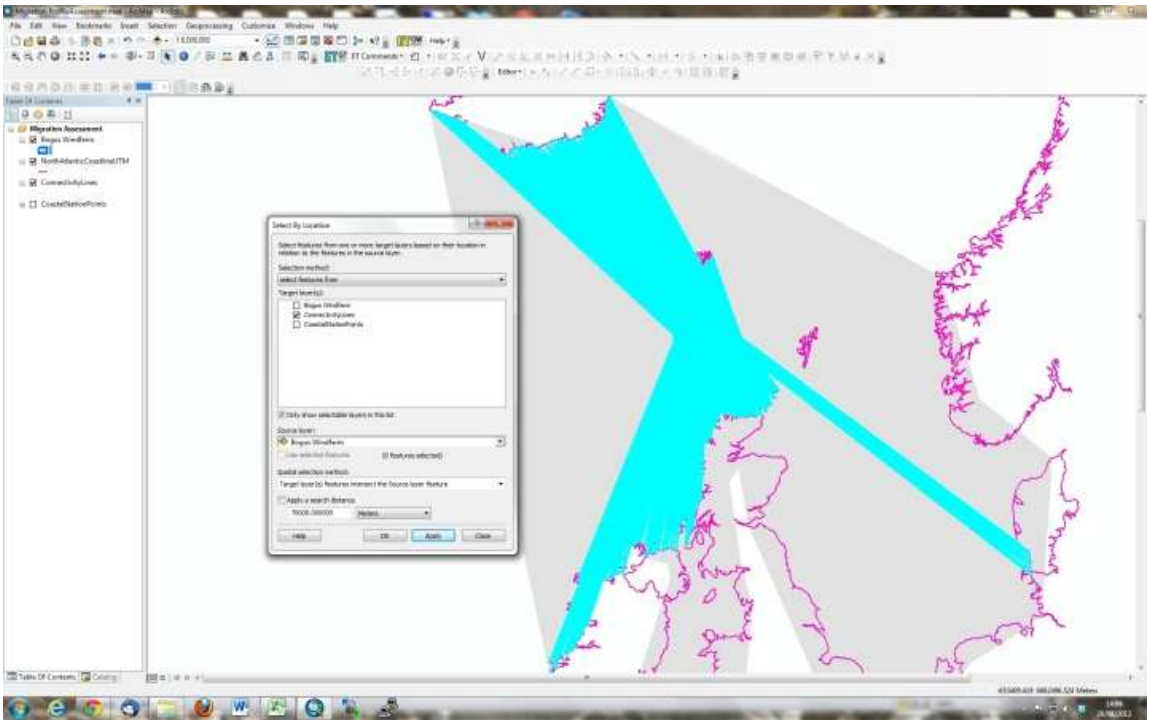
2) add a shapefile containing a polygon of your wind farm footprint(s).



3) from the menu bar bring up the 'select by location' dialogue and set the following parameters:

- Selection method dropdown - 'select features from'
- Target layer(s) check-boxes - 'ConnectivityLines'
- Source layer dropdown – ‘your wind farm polygon layer’
- Use selected features check-box – optional (see below*)
- Spatial selection method dropdown - 'Target layer(s) features intersect the Source layer feature'

*By default if you have more than one footprint polygon all lines crossing any one of them will be selected. If however, you have previously selected one or more polygons in your footprint layer you have the option to 'use selected features' (check-box below Source layer dropdown) to restrict the selection to lines crossing those polygons you have selected. Thus if you have multiple footprints to assess you can select each in turn or combinations of several as you work through the steps that follow to populate a footprint field for each.

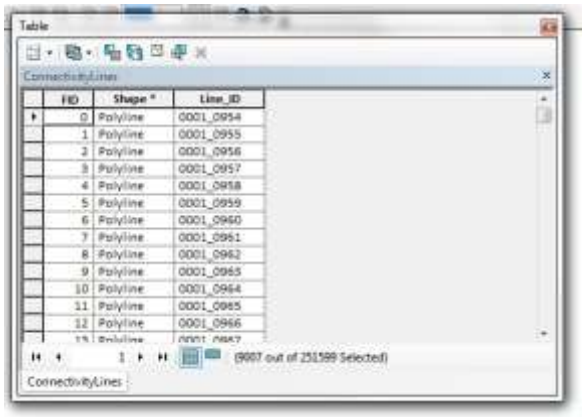


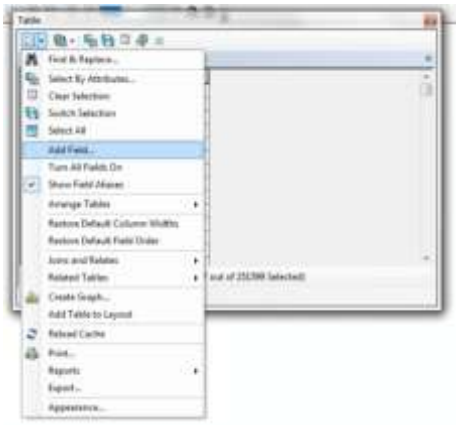
4) Now add a new field to the attribute table of ConnectivityLines

