BTO Research Report 448

Avian Influenza Incursion Analysis (through wild birds)

Authors

Humphrey Q P Crick, Philip W Atkinson, Stuart E Newson, Robert A Robinson, Lucy Snow, Dawn E Balmer, Dan E Chamberlain, Jacquie A Clark, Nigel A Clark, Peter A Cranswick, Ruth L Cromie, Baz Hughes, Mark J Grantham, Rebecca Lee & Andrew J Musgrove

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Wildfowl & Wetlands Trust and Veterinary Laboratories Agency
to the Department for Environment, Food and Rural Affairs

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EXECUTIVE SUMMARY

1) Avian influenza (AI) is a contagious disease of animals caused by influenza A viruses. A small number of AI virus strains can cause a high number of deaths in domestic poultry flocks, these are known as Highly Pathogenic AI (HPAI). A particular strain of HPAI has been causing worldwide concern recently: the H5N1 strain has resulted in the death of more than 150 million poultry worldwide, through infection or attempts to control its spread.

2) Since 2005, when outbreaks of HPAI have been found in Europe (including Britain in the spring of 2006), Defra has sought the advice of an ornithological expert group to assist in making Qualitative Risk Assessments (QRAs) of the likelihood of the disease spreading to and within Great Britain though wild bird movements. Defra commissioned this project to develop methods of analysing rapidly the large datasets on bird movements and abundance held within Britain. The aim was to create 'tools' that would allow rapid risk assessments in the case of future outbreaks in or near populations of wildbirds that might migrate to Britain.

3) **British Bird Biology Spreadsheets** were developed to contain information on all bird species occurring in the wild in Britain. This includes information on migratory status, as well as the summer and winter ranges of each species and the months during which the species occurs in Britain. The spreadsheets provide a ready source of information for reference should a species be reported as carrying HPAI in Europe or elsewhere. In addition, there are worksheets of information on the worldwide occurrence of AI in bird species found in Britain and of the results of surveillance for HPAI in bird species found in Britain.

4) **A Migration Mapping Tool** was developed to provide a rapid assessment of information on the movements of marked birds for migrant species found in Britain. The methods developed as part of this tool, allow a rapid assessment of (a) main directions of movement made by a species to and from Britain; (b) timing of migration along the routes identified; and (c) the geographical spread of the population that visits Britain at different times of the year. By combining sophisticated statistical smoothing techniques with the capabilities of geographic information systems (GIS) we have been able to present a much more accurate pattern of bird movements than has hitherto been possible. As examples, the seasonal pattern of movements of 12 species that are thought to pose a particularly high HPAI incursion risk are presented in a readily interpretable way. Such maps can then be used to assess the likelihood that a species, found with HPAI in Europe or elsewhere, could migrate to Britain.

5) **A Priority Surveillance Mapping Tool** was developed to allow an assessment of the priority areas for surveillance with respect to the relative abundance of wild bird populations and of poultry. Data from a wide range of major national bird surveys were used to allow the creation of single and multi-species abundance maps for each month, at the 10-km square spatial scale. This was combined with spatial data from Defra's Poultry Register to allow an assessment of areas where surveillance could be targeted should HPAI reach Britain. Information on domestic poultry holdings was used to rank them according to the estimated likelihood of an incursion of H5N1 directly from a wild bird source. The combined maps show areas where high abundance of wild birds and potentially susceptible poultry co-occur, though these are still subject to further refinement.

6) **Poultry Incursion Likelihood Mapping** was developed that is based on the priority surveillance mapping tool but introduces weightings for a variety of factors, such that wild birds most likely to transmit H5N1 to domestic poultry would contribute more than others. The aim is to provide a tool that would consider a wider group of species that might transmit HPAI to poultry, should HPAI become established in wildbirds in Britain, and identify priority areas for surveillance. The method developed is readily adaptable and is likely to require further refinement as the needs for such a tool become defined.

7) A Cold Weather Movements Review was undertaken to provide an overview of evidence for the large but irregular movements of birds in response to periods of severe weather in winter. Geese, ducks and waders are all likely to move to Britain from continental Europe in substantial numbers. The web-based Bird Track scheme for the daily reporting of bird lists provides a potential medium for the rapid monitoring of cold weather movements and might aid HPA1 surveillance targeting under such conditions.

8) The tools developed as part of this project make use of a wide variety of data sources that have a range of potential caveats or biases that need to be considered carefully. It is anticipated that the results from such tools would be presented only after suitable interpretation by ornithological experts.

1. INTRODUCTION

Avian influenza (AI) is a contagious disease of animals caused by influenza A viruses. AI viruses are normally only found in birds, but they may infect pigs and other mammals and, on rare occasions, may infect humans, although they are not usually spread between humans. There are at least 144 strains that have been formally identified and the majority of these are very mild (LPAI, or Low Pathogenic AI), causing symptoms in birds such as ruffled feathers, a drop in poultry egg production and breathing changes, that can go unnoticed. A small number of AI virus strains can cause a high number of deaths in domestic poultry flocks, these are known as Highly Pathogenic AI (HPAI). However, these are rare in wild birds.

A particular strain of HPAI has been causing worldwide concern since 2005: the H5N1 strain has resulted in the death of more than 150 million poultry worldwide, through infection or attempts to control its spread. H5N1 has been circulating in Asian poultry populations since 2003. During 2005, as the virus spread from its original focus in south-east Asia to central Asia, then the Black Sea region, and more recently into West Africa, the means of its transmission was unclear. Whilst there was much speculation about the role of wild birds, there were also clear grounds for suspecting that movements of poultry and cagebirds were at least partly responsible. However, the cases in western Europe in late winter 2005-06 point strongly towards the spread by wild birds following cold-weather influxes of birds from further east.

The only recent case of H5N1 in GB was of a dead Whooper Swan *Cygnus cygnus* found on the coast at Cellardyke, Fife, Scotland on 29 March 2006. It was thought that the bird had been dead for at least 7 days, but the origins and movements of the bird are unclear. The most likely scenario is that the bird may have been exposed to the virus in the Baltic region and that it may have moved as a result of severe cold weather. Despite a large programme of surveillance for the virus in GB, through analyses of samples from dead birds reported by the public and ornithologists, dead shot birds by wildfowlers and live birds caught by teams from the Wildfowl & Wetlands Trust (WWT), no other positive case had been identified, as of September 2006.

Since 2005, when outbreaks of HPAI were found in Europe (and GB), Defra has sought the advice of an ornithological expert group to assist in making Qualitative Risk Assessments (QRAs) of the likelihood of the disease spreading to and within GB though wildbird movements. It became apparent that there were datasets on bird movements and relative abundance that could be analysed to assist with these QRAs, although there would be the need for some methodological development to assist with these analyses. This project was commissioned to develop these methods with a view to creating tools that would allow rapid risk assessments in the case of future outbreaks in or near populations of wildbirds that might migrate to Britain.

1.1 Project Aims

The overall aims of the project are to provide sources of information and analytical tools that will help Defra target action appropriate to the perceived level of risk that migrating birds might introduce HPAI into domestic poultry in Britain. These tools aim to help the interpretation of the results of HPAI surveillance in migratory birds. In particular, the tools aim to help understanding of the behaviour and distribution of migratory birds that visit GB and to identify the areas in which domestic poultry are potentially at risk of becoming infected with AI. In addition the project has reviewed the available European AI surveillance data, with a view to informing Defra with regard to its surveillance strategy and tactics, as well as developing ornithological fieldsheets to assist Defra field staff attending at a potential infected site; these will be reported elsewhere.

The main components of the project included in this report will assist Defra in the compilation of Qualitative Risk Assessments (QRAs) in the event of future detections of HPA1 in Europe or elsewhere. These are:

British Bird Biology Spreadsheets

The development of a detailed spreadsheet of information on all bird species occurring in the wild in Britain. This includes information on migratory status, as well as the summer and winter ranges of each species and the months during which the species occurs in Britain. The aim is to provide a ready source of information for reference should a species be reported as carrying HPAI in Europe or elsewhere. In addition there are worksheets of information on the worldwide occurrence of AI in bird species found in Britain and of the results of surveillance for HPAI in bird species found in Britain.

Migration Mapping Tool

The development of a rapid assessment tool that analyses information on the movements of marked birds for migrant species found in Britain. This tool will allow the rapid assessment of the potential that a species, found with HPAI in Europe or elsewhere, will migrate to Britain. The results for 12 key species are presented.

Priority Surveillance Mapping Tool

The development of a GIS-based mapping method to reveal the relative abundance of species likely to be involved in the primary incursion of HPAI into Britain. The GIS tool can be used to identify areas of high relative abundance of a species or groups of species in any month, at a 10-km square spatial scale. This is combined with maps of poultry locations from Defra's Poultry Register analysed by the Veterinary Laboratories Agency to take into account the likelihood that birds on individual farms might come into contact with wildbirds, directly or indirectly. The cross-comparison of maps of high poultry and wildbird abundance will reveal the highest priority for HPAI surveillance.

Poultry Incursion Likelihood Mapping

Using the GIS system developed for the Priority Surveillance Mapping Tool, it is possible to indicate the relative likelihood that wildbirds in an area might spread HPAI to poultry in a 10-km square. The method developed assesses the likelihood that a species might contract HPAI and, based on its ecology and biology, the likelihood that a species will come into contact with domestic poultry.

Cold Weather Movements Review

Wildbirds not only make predictable migrations each year, such as those between breeding and wintering grounds, but they also respond to severe periods of cold weather by moving to areas that may enhance their survival. Such cold weather movements are relatively unpredictable, but could be important in the context of the primary incursion of HPAI into Britain from Europe. A brief review of this issue has been undertaken with a view to assessing the scale of the problem and whether the BTO/RSPB/BWI BirdTrack monitoring scheme might allow the rapid monitoring and assessment of such movements in the future.

1.2 Project Team

The project was undertaken by a team from the British Trust for Ornithology and the Wildfowl & Wetlands Trust, working closely with staff from the Veterinary Laboratories Agency who undertook a parallel project to analyse data from Defra's Poultry Register. We were able to utilise major ornithological databases held by the two organisations, particularly the national ringing database, which holds information on the finding circumstances of retrapped and dead birds that have been ringed with uniquely numbered individual metal leg rings. These data allow the analysis of bird migration and movements. In addition, the team was able to utilise data from a range of major census and distributional mapping schemes and projects, as well as information collated on the incidence and occurrence of HPAI worldwide.

The project was guided by a Steering Group that included staff from Defra, BTO, WWT and VLA.

We are particularly grateful for advice and guidance provided by Fletcher Morgan and Professor John Wilesmith from Defra, as well as from Mirzet Sabirovic, Alice Rogers, Keith Hamilton, Simon Hewitt, David Harris and Sheila Bird. The project has also involved a very productive collaboration with Lucy Snow from the Veterinary Laboratories Agency.

2. STATUS OF BIRDS IN GREAT BRITAIN AND LIKELY RISK OF AVIAN INFLUENZA INCURSION

Dawn E. Balmer and Robert A. Robinson

British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU, United Kingdom

2.1 INTRODUCTION

Highly pathogenic forms of avian influenza (HPAI) have been reported in a wide range of species (Olsen 2006). The current outbreak (of the H5N1 strain) originated in Asia and has since spread into Europe and Africa; though, so far only one case has been recorded in Britain (see Chapter 1). The role of migratory wild birds in spreading HPAI is still debated, but clearly migratory movements of birds pose a possible mechanism for HPAI entering the country. This risk of catching HPAI and of carrying it to Britain will vary between species, depending on the degree and frequency of movements of individuals in the population and other associated ecological characteristics.

In this section we developed an accompanying spreadsheet, summarising as far as is known the relevant ecological factors that may affect the risk of individual species bringing HPAI into the country.

2.2. METHODS

The literature was reviewed and summarised for all species of wild birds recorded in Britain in an apparently wild state as at 31/5/2006 with specific reference to features pertinent to assessing the risk of incursion of AI into Britain. It is derived from a number of sources, which are documented below, separately for each character. Where possible, we have tried to quantify information to facilitate the development of a qualitative risk assessment (QRA) score for the risk of HPAI incursion posed by each species. Inevitably, in many cases information in the literature is incomplete, or insufficiently detailed, so we have relied heavily on expert assessment of the information available to interpret it under the quantitative framework presented here. The BTO is the "the most influential conservation organisation in Britain in Britain today" (Lawrence 2006) and employs a large number of ornithological experts whose views were sought during this process. The information has also been reviewed by experts at the Wildfowl & Wetlands Trust (WWT), so that the assessment here should prove as robust as possible.

2.3 THE SPREADSHEET

The spreadsheet, consists of three components:

- (I) General information on occurrence and behaviour of birds pertinent to assessing the risk of HPAI incursion into Britain.
- (II) Evidence for the occurrence of avian influenza, of any strain, in wild bird populations, based on published records
- (III) A summary of the occurrence of the H5N1 strain of avian influenza in birds.

2.3.1 General Data

This spreadsheet is based on all species occurring in Britain in an apparently wild state as listed on the "British List" maintained by the British Ornithologists' Union (BOU) as at 31/5/2006 (Dudley *et al* 2006). This list includes 573 species, of which around 270 occur regularly, and all species have been definitively confirmed as having occurred naturally in Britain after thorough scrutiny of the available evidence.

English Name

The most usual form of the name is given, frequently an epithet is applied to distinguish the British species (which often has a generic name, such as snipe), this is indicated in parentheses, so (Common) Snipe. Commonly used alternative names are also given (see below).

Source: Dudley *et al.* (2006).

Scientific name

Taxonomy follows the official British List maintained by the British Ornithologists' Union (as at 31/5/2006).

Source: Dudley *et al.* (2006).

Alternative names

Other English names for a species that are commonly in use, e.g. in North America.

Source: Robinson (2005)

Order

Higher level taxonomic grouping.