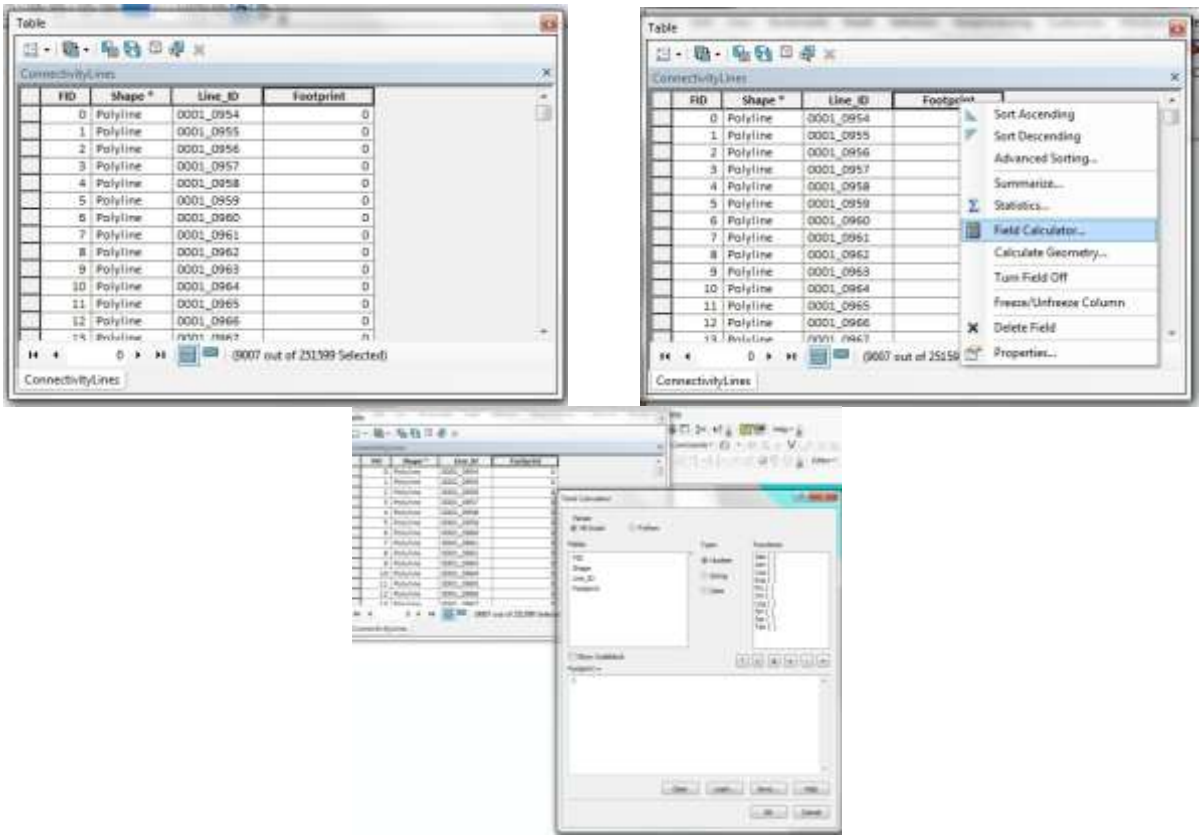
- open the attributes table of ConnectivityLines and create a new field 'Footprint1' as a short integer. It will be initialised with value '0'.
- as all those lines crossing your footprint are already selected right mouse click and select 'Field Calculator'.
- Enter 1 in the dialogue box.

All lines crossing your footprint should now be coded '1' and all other lines '0'.

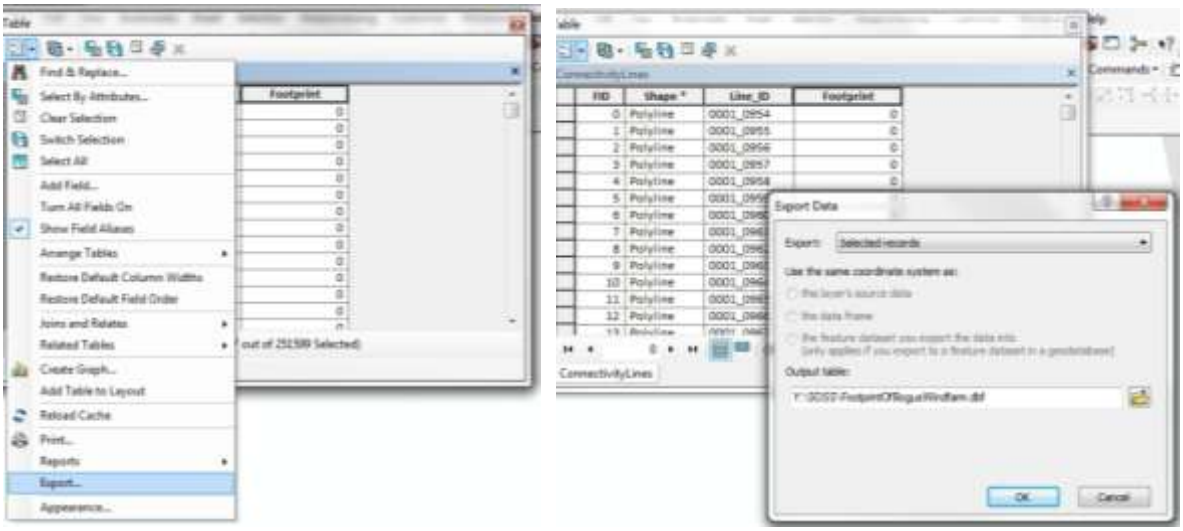
- Clear selection (very important)
- Repeat as necessary to populate Footprint2, Footprint3 ... and so on.



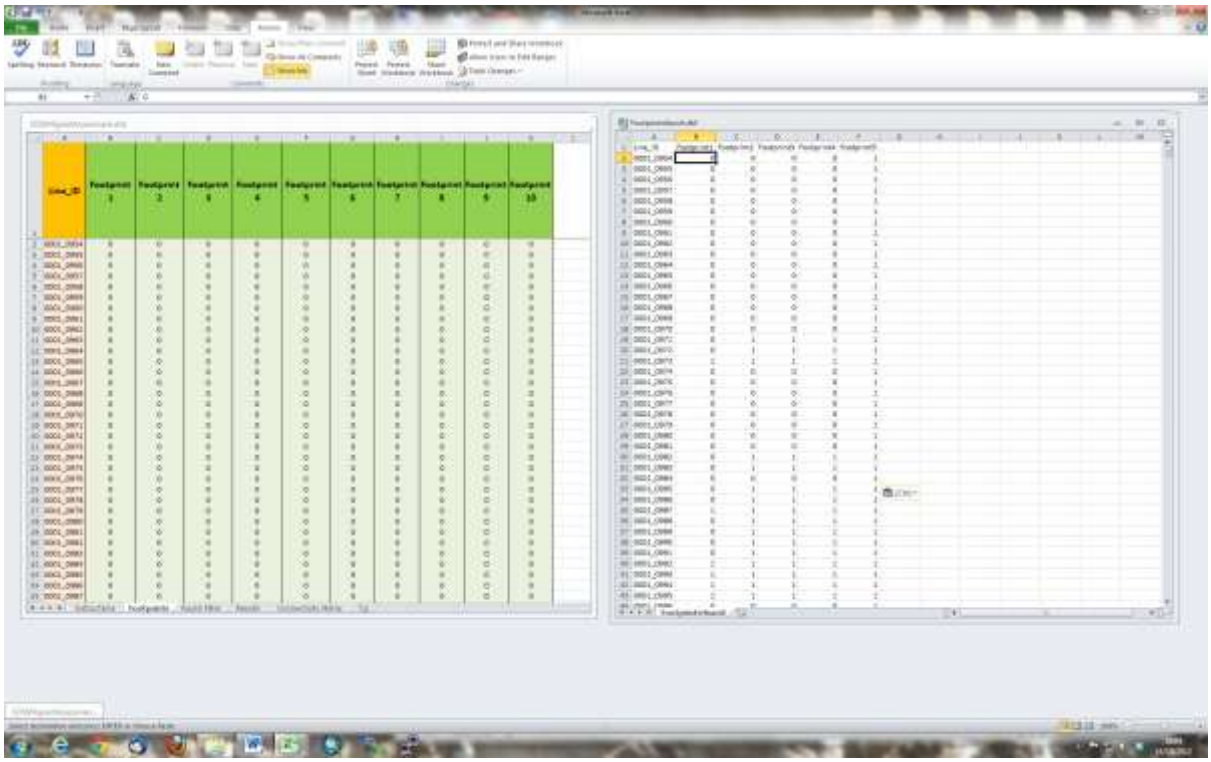




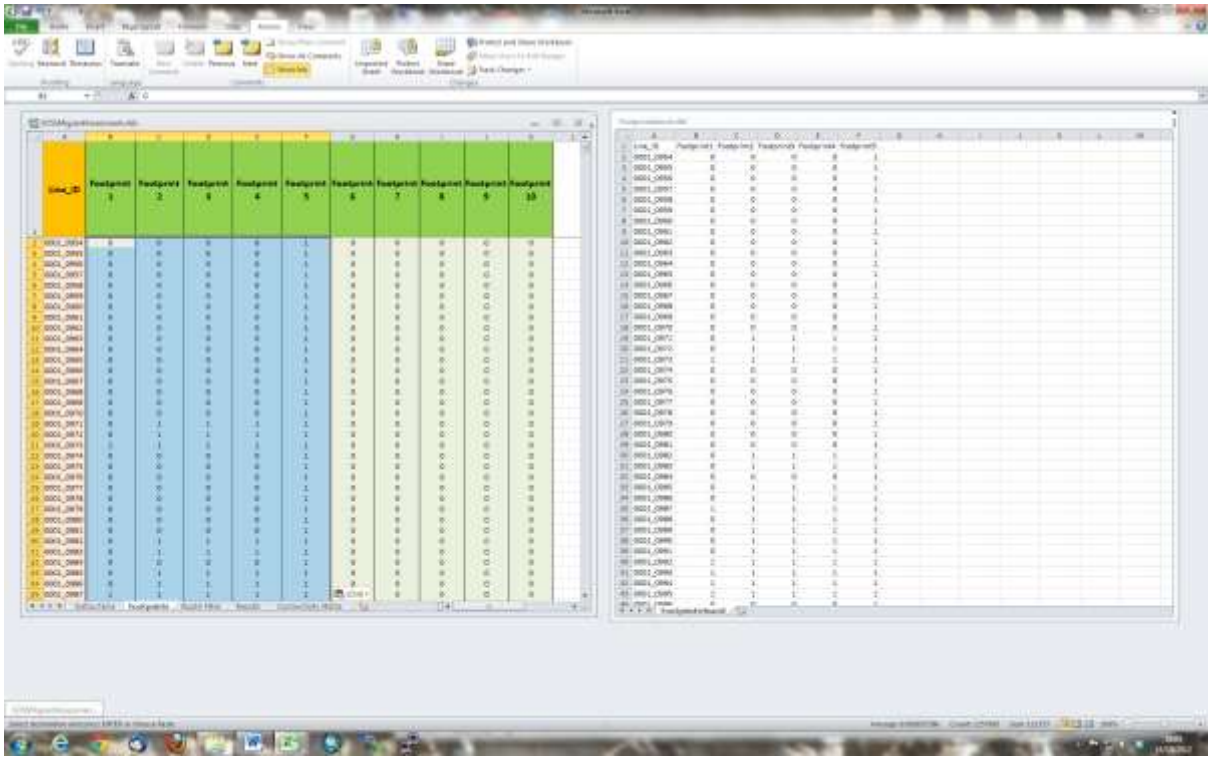
5) Ensure that no features are highlighted and then export the attribute table as a DBF file (safer than using the DBF associated with the shapefile directly for the next step in case of accidental edits). Note, if you neglect to clear the selection before the export, the exported DBF will only contain records for selected features rather than all 251,599 records. You need all 251,599 records.



6) Open the SOSSMAT Workbook and select the worksheet 'Footprints'. In Windows explorer, find the DBF file you have just exported from GIS and drag and drop it on your Excel window - a new sheet should open up containing the data just exported from the GIS.



7) Ensure both the 'Footprint' worksheet and the DBF sheet are sorted by Line_ID (this is critical). A straightforward "copy and paste" can now be used to populate the worksheet 'Footprint(s)' with up to 10 different project footprints (to highlight cells to be copied, click cell B2 of DBF, while holding down <shift> <Ctrl> then press <down arrow> followed by ,<right arrow>, then release.)



Detailed instructions for populating Route Filter in the SOSSMAT

The worksheet 'Route Filter' in SOSSMAT is used to filter out sea crossings that are not pertinent to the wind farm being assessed.