Order is a taxonomic term that identifies groups of species with similar morphology, for example all ducks and geese are in the order Anseriformes. There are 28 orders of birds in the world, of which 21 are represented in Britain. The largest order (Passeriformes – the perching or song birds) contains about half of the world's (and Britain's) bird species.

Source: Dudley *et al.* (2006).

BOU Category

Status of the bird in Britain.

The BOU classifies birds according to whether they have occurred in a wild state in Britain, or whether they have been introduced, or merely have escaped from collections. Only birds in Categories A, B, and C (i.e. those which form the official "British List") are considered in this spreadsheet (species in categories D or E are considered likely to have escaped from captive bird collections). For further details see (www.bou.org.uk/reccats.html).

Category A Species recorded in an apparently natural state at least once since 1 January 1950.

Category B Species that were recorded in an apparently natural state at least once between 1 January 1800 and 31 December 1949, but not subsequently.

Category C Species that, although introduced, now derive from the resulting self-sustaining populations. Split into a number of sub-categories:

C1 Naturalized introduced species – species that have occurred only as a result of an introduction

C2 Naturalized established species - species with established populations resulting from introduction, but which also occur in an apparently natural state

C3 Naturalized re-established species - species with populations successfully re-established by Man in areas of former occurrence

C4 Naturalized feral species - domesticated species with populations established in the wild

C5 Vagrant naturalized species - species from established naturalized populations abroad occurring in Britain. There are currently no species in this category.

C6 Former naturalized species – species formerly placed in *C1* whose naturalized populations are either no longer self-sustaining or are considered extinct.

Source: Dudley *et al*. (2006).

Legal Recognition

Legal status within Britain and Ireland.

Listing of species on the various Appendices and Schedules of wildlife Acts, Conventions or Agreements. See the original texts for a full definition of the relevant Appendix or Schedule. The instruments covered are:

AEWA – African-Eurasian Waterbird Agreement
Bern – Bern Convention on the conservation of European wildlife and habitats
Bonn – Convention on the Conservation of Migratory Species
CITES – Convention on the International Trade of Endangered Species
WBD – Wild Birds Directive
WCA – Wildlife & Countryside Act 1981

Sources: *Wildlife & Countryside Act* (1981): Chapter 69. Her Majesty's Stationery Office, London. (www.jncc.gov.uk/page-3614). [WCA]
European Community (1979) *Council Directive on the conservation of wild birds (79/409/EEC)*, Office for Official Publications of the European Communities.
(http://europa.eu.int/eur-lex/en/consleg/pdf/1979/en_1979L0409_do_001.pdf). [WBD]
Council of Europe (1979) *Convention on the Conservation of European Wildlife and Natural Habitats (European Treaty Series 104).* Bern, Switzerland. (http://conventions.coe.int/Treaty/en/Treaties/Html/104.htm). [Bern]
Convention on the Conservation of Migratory Species of Wild Animals (1979), Bonn Germany (www.cms.int). [Bonn]
Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973), Washington, USA. (www.cites.org). [CITES]
African-Eurasian Waterbird Agreement (1995), the Hague, the Netherlands. (www.unep-aewa.org/). [AEWA]

Status in Britain

Seasonal occurrence in Britain. (eg resident, winter visitor etc).

Most categories are self-explanatory. Passage Visitors occur in Britain on their journey between breeding and wintering grounds elsewhere; Scarce Visitors occur rarely, but there are usually one or more records each year; Accidentals occur on a less than annual basis (i.e. will not be recorded in many years). Many species will occur in multiple categories, e.g. a resident population augmented in winter by birds that have bred in continental Europe.

Source: Dudley *et al*. (2006).

Conservation Status in Britain

All native resident and regularly visiting species in Britain have been considered in terms of their level of conservation concern:

Red	Red List of highest conservation concern, i.e. species that are globally threatened, have undergone a large historical decline, or a rapid recent decline or contraction in range of the breeding population
Amber	Amber List of medium conservation concern, i.e. species that have suffered a moderate decline in numbers or contraction in range of the breeding population, species with small or localised populations, or of unfavourable conservation status in Europe.
Green	Green List, not of conservation concern, i.e. species that regularly occur in the UK, but do not fulfil the criteria for Red or Amber listing.

Species not considered for listing (mostly accidentals and introduced species) are indicated by a dash.

Source: Gregory *et al.* (2002).

Conservation Status - Global

Indicates species that are globally threatened according to internationally recognised criteria, defined by the International Union for Conservation of Nature and Natural Resources (IUCN, www.redlist.org). The primary categories are, in descending order of threat:

CR	Critically Endangered
EN	Endangered
VU	Vulnerable
D	Declining
R	Rare
H	Depleted
L	Localised
DD	Data Deficient
S	Secure
NE	Not Evaluated

See http://www.redlist.org/info/categories_criteria2001.html for a full explanation of the qualifying criteria for each category.

Source: BirdLife International (2000).

Conservation Status in Europe

Consists of two parts, separated by a hypen: the first assesses the conservation status of each species, in a European context, according to internationally recognised IUCN guidelines (see Global Conservation Status above); the second assesses Species of European Conservation Concern (SPEC) as defined by Birdlife International:

1	species of global conservation concern.
2	species with the majority of their population in Europe that also have Unfavourable Conservation Status (i.e. species for which populations are declining, localised or threatened)
3	species with an Unfavourable Conservation Status in Europe, but whose populations are not concentrated in Europe.
N	Non-SPEC species of least conservation concern.

Species occurring only accidentally in Europe, and those whose populations are of captive origin are not assessed and are indicated by a dash ('-'). Where the conservation concern applies to specifically to populations on the wintering grounds (e.g. wildfowl with breed in arctic Asia, but winter in Europe), the SPEC category is qualified by a 'w'. For example, Bewick's Swan (VU – w3) is assessed as Vulnerable within Europe, and it's winter population in Europe is of unfavourable conservation status, but it also occurs in good numbers outside Europe (SPEC 3).

Source: Burfield & van Bommel (2004).

Migratory Status

The tendency of birds occurring in Britain to migrate, based on analyses of ring recovery information. Separate entries are given for summer and winter as, in many cases, birds occurring in Britain represent more than one population (see Status in Britain, above). In particular many British breeding species are sedentary, but populations are augmented in autumn and winter by migratory birds from continental Europe.

Sedentary	No difference between ringing and finding locations in the appropriate seasons.
Long-distance	Significant difference between ringing and finding locations and the average finding location is outside Britain and Ireland.
Short-distance	Significant difference between ringing and finding locations but both are within Britain and Ireland.
Passage	Occurs in Britain and Ireland during passage periods (mainly spring and autumn) only.
Accidental	Rarely occurs in Britain and Ireland (equivalent to Scarce Visitor and Accidental species listed under 'Status in Britain', above).

Source: Wernham *et al.* (2002), updated as appropriate.

World Range

A brief summary of the distribution of each species around the world, it is, of necessity, highly condensed, so only a broad outline is given. The breeding and wintering ranges of migratory species are indicated separately. Where a wintering range is described as "south to" it may be taken that the two ranges overlap and some individuals may not migrate the full distance. Where only a single range is given, the species may be resident (sedentary) in that area, or a proportion of the population may migrate a relatively short distance within that range. Areas where a species has been introduced and become well established away from its native range are also indicated. The use of abbreviations has been limited to n, s, e and w for northern, southern, eastern and western, or combinations of these.

Source: Sibley & Monroe (1990).

Range of species visiting Britain

Distributional origins of populations in Britain during the breeding and wintering seasons

Two fields give the origins of British breeding and wintering populations. Information is also given for birds that occur regularly on passage in either the spring (in the Breeding field) or the autumn (in the Wintering field). Information from the published sources was amended and updated where necessary.

Sources: Snow & Perrins (1998), Wernham *et al.* (2002).

Origins of sub-populations that visit Britain

Because of its geographical location, Britain hosts distinct populations from different areas of several species, particularly wildfowl (Anseriformes) and shorebirds (Charadriiformes). Where information is available we have provided an indication of these different populations and their origins. Information from the published sources was amended and updated where necessary.

Sources: Delany & Scott 2002, Snow & Perrins 1998, Wernham *et al.* (2002).

Months during which the species occurs in Britain

Gives the months during which the species occurs in Britain.
Months are numbered 1-12 (January – December) and split into Early (E), Mid (M) and Late (L) where appropriate. To improve the utility of the spreadsheet we have included 12 extra columns (labelled Jan through Feb) indicating with a 'Y' if that species is present in significant numbers in each month.

Sources: Couzens (2005), Birdguides (2006).

Summer abundance in the UK

The best estimate of the breeding population in the UK. Where there is some uncertainty, lower and upper limits are indicated in parentheses. Where a range (only) is given, numbers breeding are variable between years. Where a bird is an occasional breeder, but common on passage, the average number of passage birds (in Britain) each year is given. Where a blank occurs, this is because there is no information, species which do not occur in Britain in summer (or on passage) are indocated.

Sources: Baker *et al.* (2006), Burfield & van Bommel (2004), Fraser & Rogers (2001).

Winter abundance in the UK

The best estimate of the wintering population in the UK. Only estimates for species that are surveyed in winter are given, blanks indicate no information on surveys. Species that do not occur regularly in winter are indicated. Where a bird occurs on passage, this is indicated under Summer Abundance (above), even though the passage period may extend into the winter months (see columns of monthly occurrence, below, for further details on timing of occurrence).

Source: Baker *et al.* (2006).

Habitat Use

A brief indication of the main habitats that a species is likely to be found in the breeding season. These are not exhaustive and individuals may be found outside these, particularly on migration (or if they have been blown off course). Where a species regularly occurs in different habitats on migration or in the non-breeding season this is indicated.

Source: Sibley & Monroe (1990).

Diet

A brief summary of the major food-types eaten by each species. Note that for most species diet varies according to the relative availability of prey items, both in different locations and through the year, so only a general guide can be given. Where 'insects' are referred to, this means the Class Insecta, e.g. beetles, flies, moths/butterflies, but not spiders, for many species, the larval forms (e.g. caterpillars, grubs, leatherjackets) are eaten, and are fed particularly to nestlings. 'Arthropods' include all the jointlegged invertebrates, i.e. insects, spiders, millipedes/centipedes and crustaceans (e.g. shrimps, crabs, woodlice). 'Invertebrates' includes arthropods, but also other groups, particularly molluscs (e.g. slugs, snails, or in marine environments, cockles, mussels etc.), earthworms and marine worms. Vertebrates include mammals, birds, reptiles, amphibians and fish of an appropriate size.

Source: Snow & Perrins (1998).

Propensity for occurring on farmland

Tendency for species to occur on any sort of farmland (excluding unenclosed and rough grazing). Qualitatively scored at three levels:

0	Generally does not occur on farmland
1	Occasionally occurs on farmland
2	Regularly occurs on farmland

Note that information is only given for regular visitors to Britain, all other species are indicated by blanks. Accidental visitors (see above), almost by definition, frequently do not occur in their preferred habitat, so may be found in a much wider range of habitats than usual. However, they are likely to be extremely scarce in any habitat.

Source: Snow & Perrins (1998), supplemented by expert opinion.

Flocking tendency

The tendency for the species to form flocks with its own species (not mixed in with other species):

0	Generally does not form large flocks
1	Regularly occurs in large flocks

Where tendency to form flocks varies by season, this is indicated. Only species which occur regularly in Britain have been assessed, all other species are indicated by blanks (and are unlikely to occur in sufficient numbers to form a flock).

Source: Snow & Perrins (1998), supplemented by expert opinion.

Propensity to undertake cold weather movements

The tendency for the species to undertake cold weather movements. Qualitatively scored at four levels:

0	Generally does not move in large numbers in response to cold weather
1	Occasionally moves in response to periods of cold weather
2	Frequently moves in response to periods of cold weather
3	Regularly moves in response to periods of cold weather

All resident species and winter visitors are considered. Trans-Saharan migrants and vagrants are not covered since they generally do not occur in Britain in winter in large numbers. Note that some other species do undertake large movements (e.g. Meadow Pipit, Woodpigeon), but these are largely driven by post-juvenile dispersal and food shortages rather than cold weather.

Sources: Snow & Perrins (1998). Wernham *et al.* (2002).

Flyway Population Size

Most waterbirds (e.g. ducks, geese, swans, waders and gulls) migrate along more or less coherent flyways, which span continents (e.g. Dunlin that breed in western Greenland, migrate through Europe, and winter in Africa). Consequently, for these species, flyway population size is a more relevant unit than a population in a particular geographical area, which may only account for part of the population. Where information from counts is available this is given, in a few cases, only a "best guess" is possible, these are categorised using an ordinal scale indicated by the following letters:

A	less than 10,000 individuals
B	10,000-25,000 individuals
C	25,000-100,000 individuals
D	100,000-1,000,000 individuals
E	more than 1,000,000 individuals

A blank indicates that a flyway estimate is not appropriate .

Source: Delany & Scott (2002).

European Population Size

Estimated breeding population size of the species in Europe (but excluding European Russia, which hosts large, but poorly known, numbers of most species). In most cases, population size is given as a range reflecting likely lower and upper estimates of population size.

Source: Burfield & van Bommel (2004).

WebLink

Internet hyperlink to the BirdFacts page on the BTO website, which contains more details and information on each species.

2.3.2 AI status

We conducted an online literature search, using the Elsevier Scopus database (containing 28 million references, including complete coverage of the MedLine database) and identified key review papers (noted below) concerning occurrence of avian influenza in wild birds (rather than domestic or captive birds), these include references to many more primary studies.

Sources: Astorga, R.J. *et al.* (1994), de Nardi, R. *et al.* (2005), Ellis, T.M. *et al.* (2004), Hanson, B.A. (2003), Olsen, B. *et al.* (2006).

Has the species been recorded with avian influenza?

Incidence of any strain (mostly LPAI strains) is noted. Where a study sampled a species but failed to find any evidence of infection, this is noted. Species with a blank entry have apparently not been sampled.