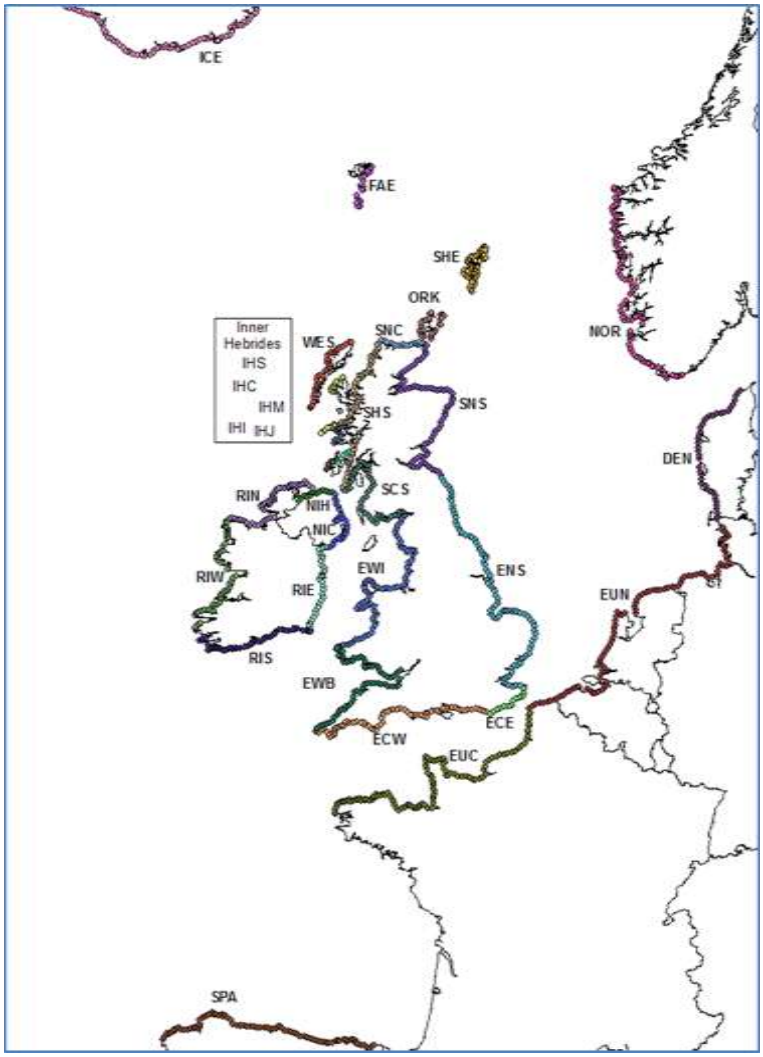
It is important to understand that the selection of sea crossing flagged to be used in the process described below will be applied simultaneously to all footprints being assessed. Consequently if multiple wind farms are being assessed for which different selections of sea crossings are appropriate, it is recommended that this should be undertaken in separate copies of the SOSSMAT workbook. Alternatively, but not recommended, values for results that need to be saved could be copied to a new Excel workbook before re-evaluating which sea crossings to flag for inclusion in a new assessment.

Regardless of the origins of the population being considered, it is important to only consider sea crossings relevant to the wind farm in question and not all sea crossings relevant to the migration route of the particular population. If this is not done the numbers of birds crossing the wind farm footprint can be seriously over- or under-estimated. For example Bar-tailed Godwit wintering in in Britain and Ireland all cross the North Sea, and those wintering in Ireland travel on to cross the Irish Sea. Assessment for a wind farm in the North Sea would use only lines of connectivity representing North Sea crossings against the population over-wintering in Britain and Ireland. Assessment for a wind farm in the Irish Sea would only use lines of connectivity representing Irish Sea crossings and only against the population over-wintering in Ireland. In either case, to have used the combined lines of connectivity for the North Sea and Irish Sea crossings would seriously underestimate the number of birds crossing the wind farm footprint.

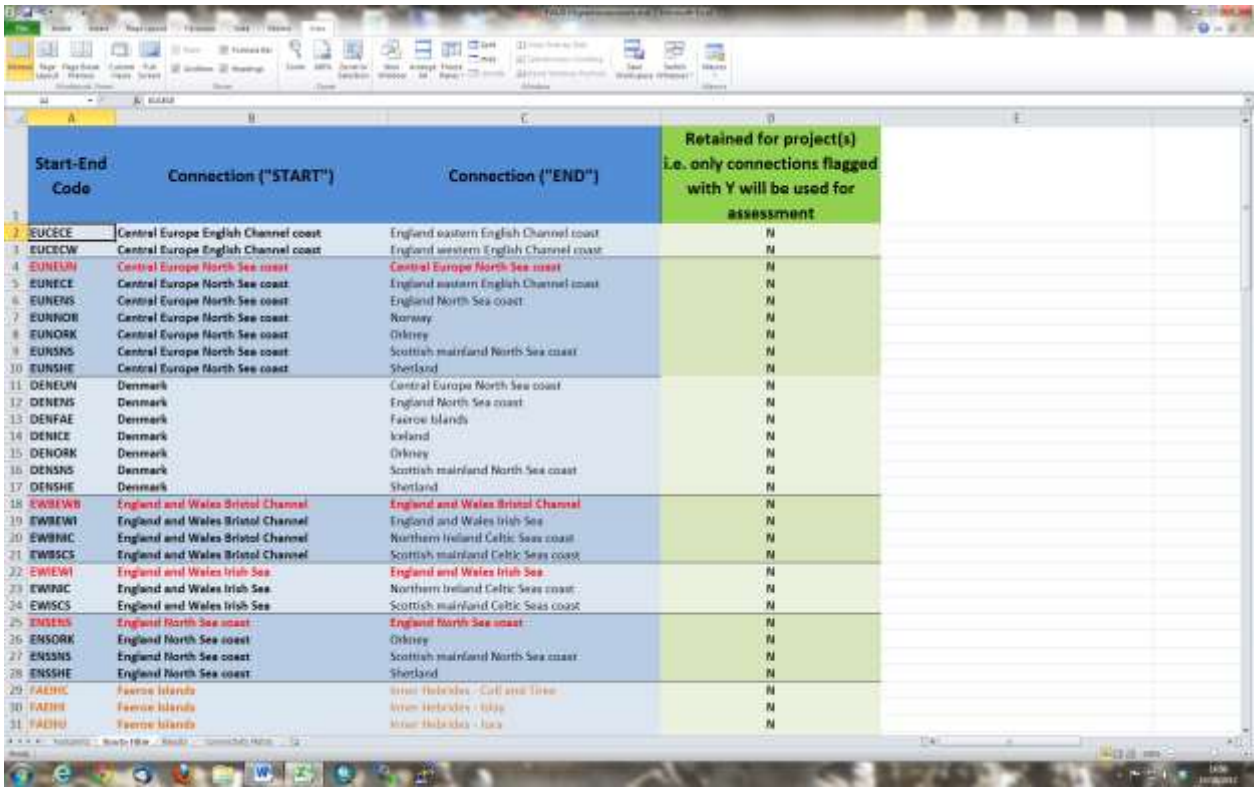
Thirty different coastal zones have been defined for the purpose of migration assessment. Note that the incorporation within the names of these zones of such terms as North Sea, Hebridean Seas, Celtic Seas and so forth does not imply correspondence with boundaries that may be defined for other purposes. They are used here to distinguish stretches of coast for the purpose of distinguishing different line-of-sight sea crossings.