Number sampled

The number of birds sampled for the virus in the study.

Number positive

The number of birds that tested positive for the virus.

Strain

The strain of AI found is given, where this information was included in the publication.

Location

The continent where the research was carried out is given.

Reference

The reference for the research is given, see sources above.

2.3.3 H5N1 status

We review the evidence for the occurrence of the H5N1 strain of avian influenza in bird populations.

H5N1 in Europe?

This lists studies which have tested for the H5N1 strain in Europe are summarised and whether they detected H5N1 or not.

Wild/Captive/Domestic/Experimental

Origins of the birds sampled:

W	Wild birds
C	Captive birds
D	Domestic birds
E	Birds in experimental studies

Live birds?

Yes, if live birds were involved.

Dead birds?

Yes, if dead birds were involved.

Number sampled

The number of birds sampled for the virus in the study.

Number positive

The number of birds that tested positive for the virus.

Reference

Gives the references of the papers or website used.

Comments

Other pertinent information.

3. MIGRATION MAPPING TOOL

Philip W. Atkinson, Robert A. Robinson and Jacquie A Clark

British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU, United Kingdom

3.1 INTRODUCTION

Avian influenza (AI) is endemic in many wild bird populations and occurs in a number of different strains. Influenza viruses are characterised by two proteins that appear on the virus coat: haemagglutinin (H, 16 subtypes) and neuraminidase (N, 9 subtypes). Nearly all possible combinations of the two different subtypes have been recorded in wild bird populations (Alexander 2000), but only H5 and H7 appear to occur in highly pathogenic strains (HPAI), and so are of particular relevance regarding possible incursion into poultry flocks. The occurrence of AI in wild bird populations appears to vary between species, with waterbirds, particularly ducks, geese and swans (Anseriformes) apparently being particularly susceptible.

Amongst birds (and other animals) migration is an adaptation to seasonal environments, with individuals moving more or less regularly between distinct areas during the breeding and non-breeding periods. (Note this is distinct from the use of migration in the human sense, which represents a more or less uni-directional drift of individuals, e.g. in response to work opportunities.) Thus birds can exploit temporarily abundant resources during the breeding season (summer) but escape harsh conditions during the non-breeding period (winter).

Many waterbirds species that occur in Europe breed at mid-high latitudes, particularly in the northern hemisphere and are consequently migratory. They generally move between breeding areas in the boreal and Arctic areas and wintering areas in central and western Europe, including Britain, though a few species (e.g. Garganey *Anas querquedula*) breed in Europe and winter further south. Additionally, wildfowl undertake movements in response to cold weather, sometimes moving long distances in search of more clement conditions (Ridgill & Fox 1990). These movements are more unpredictable than migratory journeys and usually shorter in duration, i.e. they generally span a period of days or weeks within a season. They occur in response to prolonged periods of severe weather when birds will depart a region because of thermal stress or food shortage.

Because of the high degree of movement within these species, waterbirds pose a risk of incursion of AI into the UK from outbreaks elsewhere (as would other susceptible migratory species). Assessment of this risk, at least in a qualitative way, can be achieved through the use of bird ringing data. Bird ringing, using individually numbered rings with a return address, commenced in 1909 in Britain, and since then over 32 million birds have been marked. This enables anyone finding the ring, on a bird which may be either alive or dead, to inform the marking scheme of its recovery. In Britain and Ireland, a national ringing scheme is operated by the British Trust for Ornithology (BTO). Each year over 2,000 volunteer ringers mark around 800,000 birds (c. 60,000 are wildfowl), and around 10,000 (c. 2,500 wildfowl) marked birds are found, either by members of the public or are caught by other ringers (Clark *et al.* 2005). For all birds recovered, information on the location and time of ringing and finding of the ring are stored in a national database, and this provides unique information on the movements of Britain’s birds (Wernham *et al.* 2002).

In this chapter, we use information on the movement of individually marked birds that have been ringed, or found, in Britain and Ireland to determine the timing of migration and the areas from which migratory waterbirds originate, or travel to or through, to provide a background for assessing the likelihood of AI incursion given an outbreak in a species in a particular area. While we developed the methodology, and illustrate its application, in waterbird species, the techniques are applicable to a wide range of migratory birds. A key aim in developing the method was to provide a tool for the rapid assessment of incursion risk in response to further outbreaks. Here we develop the methodology using a range of selected species, but it is readily applicable to other species and circumstances.

3.2 METHODS

The main aim of this assessment is to map migration routes in both space and time to determine whether outbreaks of H5N1 amongst wild birds in Eurasia are likely to be carried to Britain and Ireland (B&I) by wild birds. We identified areas from which birds move into B&I, or move out of B&I, by using recoveries of birds marked with individually identifiable rings, usually uniquely numbered metal leg rings (Wernham *et al.* 2002). For these purposes, we use birds that were either originally marked, or subsequently refound in B&I (though short distance recoveries are excluded, (see below)). In essence, then, an individual datum for this analysis is an individual bird which has moved between two known locations, one of which was in B&I. A very small proportion of birds (< 1%) have been reported multiple times (usually because they bear a mark which is individually identifiable at a distance in the field), but since we are interested in describing overall patterns, this degree of non-independence in the data is of negligible importance.

After marking, birds may subsequently be found either (i) alive, usually either caught by another ringer or because they bear a mark which is individually identifiable at a distance in the field, or (ii) dead. Many wildfowl are shot, but there are many other causes of death, some anthropogenic, e.g. collision with power lines, other more natural, e.g. found apparently starved after a period of cold weather. There will be a degree of bias associated with the likelihood of recovery of marked birds. The number of birds shot will, of course, reflect, to a certain extent, the degree of hunting pressure present. The popularity of hunting across Europe and the tendency for hunters to congregate in areas where their quarry are common mean that concentrations of recoveries may appear in heavily hunted areas. However, the spread of points will reflect broad range over which birds that occur in Britain are found. Similarly, although the frequency of reporting of marks on living birds will reflect, to a certain extent, human population density (more observers means that more marks are likely to be found), the broad area over which such recoveries are made will reflect the range over which birds from B&I will occur (Wernham *et al*. 2002). We have therefore included information on all birds recovered (subject to certain exclusions below), irrespective of the manner of their recovery. This maximises the sample sizes available, enabling a more comprehensive picture of the extent of occurrence to be assembled.

A three-stage process was used to identify movement patterns: (i) data filtering, (ii) identifying main directions of movement and (iii) determining the timing of the movements. We present movement patterns for eleven species as case studies. These are Bewick's Swan *Cygnus columbianus*, White-fronted Goose *Anser albifrons*, Brent Goose *Branta bernicla*, Eurasian Wigeon *Anas penelope,* Mallard *Anas platyrhynchos*, Eurasian Teal *Anas crecca*, Northern Pintail *Anas acuta*, Common Pochard *Aythya ferina*, Tufted Duck *Aythya fuligula*, Northern Lapwing *Vanellus vanellus* and Black-headed Gull *Larus ridibundus*. These species were selected as a representative range of the species identified as of high risk by the Scientific Panel on Animal Health and Welfare (AHAW 2006). Additionally, we have considered Whooper Swan *Cygnus cygnus*, as this species represents the sole recorded case of HPAI infection in Britain.

3.2.1 Data filtering and quality control

First, a filtering phase was used (See Fig 3.2.1.1) to remove any birds where the finding condition was unknown (e.g. a ring was sent in but no finding details supplied) or where the date of recovery had an error of greater than +/- 15 days associated with it (for example when a bird was found long after its death). Records were then further filtered to select records from suitable time periods. For the purposes of this analysis, we selected birds that were ringed or recovered in Great Britain and Ireland during the period October to March. This could be altered for any future analysis but as this analysis is concerned with primary incursion into the B&I from Europe, we used only recoveries of birds ringed or found in the B&I in autumn, spring and winter. Further to this, we removed recoveries, where a bird had travelled less than 100km to reduce the effect of local movements. Where a foreign-recovered bird was recovered in B&I, we reversed the finding and ringing details so that they were treated in the same manner as British and Irish-ringed birds. Once a clean dataset was obtained, the distance and direction of each movement away from the B&I was calculated using a great circle route.

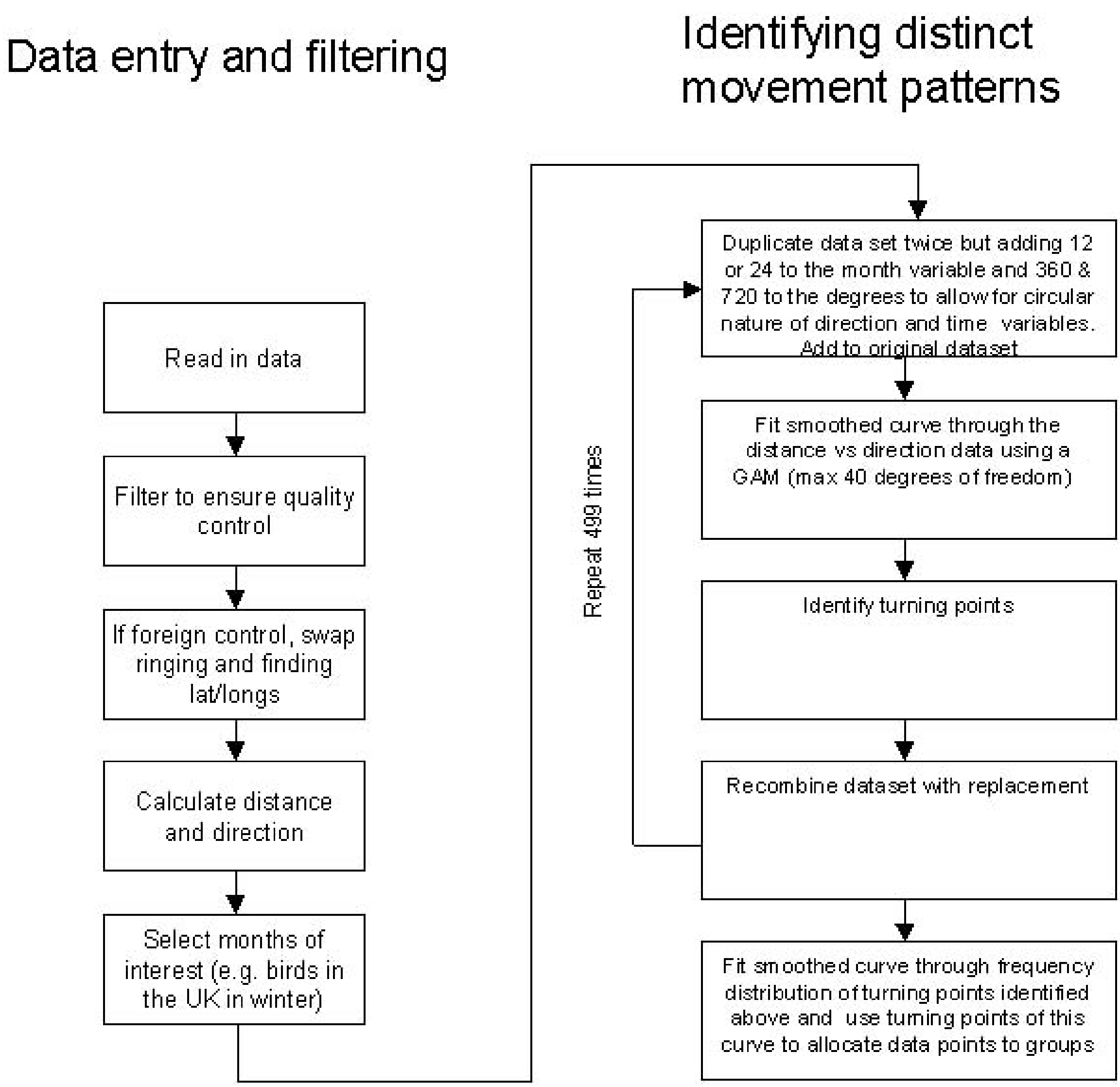


Figure 3.2.1.1 Schematic flowchart to show processes involved in analysing bird ringing recovery data to identify distinct movement patterns.

3.2.2 Identifying major directions of movement

In the second stage, the main direction of movements of birds to and from B&I were identified by plotting the distance of each recovery against the direction travelled (See Fig 3.2.3.1). A smooth line was fitted through the data using a General Additive Model (Hastie & Tibsharani 1990) with a maximum of 40 degrees of freedom and the minimum turning points were identified. The degrees of freedom alter the amount of smoothing, so a GAM with df=1 would result in a straight line and one with the maximum of 360 degrees of freedom would result in no smoothing. The choice of the final number degrees of freedom was a balance between being able to identify the main directional movements and avoiding producing so many separate different movement types that they were biologically meaningless and uninterpretable. The amount of smoothing needed was determined by sample size and by the range of possible values for the direction of movement. As there are a limited number of directions in which a bird can travel (bounded between 0 and 360 degrees), to obtain biologically meaningful results the degrees of freedom used was calculated as the integer value of the $\log_{10}[n]^4$ where *n* was the number of recoveries, and capped at 40.

The White-fronted Goose example in Figure 3.2.3.1a illustrates the process. The graph shows a series of north-easterly movements through the Low Countries up into the Siberian breeding areas and a movement through Iceland to Greenland. This fits in with our knowledge that White-fronted Geese in B&I are from breeding areas in Siberia and Greenland. At this stage, the data were inspected to determine if any outlying points were severely skewing the smooth curve. In this case there was one recovery in Pennsylvania, USA. White-fronted Goose is a vagrant to North America and this data point was removed and the smooth curve recalculated (Figure 3.2.3.1b).

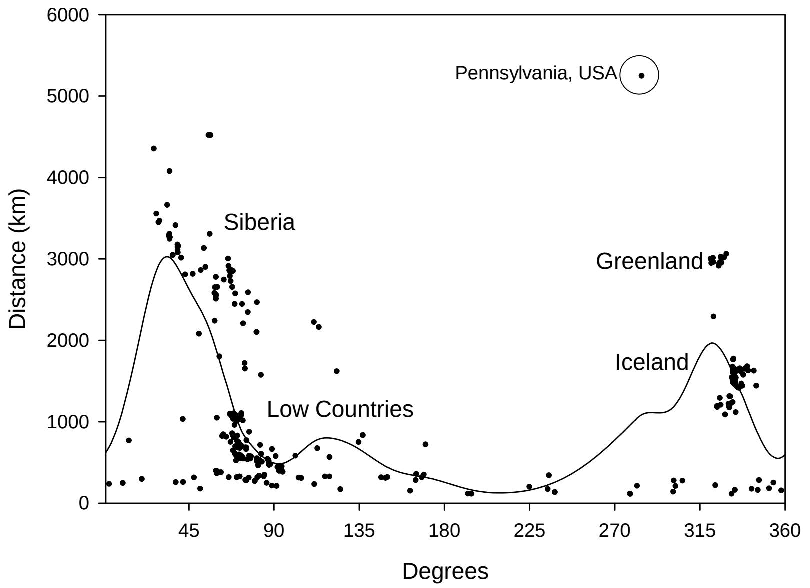
To identify groups of similar movement, the minimum turning points in the smooth curve were identified. For example, Figure 3.2.3.2 shows the Icelandic / Greenland movements occurring between turning points at approximately 270 and 355 degrees, and the Low Countries/Siberian movements between 355 and 90 degrees. To ensure that there was confidence in where the turning points occurred, a bootstrapping technique was used. The distance and direction data was recombined at random with replacement 499 times, and the turning points found. A frequency distribution of these were plotted (Figure 3.2.3.2) and showed 5 main groups of turning points. These were identified by fitting a smooth curve (a GAM with 90 degrees of freedom) through this frequency distribution and identifying maximum turning points which had a frequency value of greater than ten. Group number (WF1, WF2 … WF5) was allocated to the ringing and recovery data based on these turning points and plotted onto a map (Figure 3.2.3.3).

3.2.3 Identifying timing of movements

The next stage was to determine the timing of these movements. Latitude and longitude were plotted against the month of recovery and a smoothed line was fitted (a GAM with 20 degrees of freedom). These monthly values were again plotted on the map (Figure 3.2.3.4) and clearly show the NE/SW movement of birds moving to and from the breeding areas. This line is indicative of a trend in timing and should not be thought of as an absolute position in space and time. To represent the spread of points, kernels showing 95% of the points may be plotted using the home range extension for ArcView (version 3, Environmental Systems Research Institute). As with all recovery data these may be biased to hotspots of ringing, shooting or resighting activity and this is certainly the case as most of the winter locations are of colour-ringed birds observed in the Low Countries.

In some cases points may occur in clusters and it may be more appropriate to treat each cluster individually. By fitting a smoothed line through the frequency distribution of the distance travelled (in 100km bands) and identifying any minimum turning points (using a GAM with 5 degrees of freedom), each group of birds was sub-divided into a number of second groups, noted with a subscript mark ('_n'). For example WF1 shows cluster of recoveries in the Low Countries and western Russia (Figure 3.2.3.5a,b). These were broken down into these two groups plotted on the monthly smoothed locations in each case. This shows most recoveries of White-fronted Geese in spring, autumn and winter are in the Low Countries but also shows their migration more clearly through Belarus, Ukraine and Russia to their northerly breeding areas. A decision, based on inspection of the data, was taken as to whether to include these in each species account.

(a)



(b)

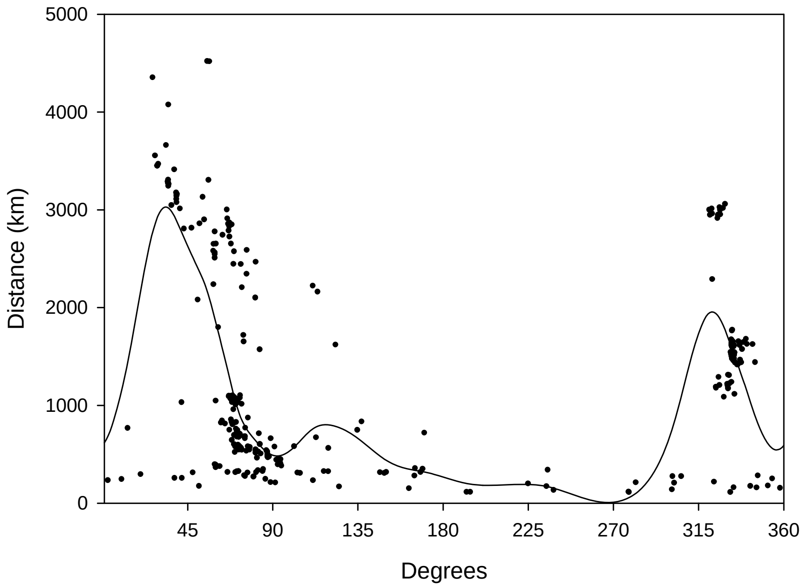


Figure 3.2.3.1 Identifying the different types of directional movements using ringing recoveries. By plotting the distance travelled against the direction of movement and fitting a smooth line, the main directional movements can be identified using the minimum turning points. (a) data for White-fronted Goose including outlying points and (b) the same data but removing the point which represents a bird recovered in Pennsylvania, USA, where this species is a vagrant.

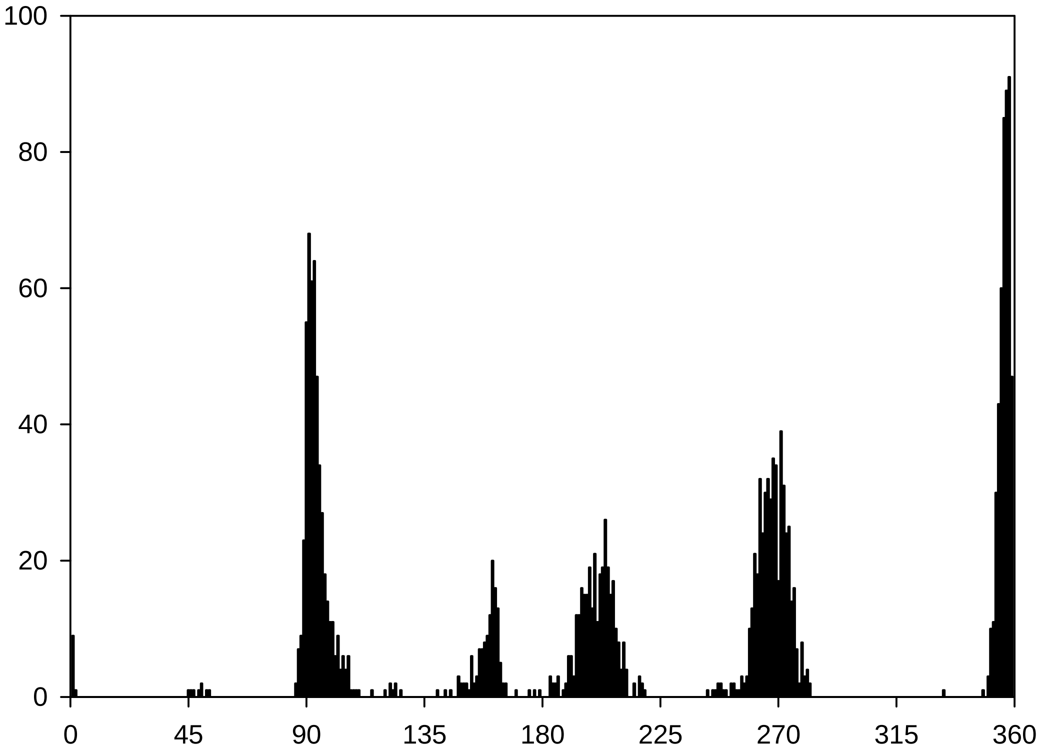


Figure 3.2.3.2 Frequency distribution of the minimum turning points identified by bootstrapping the distance vs direction data in Figure 3.2.3.1(b) 499 times. The appropriate value was selected by fitting a GAM with 90 degrees of freedom through this data and identifying the maximum turning points. To avoid spurious turning points being identified, only those which had an expected value of greater than 10 were used.

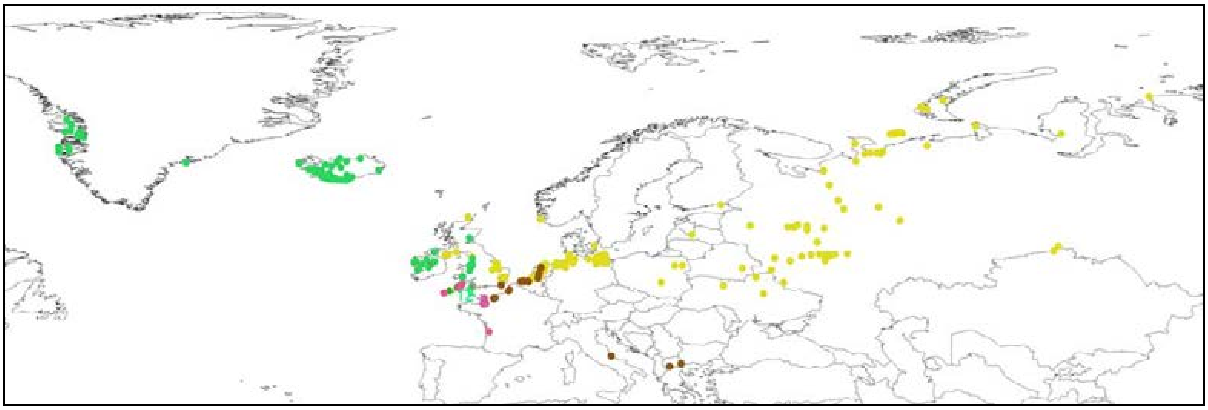


Figure 3.2.3.3 White-fronted Goose movements as identified by this analysis, split into distinct groups, separated by colour (movement WF1 as described in the text is denoted by yellow dots).

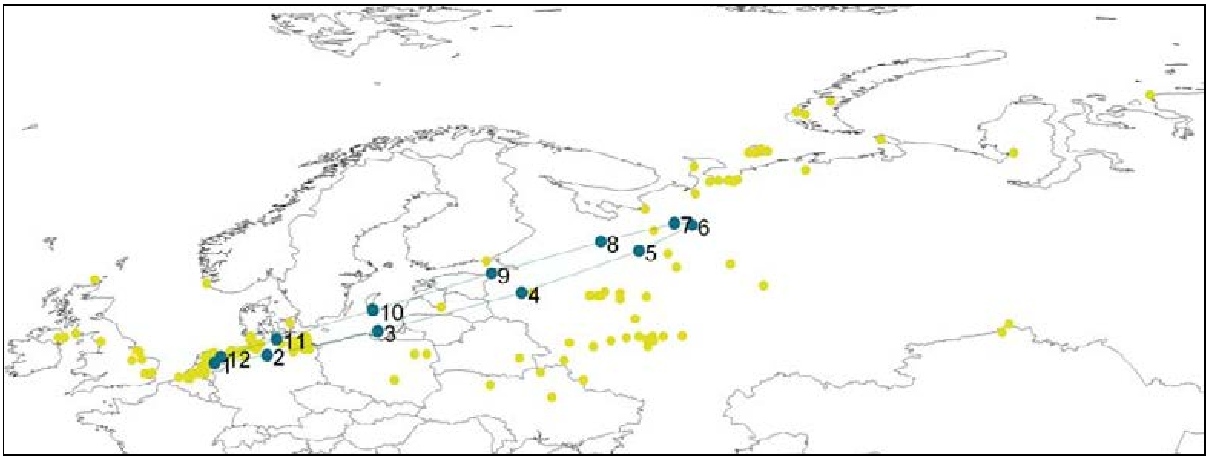
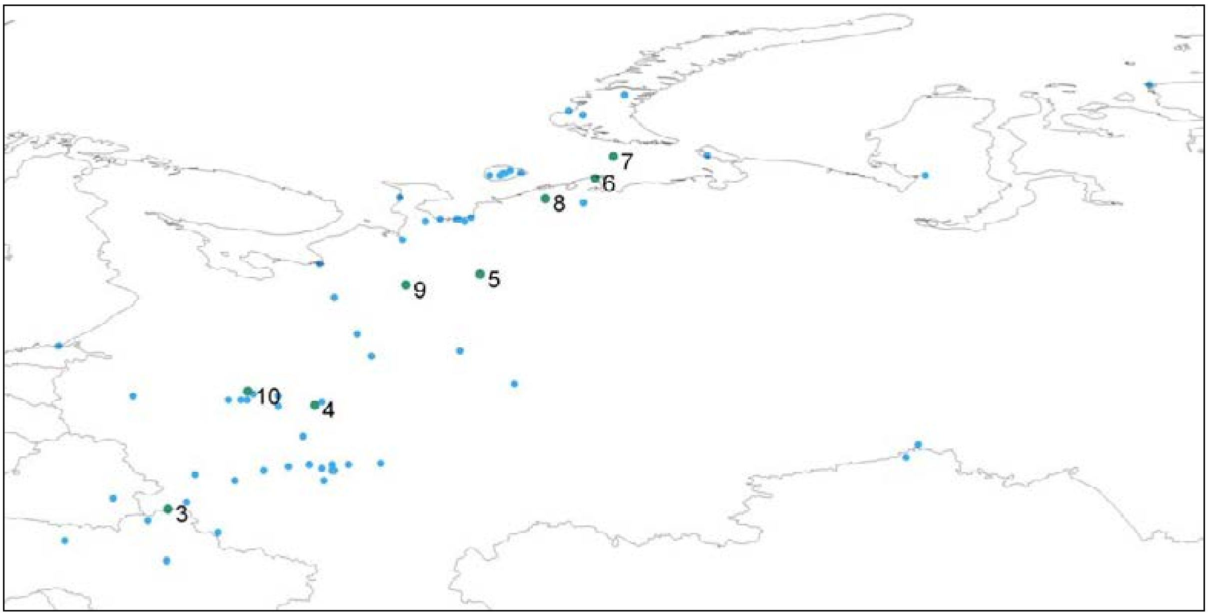


Figure 3.2.3.4 Smoothed location of White-fronted Geese identified as belonging to group WF1, which represents a north-easterly / south-westerly movement. The smoothed location in each month is indicated by 1 = January, 2=February … 12 = December.