Coastal zones defined for the SOSSMAT	**Sea crossings considered by the SOSSMAT** Curved parentheses indicate sea crossings that are only appropriate for wind farms closer to shore, squared parentheses indicate sea crossings that should only be considered for a small suite of species terminating migration in the Western Isles and Inner Hebrides.
DEN: Denmark	**DEN →** ENS; EUN; FAE; ICE; ORK; SHE; SNS
ECE: England eastern English Channel coast	**ECE →** EUC; EUN
ECW: England western English Channel coast	**ECW →** EUC;SPA
ENS: England North Sea coast	**ENS →** DEN; EUN; NOR; ORK; SHE; (SNS)
EUC: Central Europe English Channel coast	**EUC →** ECE; ECW; RIS
EUN: Central Europe North Sea coast	**EUN →** DEN; ECE; ENS; NOR; ORK; SHE; SNS
EWB: England and Wales Bristol Channel	**EWB →** (EWB); RIS
EWI: England and Wales Irish Sea	**EWI →** (EWI); SCS; NIC; RIW
FAE: Faeroe Islands	**FAE →** DEN; NOR; ORK; RIN; SHE; SHS; SNC; WES
ICE: Iceland	**ICE →** DEN; NOR; ORK; RIN; SHE; SNC; SHS; WES; [IHC; IHI; IHJ; IHM; IHS]
IHC: Inner Hebrides - Coll and Tiree	IHC → [FAE; ICE; IHI; IHJ; IHM; IHS; SHS; WES]
IHI: Inner Hebrides - Islay	IHI → [FAE; ICE; IHC; IHJ; IHM; IHS; SHS; WES]
IHJ: Inner Hebrides - Jura	IHJ → [FAE; ICE; IHC; IHI; IHM; IHS; SHS; WES]
IHM: Inner Hebrides - Mull	IHM → [FAE; ICE; IHC; IHI; IHJ; IHS; SHS; WES]
IHS: Inner Hebrides - Skye and Lewis	IHS → [FAE; ICE; IHC; IHI; IHJ; IHM; SHS; WES]
NIC: Northern Ireland Celtic Seas coast	**NIC →** EWI; SCS
NIH: Northern Ireland Hebridean Seas coast	**NIH →** SHS; WES; [IHC; IHI; IHJ; IHM; IHS]
NOR: Norway	**NOR →** ENS; EUN; FAE; ICE; ORK; SHE; SNS
ORK: Orkney	**ORK →** DEN; ENS; EUN; FAE; ICE; NOR; SHE; SNC; SNS;
RIE: Republic of Ireland - Celtic Seas eastern coast	**RIE →** EWB; EWI

Coastal zones defined for the SOSSMAT	Sea crossings considered by the SOSSMAT Curved parentheses indicate sea crossings that are only appropriate for wind farms closer to shore, squared parentheses indicate sea crossings that should only be considered for a small suite of species terminating migration in the Western Isles and Inner Hebrides.
RIN: Republic of Ireland Atlantic northern coast	**RIN →** ICE; FAE; SHS; WES; [IHC; IHI; IHJ; IHM; IHS]
RIS: Republic of Ireland Celtic Seas southern coast	**RIS →** EWB; SPA
RIW: Republic of Ireland Atlantic western coast	**RIW →** ICE
SCS: Scottish mainland Celtic Seas coast	**SCS →** EWI; NIC; RIE
SHE: Shetland	**SHE →** DEN; ENS; EUN; FAE; ICE; NOR; ORK; SNC; SNS; WES
SHS: Scottish mainland Hebridean Seas coast	**SHS →** FAE; ICE; NIH; RIN; WES; [IHC; IHI; IHJ; IHM; IHS]
SNC: Scottish mainland northern coast	**SNC →** FAE; ICE; ORK; SHE
SNS: Scottish mainland North Sea coast	**SNS →** DEN; EUN; NOR; ORK; SHE; (ENS; SNS)
SPA: Spanish north coast	**SPA →** ECE; ICE; RIS
WES: Western Isles	**WES →** FAE; ICE; NIH; RIN; SHE; SHS; [IHC; IHI; IHJ; IHM; IHS]



Only the cells colour coded 'green' in the worksheet 'Route Filter' are editable. There are 130 sea-crossings to consider. The terms 'start' and 'end' have no meaning relative to the direction of migration. Note that it is not possible to sort such a table in such a way that all sea crossings involving a particular coastal zone appear together therefore ensure you have considered all rows.