(a) Movement type WF 1_1



(b) Movement type WF 2_2

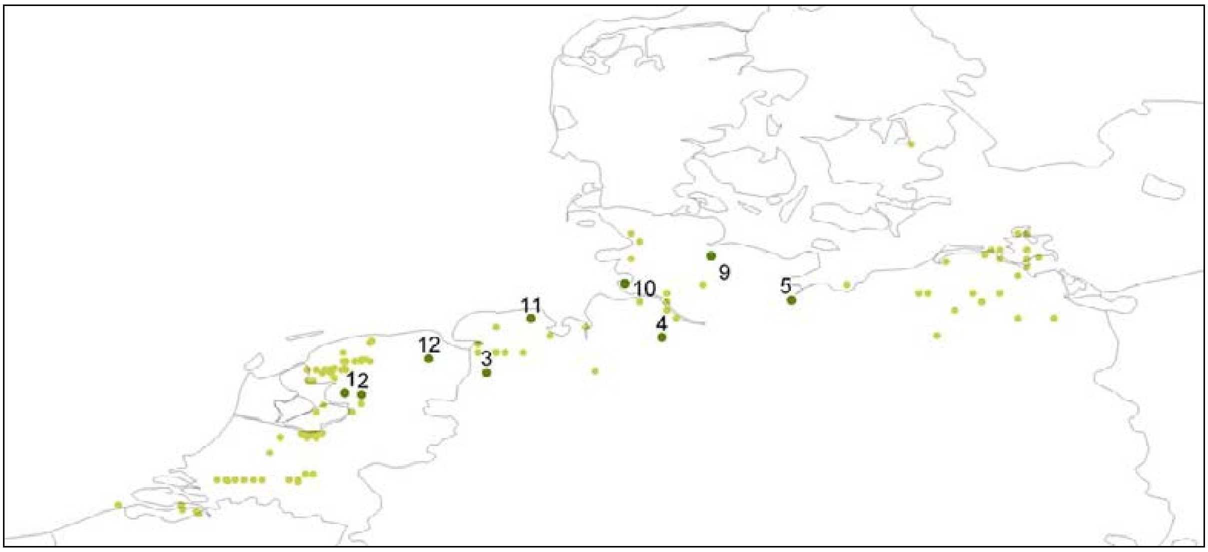


Figure 3.2.3.5 (a,b) After identifying the main types of movement, the data can be further subdivided by distance away from Great Britain & Ireland. In this case two further groups (a & b in this figure) were identified from Figure 3.2.3.3 and shows the route taken to the breeding areas from the wintering areas around the North Sea to the Russian breeding areas.

3.3 RESULTS

For each species, a series of four seasonal maps are presented, divided up as follows: Winter (December, January, February), Spring (March, April), Summer (May, June and July) and Autumn (August, September, October & November).For these, the location of every recovery is shown as well as a kernel representing 95% of these points where appropriate (blue shading) and a kernel representing 50% of the points (red shading). For species which have few recoveries the 95% kernel will inevitably cover the majority of the points and may well include outliers. Interpretation using expert opinion is therefore extremely important in these cases.

Following these seasonal figures, a series of maps with the directional movements identified in this analysis are presented. These include the relevant recoveries (recovery point is designated by a green point) and the smoothed month of occurrence (denoted by a blue point). Not all maps will contain recoveries from every month.

3.3.1 Bewick's Swan *Cygnus columbianus*

Bewick's Swans breed on the arctic tundra. Approximately 18,000 birds breed west of the Urals and the ringing recoveries reflect this with a large concentration in this area. Bewick's Swan movements are relatively well known and the maps presented here support the known pattern. Birds that winter in B&I are limited in their migration routes and most move from the breeding areas along the White Sea and Baltic Sea coasts to wintering areas in B&I. Bewick's Swans stage in a number of areas, particularly the Low Countries in both spring and autumn.

The analysis identified four main movement types. The first three reflect an (N)E-(S)W movement to and from the breeding areas (BS 1_0), via staging areas in the Low Countries (BS 2_0 & BS 3_0) and the fourth (not shown on the maps) reflects a NW movement through B&I. There is one record of a bird overshooting and appearing in Iceland.

Staging areas in the low countries appear to be used mostly in October and November, before birds move into B&I. In spring, Bewick's Swans move back in to the Low Countries in March, stage, and then move through the Baltic in April before reaching Russia in May. Birds remain in Russia until August before moving back along a similar migration route to B&I wintering areas.

There are a two other outlying points in addition to the Icelandic recovery. Two birds have been recovered in southern Russia in January and June. The first represents a bird moving wintering area and the second, possibly a moult migration. Populations of birds are known to winter in the region of the Caspian Sea and it appears that some birds may swap flyways and wintering areas between years.

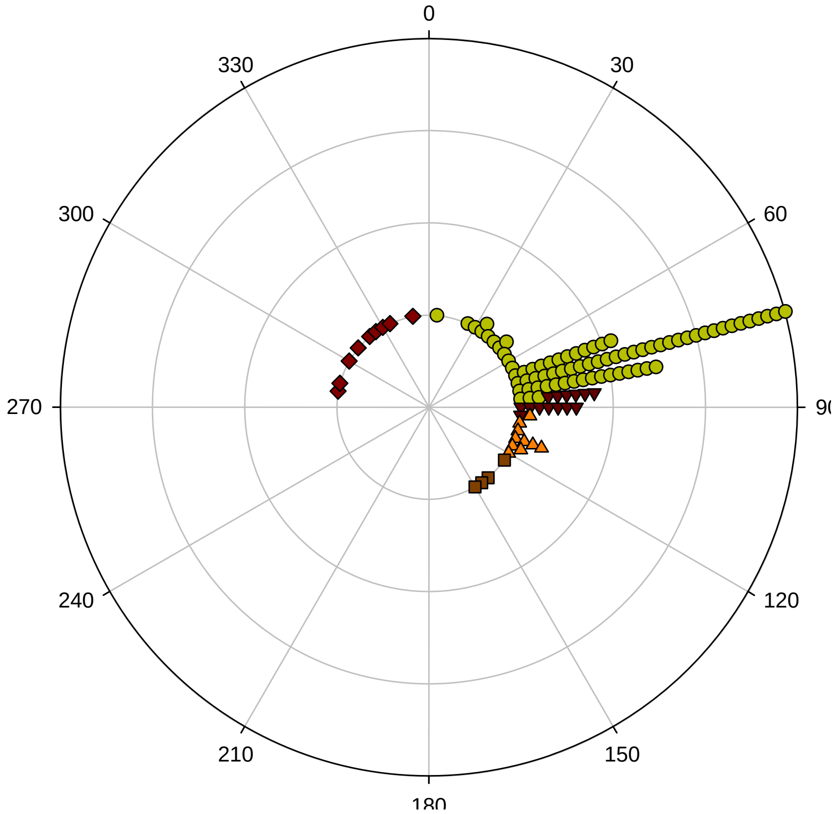
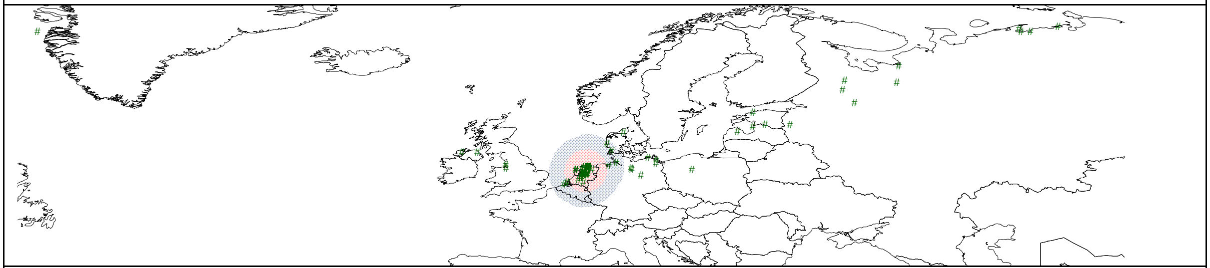


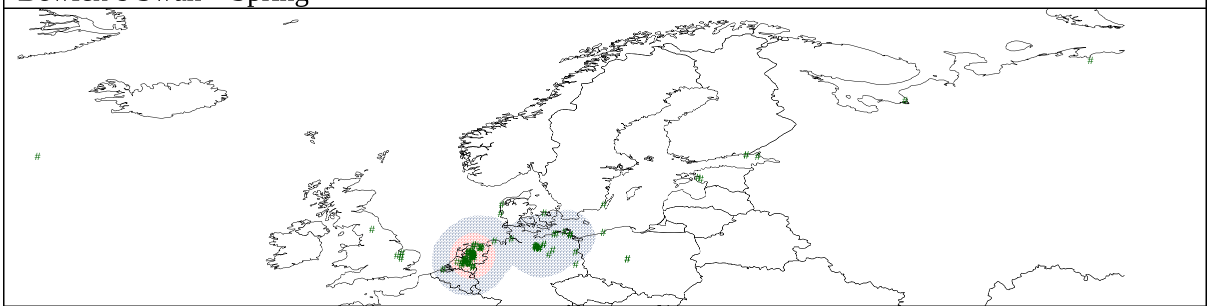
Figure 3.3.1.1 The number of directional movements of Bewick's swan to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 906