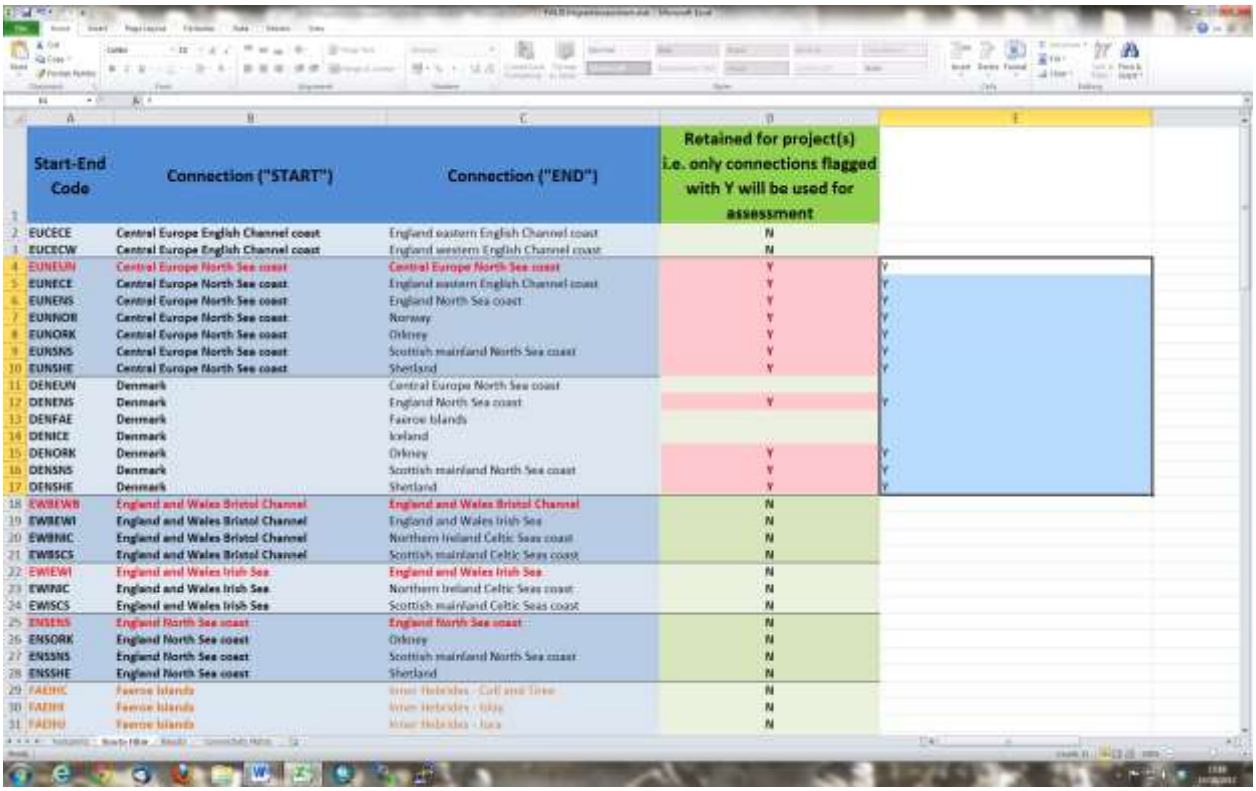
Start-End Code	Connection ("START")	Connection ("END")	Retained for project(s) i.e. only connections flagged with Y will be used for assessment
EUCECE	Central Europe English Channel coast	England eastern English Channel coast	N
EUCECW	Central Europe English Channel coast	England western English Channel coast	N
EUNEUN	Central Europe North Sea coast	Central Europe North Sea coast	N
EUNECE	Central Europe North Sea coast	England eastern English Channel coast	N
EUNENS	Central Europe North Sea coast	England North Sea coast	N
EUNNOR	Central Europe North Sea coast	Norway	N
EUNORK	Central Europe North Sea coast	Orkney	N
EUNSNS	Central Europe North Sea coast	Scottish mainland North Sea coast	N
EUNSHE	Central Europe North Sea coast	Shetland	N
DENEUN	Denmark	Central Europe North Sea coast	N
DENENS	Denmark	England North Sea coast	N
DENFAE	Denmark	Faeroe Islands	N
DENICE	Denmark	Iceland	N
DENORK	Denmark	Orkney	N
DENSNS	Denmark	Scottish mainland North Sea coast	N
DENSHE	Denmark	Shetland	N
EWBEWB	England and Wales Bristol Channel	England and Wales Bristol Channel	N
EWBEWI	England and Wales Bristol Channel	England and Wales Irish Sea	N
EWBNIC	England and Wales Bristol Channel	Northern Ireland Celtic Seas coast	N
EWBSCS	England and Wales Bristol Channel	Scottish mainland Celtic Seas coast	N
EWIEWI	England and Wales Irish Sea	England and Wales Irish Sea	N
EWINIC	England and Wales Irish Sea	Northern Ireland Celtic Seas coast	N
EWISCS	England and Wales Irish Sea	Scottish mainland Celtic Seas coast	N
ENSENS	England North Sea coast	England North Sea coast	N
ENSORK	England North Sea coast	Orkney	N
ENSSNS	England North Sea coast	Scottish mainland North Sea coast	N
ENSSHE	England North Sea coast	Shetland	N
FAEHIC	Faeroe Islands	Inner Hebrides - Coll and Tiree	N
FAEHII	Faeroe Islands	Inner Hebrides - Islay	N
FAEHIU	Faeroe Islands	Inner Hebrides - Iona	N

To flag a particular sea crossing for inclusion in the assessment simply enter a Y (or y – it is not case sensitive) in the editable field (column D) of the relevant row. Note that because the value you have just entered feeds into formulae in the 'Connectivity matrix' worksheet, you may get a moment of unresponsiveness as values in 251,599 cells are updated and in turn feed through into the 'results' worksheet. Cells will turn 'red' once the update has concluded.

(Tip: copy column D and paste VALUES into column E; change N to Y as appropriate in column E; copy column E and paste VALUES back into column D. In this way all the updates in other worksheets will be done in one operation and you will not have to wait between flagging each record).

The colour coding of the text in the first three columns provides a little further guidance to selecting sea crossings for inclusion in an assessment.

- **Black text:** In most cases you would make your selection from these.
- **Red text:** These are within coast zone sea crossings. These should be used only when considering wind farms relatively close to land for example in the Bristol Channel, Irish Sea, Firth of Forth and The Wash where long distance migrants may "clip the coast" as they pass through.
- **Orange text:** These are sea crossings involving the Hebrides. These should only be used for a few specific species for which the final destination is within the Hebrides (such as Greenland White-fronted Geese the majority of which winter on Islay, or Corncrake for which Coll and Tiree support the majority of the UK population) and then only for wind farms actually located within those areas. In other cases you would ignore the existence of the Hebrides and consider sea crossings to the mainland of Ireland and Scotland.



	A	B	C	D	E
1	Start-End Code	Connection ("START")	Connection ("END")	Retained for project(s) i.e. only connections flagged with Y will be used for assessment	
2	EUCECE	Central Europe English Channel coast	England eastern English Channel coast	N	
3	EUCECW	Central Europe English Channel coast	England western English Channel coast	N	
4	EUNEUN	Central Europe North Sea coast	Central Europe North Sea coast	Y	Y
5	EUNECE	Central Europe North Sea coast	England eastern English Channel coast	Y	Y
6	EUNENS	Central Europe North Sea coast	England North Sea coast	Y	Y
7	EUNNOR	Central Europe North Sea coast	Norway	Y	Y
8	EUNORK	Central Europe North Sea coast	Orkney	Y	Y
9	EUNSNS	Central Europe North Sea coast	Scottish mainland North Sea coast	Y	Y
10	EUNSHE	Central Europe North Sea coast	Shetland	Y	Y
11	DENEUN	Denmark	Central Europe North Sea coast		
12	DENENS	Denmark	England North Sea coast	Y	Y
13	DENFAE	Denmark	Faeroe Islands		
14	DENICE	Denmark	Iceland		
15	DENORK	Denmark	Orkney	Y	Y
16	DENSNS	Denmark	Scottish mainland North Sea coast	Y	Y
17	DENSHE	Denmark	Shetland	Y	Y
18	EWBEWB	England and Wales Bristol Channel	England and Wales Bristol Channel	N	
19	EWBEWI	England and Wales Bristol Channel	England and Wales Irish Sea	N	
20	EWBNIC	England and Wales Bristol Channel	Northern Ireland Celtic Seas coast	N	
21	EWBSCS	England and Wales Bristol Channel	Scottish mainland Celtic Seas coast	N	
22	EWIEWI	England and Wales Irish Sea	England and Wales Irish Sea	N	
23	EWINIC	England and Wales Irish Sea	Northern Ireland Celtic Seas coast	N	
24	EWISCS	England and Wales Irish Sea	Scottish mainland Celtic Seas coast	N	
25	ENSENS	England North Sea coast	England North Sea coast	N	
26	ENSORK	England North Sea coast	Orkney	N	
27	ENSSNS	England North Sea coast	Scottish mainland North Sea coast	N	
28	ENSSHE	England North Sea coast	Shetland	N	
29	FAEINC	Faeroe Islands	Inner Hebrides - Coll and Tiree	N	
30	FAEINI	Faeroe Islands	Inner Hebrides - Islay	N	
31	FAEINU	Faeroe Islands	Inner Hebrides - Iona	N	

The following table gives some general guidance to the sea crossings that should be considered depending on the approximate location of a given wind farm and broad guidance to species to be considered.

Wind farm location	Species to consider
Wind farms in the North Sea would need to consider sea crossings crossing the North Sea involving all combinations to/from Norway, Denmark, the North Sea coast of Central Europe, Shetland, Orkney, and the east coasts of Scotland and England.	Those migrating to winter in the UK from/via Scandinavia and the east. Those migrating to breed in the UK from the south.
Wind farms in the English Channel would need to consider sea crossings crossing the English Channel involving movement to/from the south coast of England, Central Europe.	Those migrating to winter in the UK from/via Iceland, Faeroe Islands, Scandinavia and the east. Those migrating to breed in the UK from the south.
Wind farms north of the Scottish mainland would need to consider sea crossings to/from Iceland, the Faeroe Islands, Scandinavia and the east, to/from the Northern Isles, the north and Hebridean Seas coast of mainland Scotland and also those between the Northern Isles and the north mainland of Scotland.	Those migrating to winter in the UK from/via Iceland, Faeroe Islands, Scandinavia and the east.
Wind farms in the Celtic Seas would need to consider sea crossings between east coasts of Ireland and the west coast of Britain (NIC & RIE to/from EWB, EWI & SCS), for those further south also sea crossings involving the Spanish north coast, the English Channel coast of Central Europe (RIS to/from EUC & SPA) and for those towards the east possibly sea crossings within the mainland coast of Britain as these could take migrants far from shore (EWB to/from EWB and EWI to/from EWI & SCS).	Those migrating from/via Iceland, Ireland and northwest Scotland to winter in England and Wales. Those migrating through Great Britain to winter in Ireland. Those migrating from the south to breed in Scotland or Ireland.

Wind farms west and northwest of the mainland of Scotland would need to consider sea crossings from/to Iceland and the north and Hebridean Seas coast of mainland Scotland, the north and west coasts of the Republic of Ireland and the north coast of Northern Ireland. Also sea crossings between the Faeroe Islands and all the above other than the west coast of the Republic of Ireland. For species where known proportions terminate their journey in the Western Isles and the Inner Hebrides (e.g. Greenland White Fronted Goose) separate analyses using sea crossings between Iceland, the Faeroe Islands and the northwest coast of mainland Scotland with the Western Isles and the Inner Hebrides may be appropriate.	Those migrating to winter in the UK from/via Iceland and the Faeroe islands.
Wind farms within the Hebridean Seas would need to consider sea crossings flight lines from/to Iceland and the north and Hebridean Seas coast of mainland Scotland, the north coast of the Republic of Ireland and the north coast of Northern Ireland. Also sea crossings between the Faeroe Islands and all the above. For species where known proportions terminate their journey in the Western Isles and the Inner Hebrides (e.g. Greenland White Fronted Goose) separate analyses using sea crossings between Iceland, the Faeroe Islands and the northwest coast of mainland Scotland with the Western Isles and the Inner Hebrides would be appropriate.	Those migrating to winter in the UK from/via Iceland and the Faeroe Islands. Those terminating in the Western Isles or Inner Hebrides either to breed (e.g. Corncrake) or to winter (e.g. Greenland White-fronted Goose).

Whilst each species of migrant should be considered individually with reference to the maps of migration corridors, in broad terms migrants fall into a small number of distinct groups. The list below outlines some of the more common migration routes but is not meant to be exhaustive:

1) Birds from Iceland wintering in the UK (to include those from Greenland and Canada coming via Iceland)

- Individuals of these species may fly directly from Iceland making first landfall on the north and east coasts of the Republic of Ireland, the Hebridean Seas coasts of Northern Ireland and mainland Scotland, the north coast of Scotland or Orkney after which they are most likely to follow the coast or migrate overland, neither of which are of concern unless further sea crossings are involved.
- Alternatively they may travel via the Faeroe Islands, Shetland or Norway and then cross the North Sea to arrive on the GB mainland.
- Onward journeys may also cross the sea, for example birds that cross Ireland and then traverse the Celtic Seas to reach mainland Britain.

2) Birds from Scandinavia wintering in the UK (to include those from the Arctic and sub-Arctic further to the east)

- Individuals of these species may fly directly across the North Sea making first landfall in Shetland, Orkney or the east coasts of Scotland or England.
- Alternatively they may move down through Central Europe and make the North Sea or English Channel crossing from there.
- Onward journeys may also cross the sea, for example migrants heading towards southern Europe and Africa, having crossed the North Sea to mainland Britain may either follow the coast southwards or cross overland thereafter crossing the English Channel leaving from the south coast of England. Migrants with a final destination in Ireland may move across Britain, either overland or following the coast to then cross the Celtic Seas or Hebridean Seas.

3) Birds from southern Europe and Africa breeding in the UK

- Individuals of these species can be expected to arrive along the south and east coasts of England from Central Europe.

- Alternatively they may arrive on the south and east coasts of Ireland from northern Spain before moving on to their final destination.