Bewick's Swan – Autumn

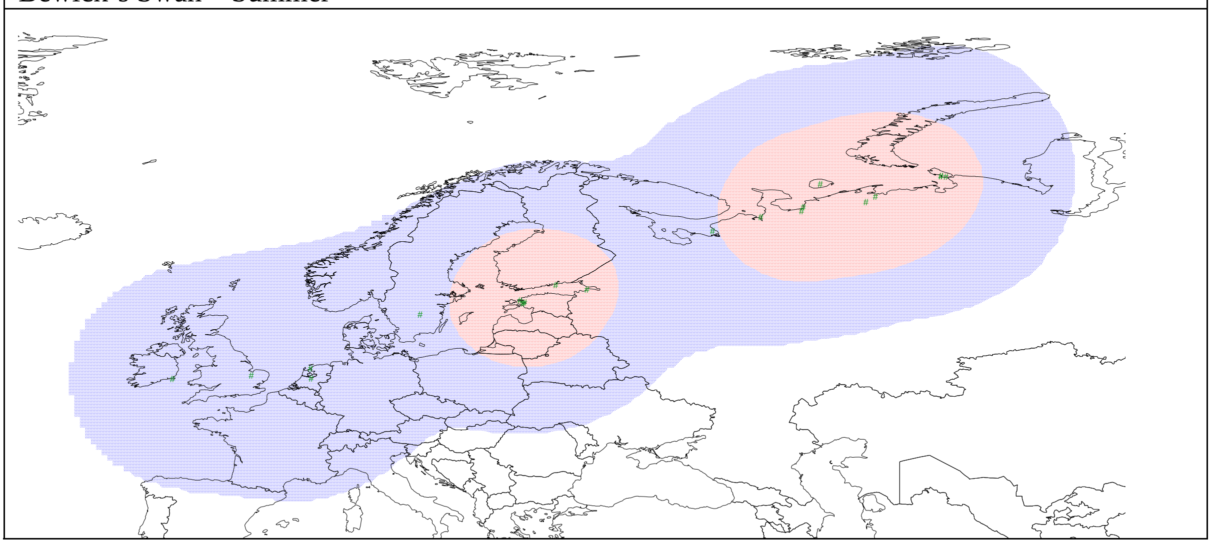


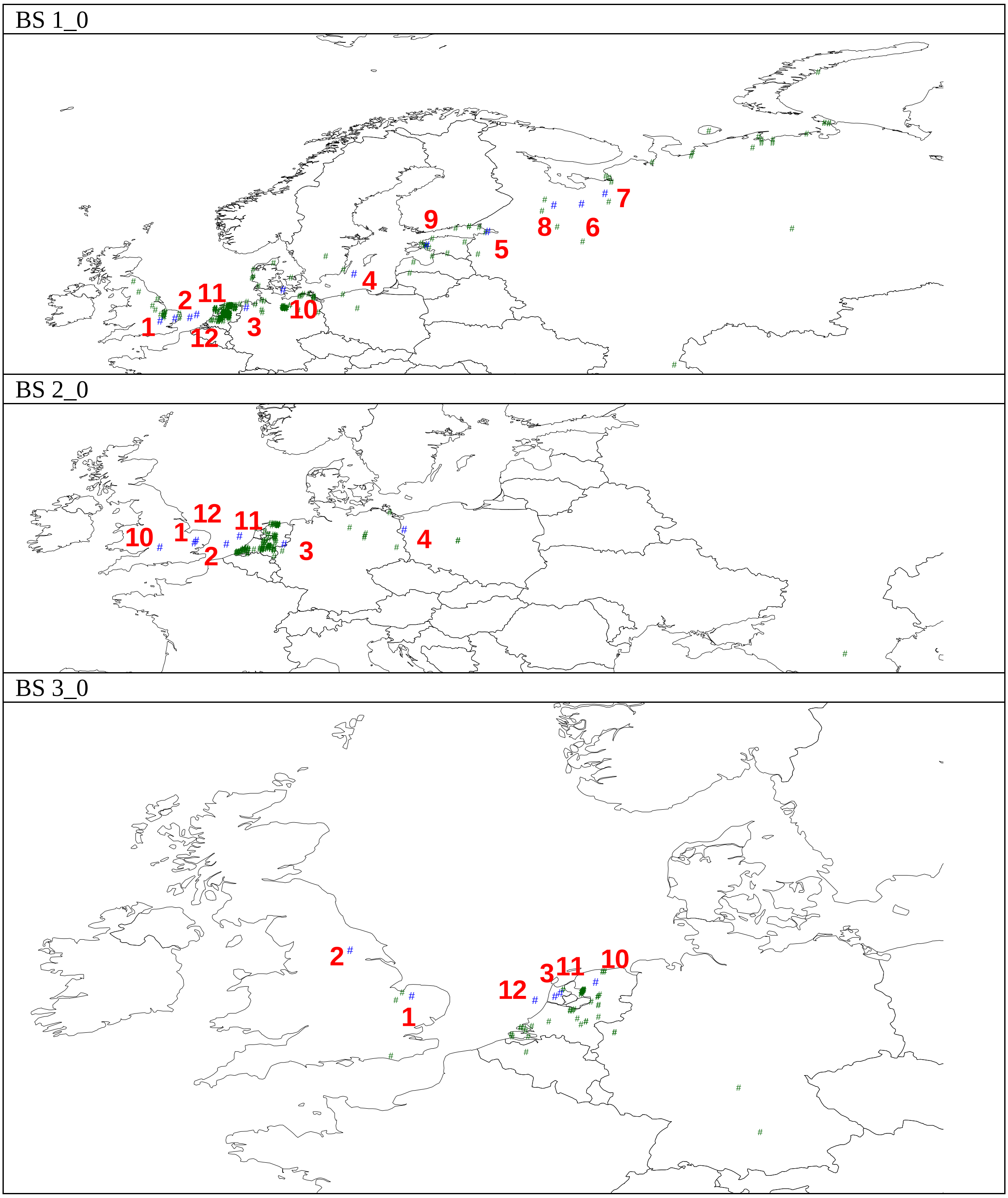
Bewick's Swan – Winter

Bewick's Swan – Spring



Bewick's Swan – Summer




BS 1_0
1
2
11
12
3
10
4
9
5
8
6
7
BS 2_0
10
1
12
2
11
3
4
BS 3_0
2
1
12
3
11
10

3.3.2 Whooper Swan *Cygnus cygnus*

Whooper Swans are a trans-Palaearctic boreal species, breeding in areas from Iceland to E Siberia. Most recoveries of Whooper Swans relating to B&I have come from the Icelandic population but recently, with the introduction of a neck-collar marking scheme in Finland, it has become evident that birds from the mainland European population winter in B&I.

The analysis identified five main movement types. The first movement (WS1_0) shows clearly the timing of the movement to the breeding areas in Iceland and back again and the majority of birds in B&I come from this breeding area. Fewer birds come from the mainland European breeding population in Finland and the number of records making up WS2_0 is limited but clearly shows the movements of these birds. The birds, marked when moulting in August, winter in B&I and migrate through the Baltic and southern Norway to B&I, with birds being recorded in B&I from November onwards. They remain in B&I before returning to the breeding areas. As no spring recoveries have been logged, it is not known which migration route they follow, but presumably move back through Denmark & southern Norway and then through the Baltic.

Two other significant movement types were recorded. WS4_0 probably represents the movement of European breeding birds through southern Norway in October and their movement across B&I to Ireland in March and return migration in May. However data are limited and it is difficult to draw firm conclusions from them. WS 5_0 represents a westerly movement, which is likely to refer to Icelandic breeding birds moving through Ireland in November and December to B&I in January and February and then a return migration through Ireland in March.

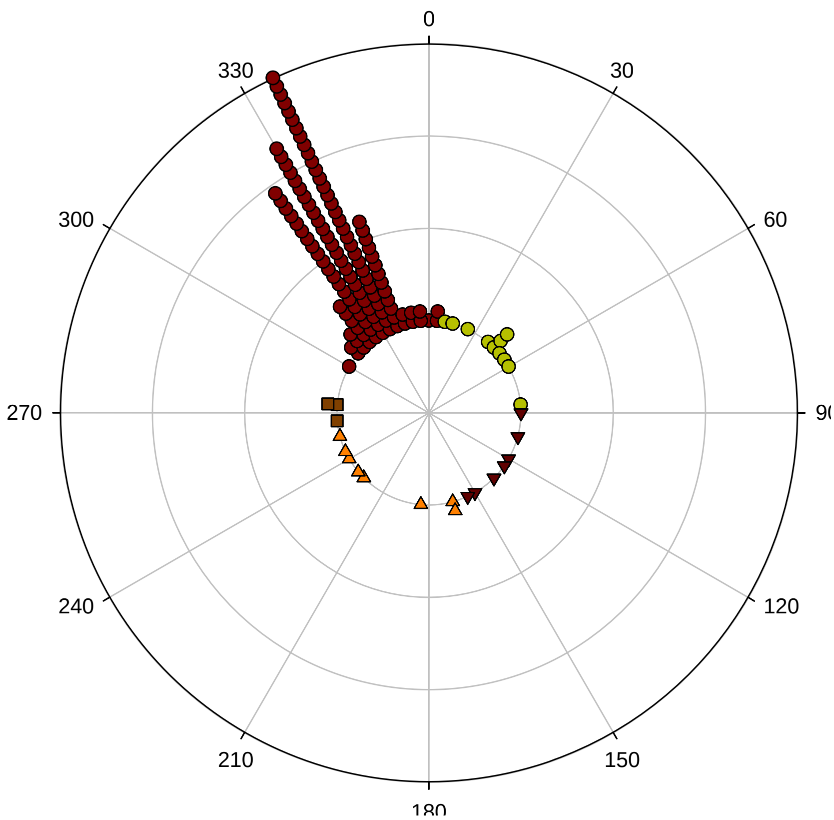
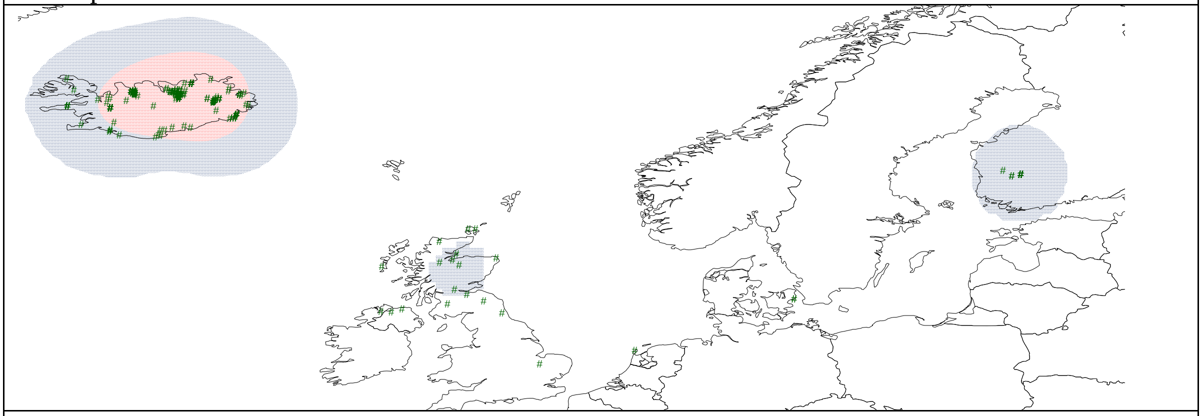
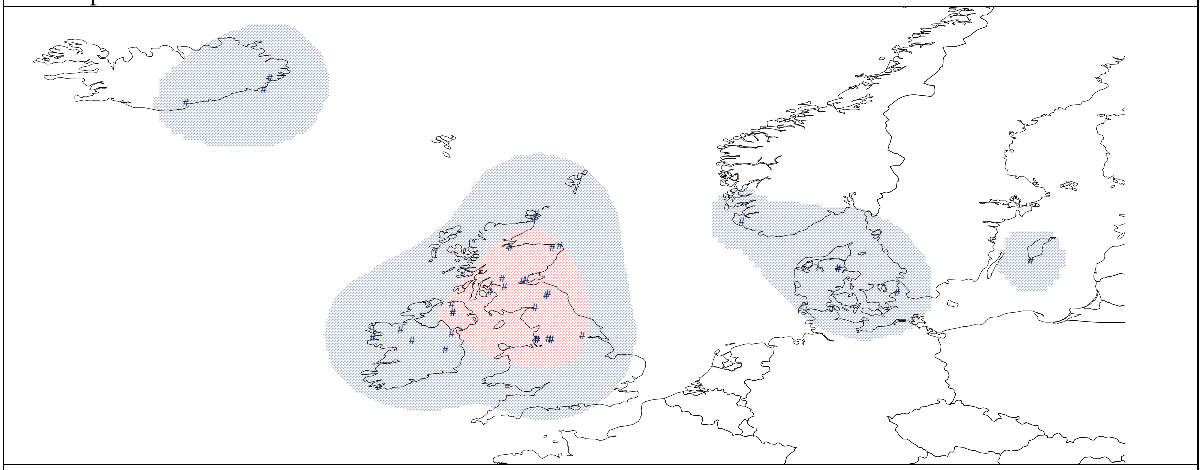


Figure 3.3.2.1 The number of directional movements of Whooper swan to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 568