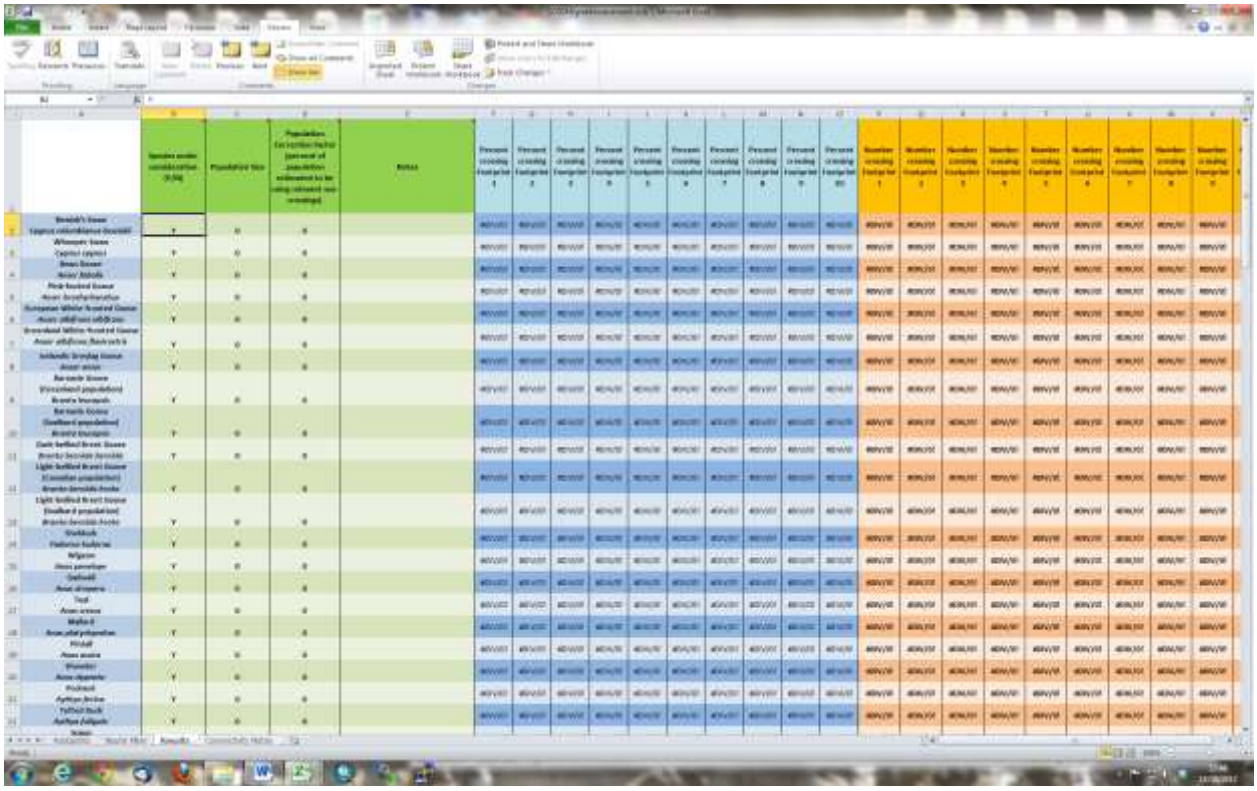
4) Pelagic seabirds, including Fulmar, Manx Shearwater, Petrels and auks
- As a general rule these species should not be assessed using this Workbook

5) Land-based seabirds that follow the coastline during migration but at some distance offshore, including skuas, gulls and terns
- Although there is scope to assess migration across open seas using this Workbook, migration that hugs the coastline is not well assessed using this Workbook.

Detailed instructions for calculating numbers of birds crossing footprint in the SOSSMAT

Once the user has populated the worksheets 'Footprints' and 'Route Filter' the percentage of birds of each species estimated to cross each of the footprints being assessed will automatically be updated in the worksheet 'Results'. Percentage values are given for up to 10 footprints in the cells colour coded 'blue'. These cells are not editable.

The SOSSMAT also facilitates the next stage in the analysis which is to estimate the actual number of birds that cross each footprint being assessed. This requires two more pieces of information to be supplied by the user.



The four fields colour coded 'green' are user editable. They are as follows:

Species under consideration

This is simply available for convenience and is not referred to by any spread sheet formulae. By flagging species with a value other than the default 'Y', this field can be used in conjunction with the filter tool in Excel to hide rows for species not being assessed.

Population Size

The user should enter the sum total of all populations of a given species associated with UK waters. This is regardless of whether it is believed that the entire population are using sea crossings relative to the wind farm being assessed (the latter is dealt with next). Key sources of information include:

- SOSS guidelines (Wright *et al*. 2012 – this report)
- National and international population of waterbirds - Wetlands International, currently WPE5 (http://wpe.voidwalkers.nl/)
- Non-breeding populations of waterbirds - GB & UK (Musgrove *et al*. 2011).
- Breeding populations of all species - GB & UK (Baker *et al*. 2006).
- Non-breeding populations of waterbirds – Ireland (Crowe *et al*. 2008)
- Breeding/Non-breeding populations Britain & Ireland (Gibbons *et al*. 1993)
- More detailed view of migration routes than in general guidance notes (Wernham *et al*. 2002)
- Finally, the next Breeding/Winter Atlas for Britain & Ireland is due for publication in late 2013 and will then supersede Gibbons *et al*. 1993.

Population Correction Factor

The user should estimate the percentage of the relevant population(s) that may be using the sea crossings relevant to the wind farm location. This estimate should be made using the maps available in the SOSS guidance (Wright *et al*. 2012 – this report) as the principal reference. In the absence of any additional guidance that may be given the value entered in this field should be a straightforward estimate of the proportion of the UK coastline covered by the migration maps for the species in question that relates to the sea crossings being considered for the assessment. For example, when considering the non-breeding Redshank of the *robusta* race i.e. those coming from Iceland a reasonable estimate might be that 50% make landfall on the North Sea coast having migrated via The Faeroe Islands, Northern Isles and Scandinavia and 50% arrive along the north and west coasts of Scotland and the North and West coast of Ireland. For an assessment of a wind farm in the North Sea it would therefore be appropriate to enter a value of 50 in this field.

For most species it will be necessary to assume that the same routes will be taken during both Spring and Autumn passage. If information is available to the contrary this would be allowed for here. For example, Black-tailed Godwits of the *islandica* race probably only cross the North Sea during Spring migration when they stage in the Netherlands. Thus for a North Sea assessment only half the percentage value could be entered here. Alternatively the final estimate could be adjusted accordingly.

In some cases it may be possible to further fine tune these estimates with reference to more detailed information from the Migration Atlas (Wernham *et al*. 2002), other published material or data that may become available in the future (e.g. from tracking studies or radar surveys).

Notes

The notes field is provided to catalogue decisions that have been made in values entered in the preceding columns. It is suggested that details of reference sources for population estimates are recorded here. For example, “Musgrove + Crowe – Baker” may be used to estimate the population size for a species in which a resident British breeding population (Baker) are joined in the non-breeding season by a migrant population that arrive from outside the UK and distribute throughout Britain (Musgrove) and Ireland (Crowe). Also memos regarding special circumstances (e.g. the *islandica* Black-tailed Godwit scenario above) should be recorded here.

Results

As values are added to the two compulsory fields (columns C and D) an estimate of the total number of birds that cross each footprint will be automatically displayed in the fields colour coded ‘orange’ (for up to 10 footprints).