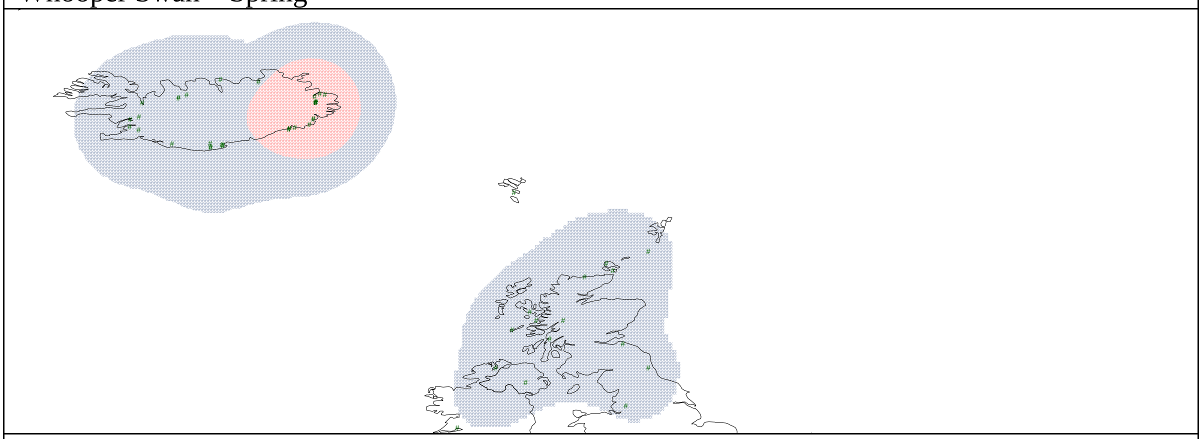
Whooper Swan – Autumn



Whooper Swan – Winter

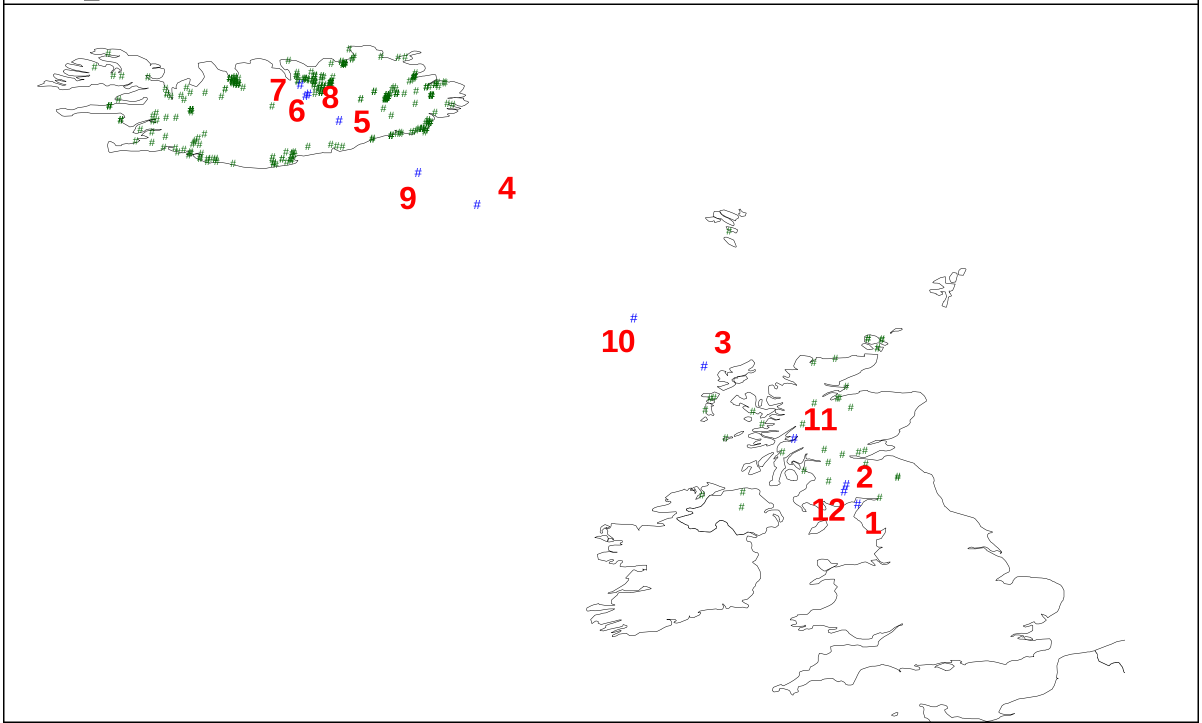


Whooper Swan – Spring



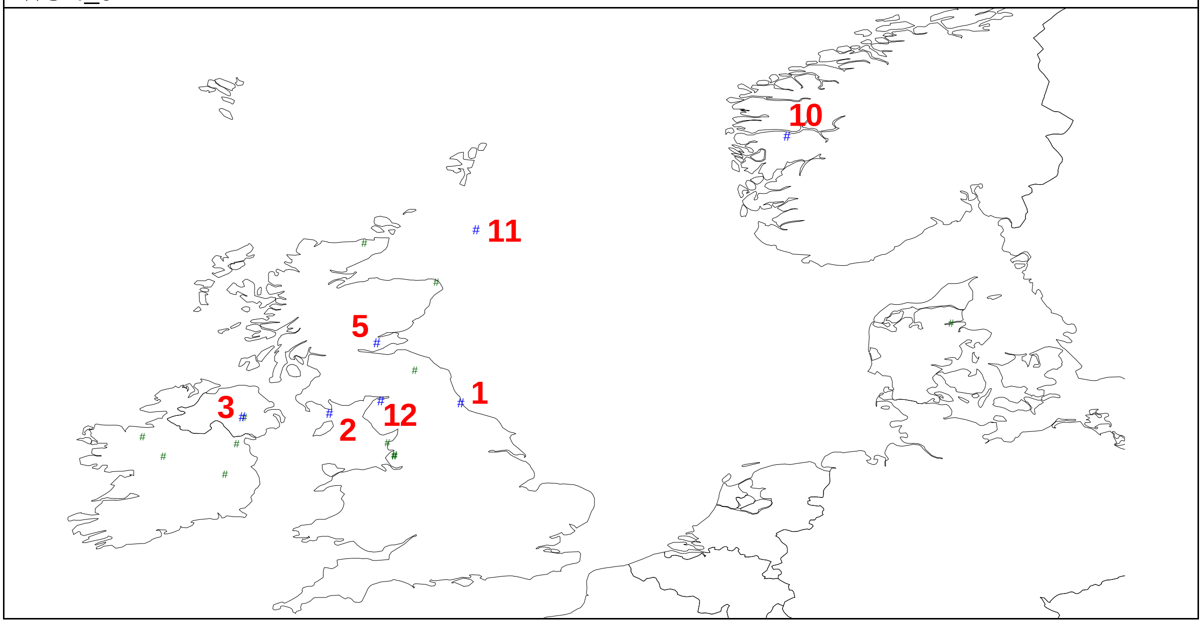
Whooper Swan – Summer

WS 1_0

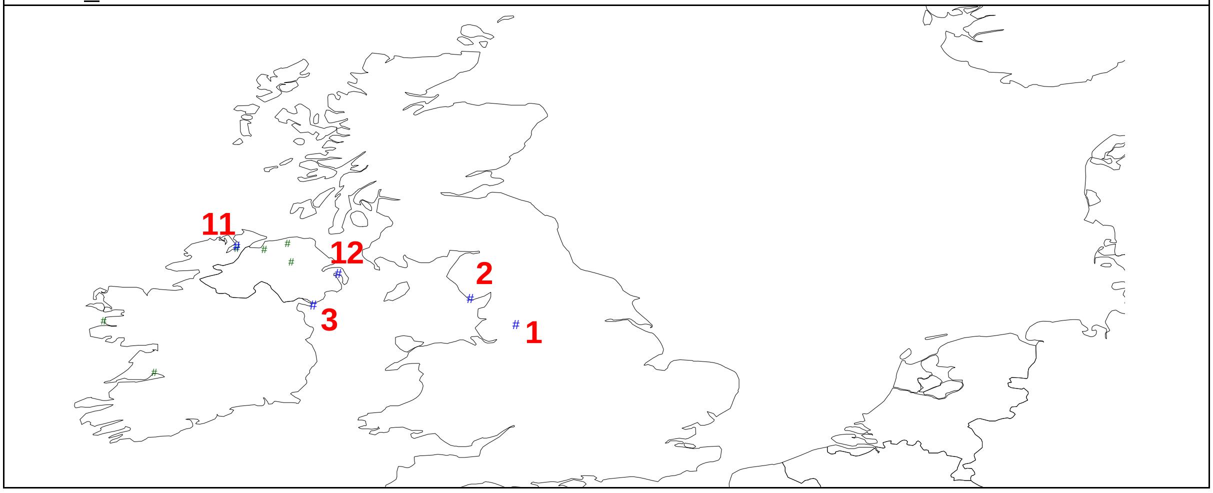


WS 2_0

WS 4_0



WS 5_0



3.3.3 Greater White-fronted goose *Anser albifrons*

The Greater White-fronted Goose has a disjunct world distribution, breeding in Greenland and on the Eurasian tundra from the Kanin peninsula in the west to the Kolyma tundra in the east. Both populations reach the Great Britain and Ireland in winter. The analysis identified seven different directional movement types.

The Greenland population winter in Ireland and also western Scotland. They stage in Iceland in April and by early May most have left for the breeding areas in Greenland (WF 6_2). After moulting near the breeding areas, they again move through Iceland, the first arriving in August but mostly during the second half of September and first half of October before reaching the wintering grounds in late October, exceptionally by the end of September. They remain until February and start the return journey in March.

The movements of nominate race *albifrons* are less well documented, with fewer ringing recoveries. They leave their arctic breeding areas in September and, move through central western Russia and Ukraine and Belarus before reaching the Baltic and moving through to reach B&I by November (WF 1_0, WF 1_1 ad WF 1_2). The return migration begins in early March and the geese mostly stage in the Netherlands but also in the Lower Rhine in Germany and the Pripyat River and Biebrza basins in Poland before moving through the Ukraine and Volga, Kama & Oka River basins where they also stage. In May birds move northwards with recoveries in the Novgorod area and by the end of the month birds are back on breeding areas on the Kanin Peninsula and Kolfuyev Island.

The remaining movement types (WF 2_2 and WF 3_0) are essentially changes in wintering area, either due to cold weather movements or a genuine change in wintering area. WF 3_0 is probably the former and WF 2_2 probably represents a genuine change in wintering area and switch in flyway. This flyway, dominated by birds that breed in Western and Central Siberia and pass through Austria and Hungary in Oct-Nov to winter in Hungary, Austria, former Yugoslavia, northern Italy, Albania and northern Greece.

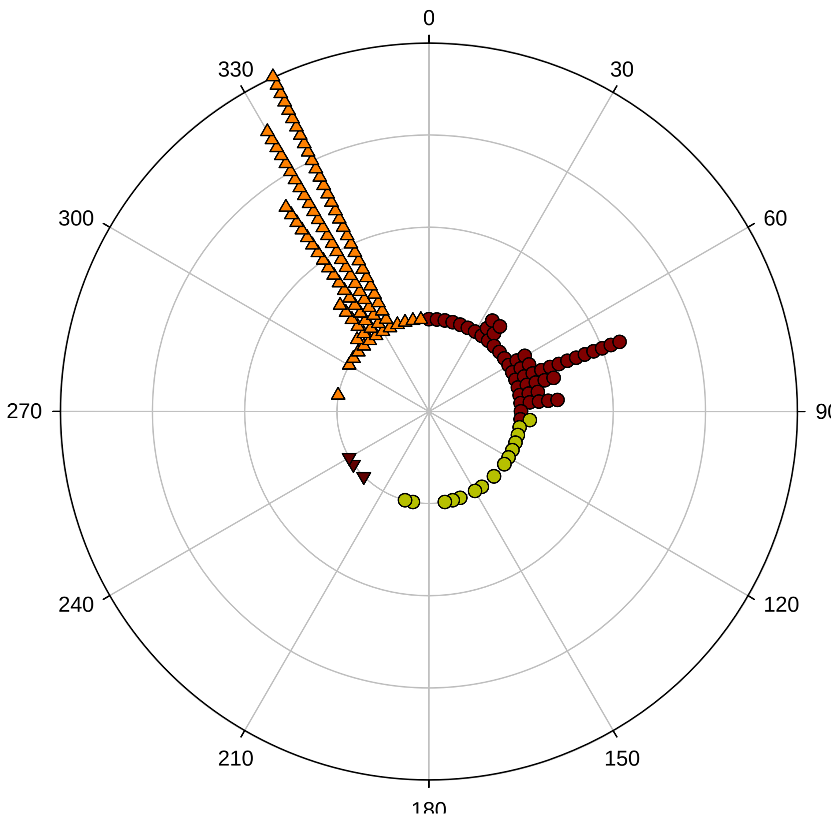
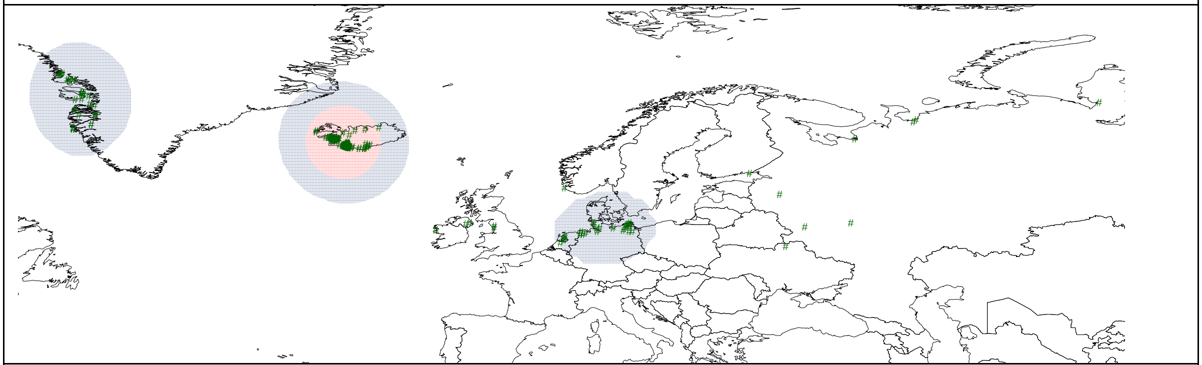
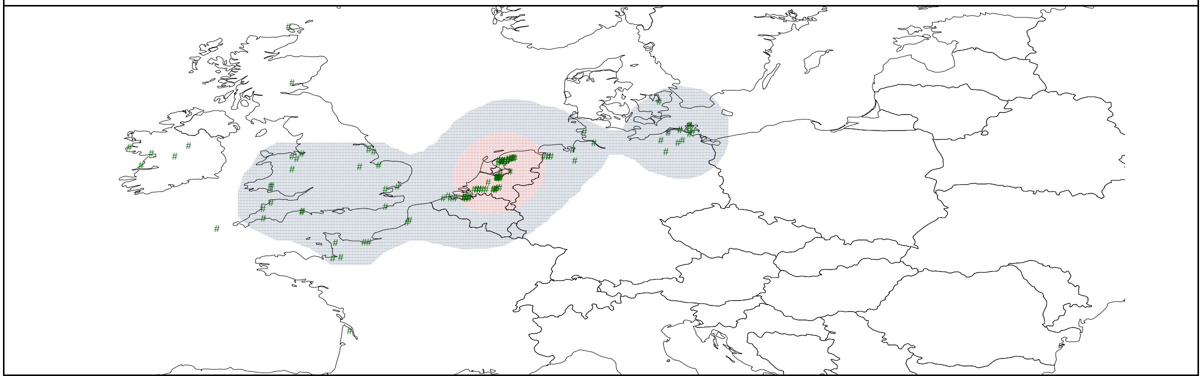


Figure 3.3.3.1 The number of directional movements of Greater White-fronted Goose to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 705

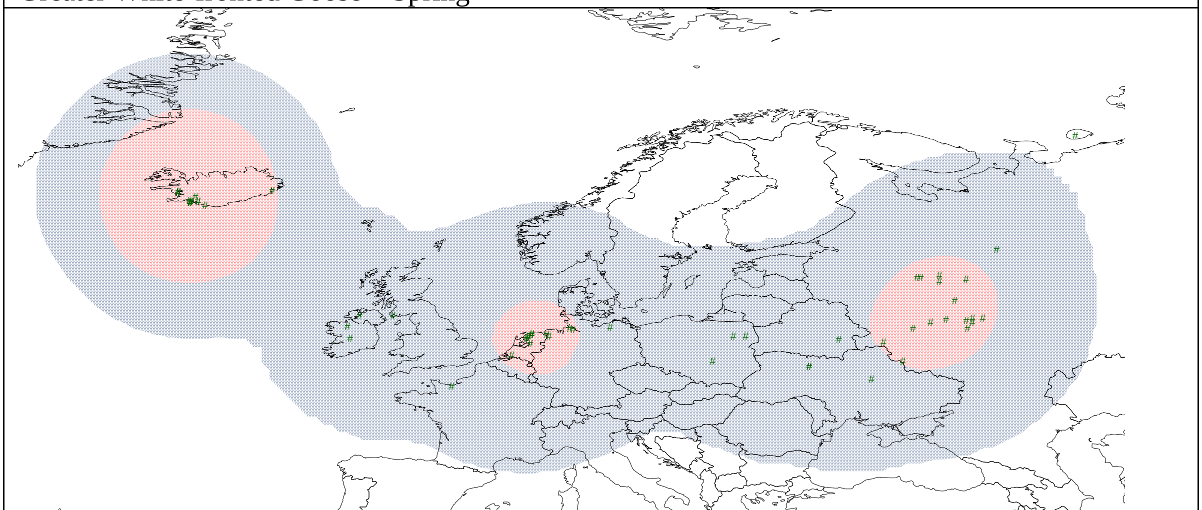
Greater White-fronted Goose - Autumn



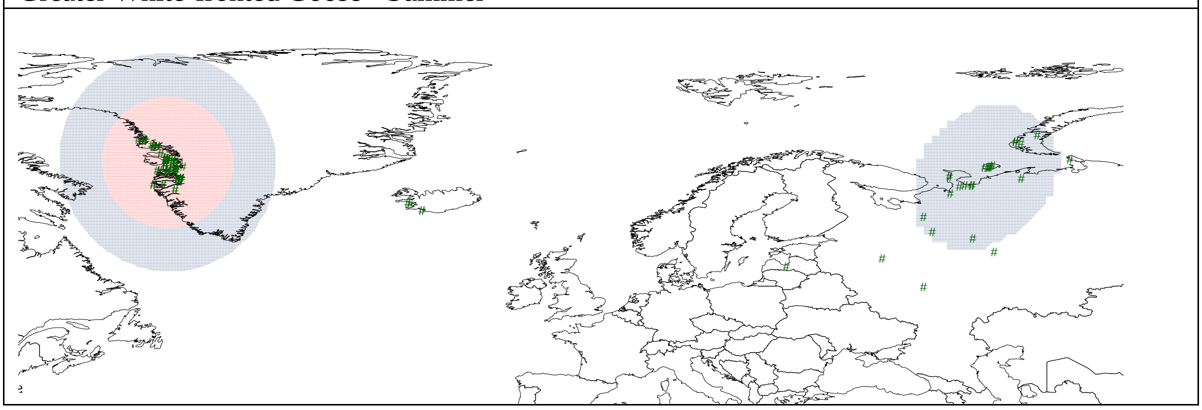
Greater White-fronted Goose – Winter



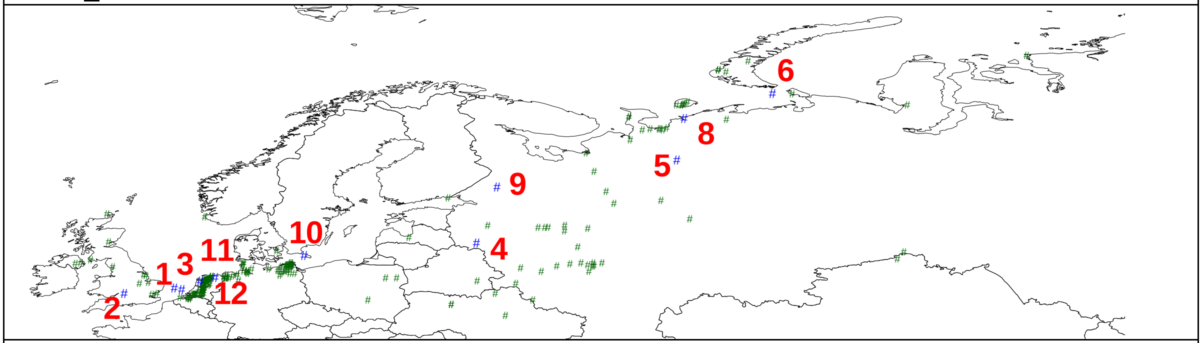
Greater White-fronted Goose – Spring



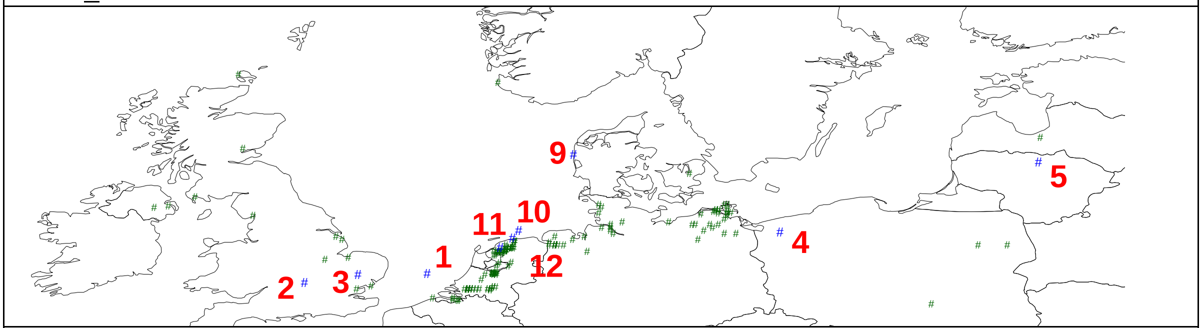
Greater White-fronted Goose - Summer



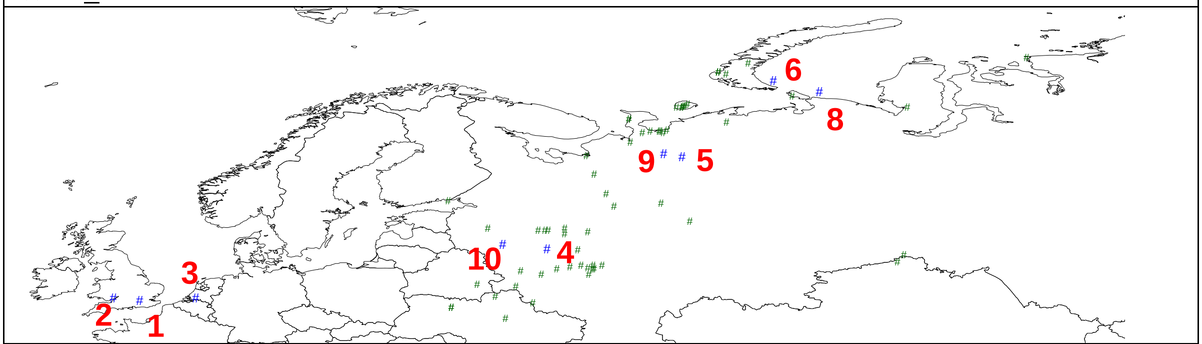
WF 1_0



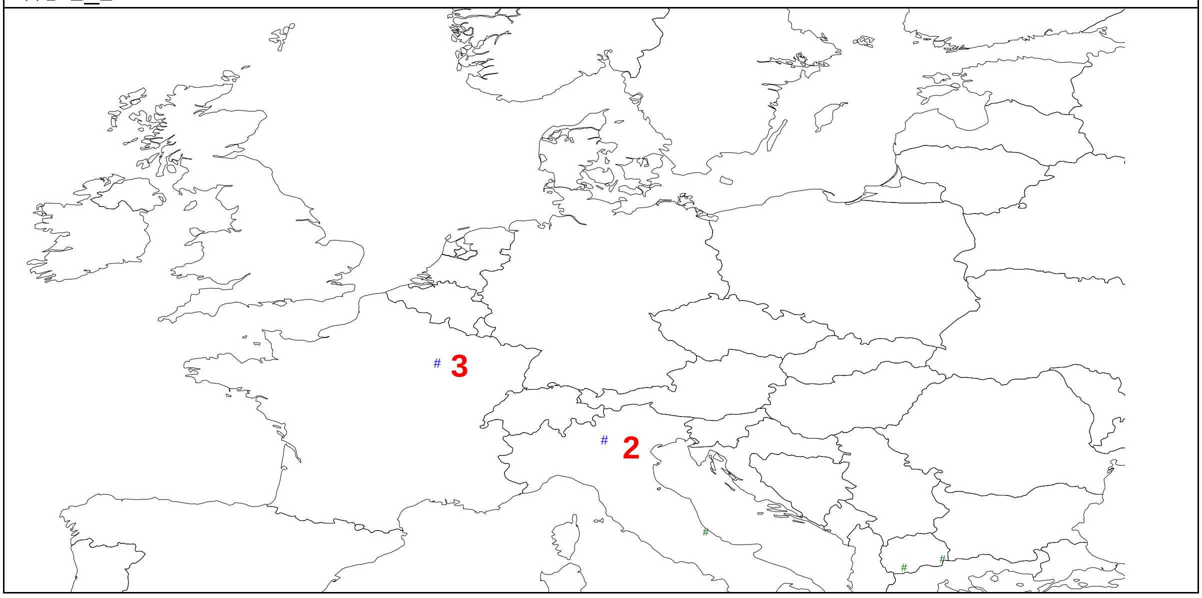
WF 1_1



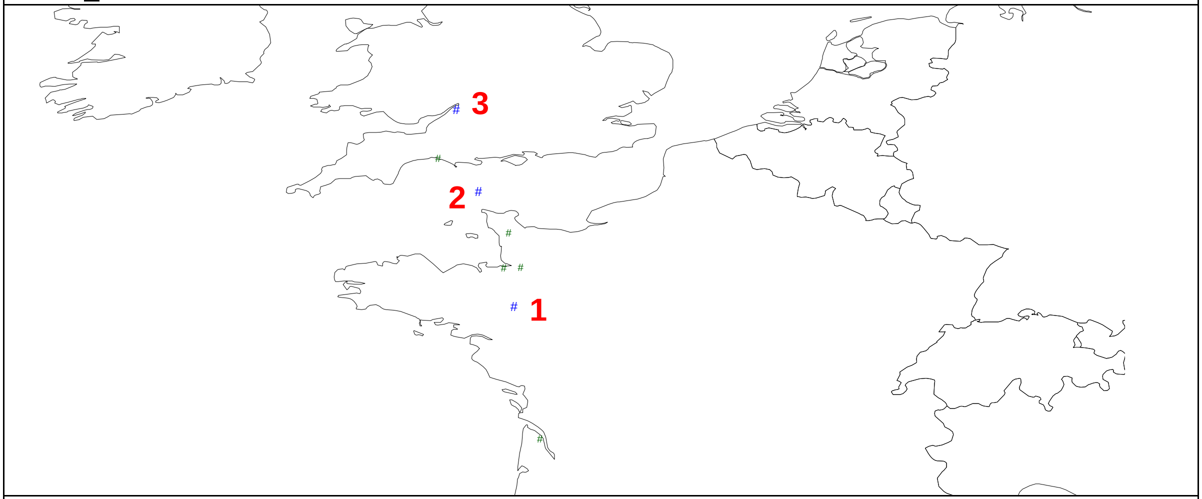
WF 1_2



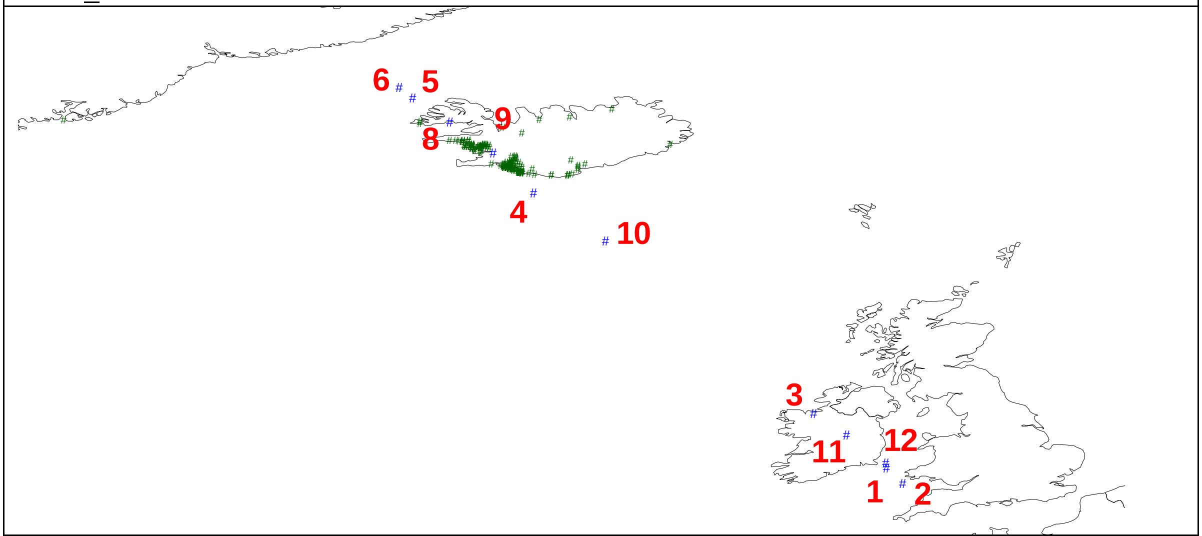
WF 2_2



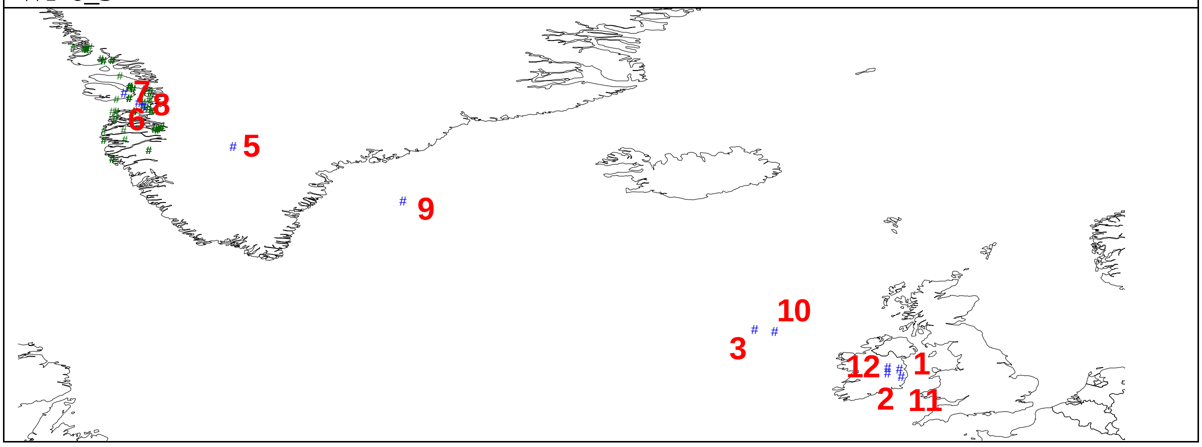
WF 3_0



WF 6_2



WF 6_3



3.3.4 Brent Goose *Branta bernicla*

Brent Goose has a circumpolar breeding distribution, nests on high Arctic coasts and winters in the Atlantic and Pacific temperate zones. Birds from three distinct breeding areas are found in Great Britain and Ireland. Light-bellied Brent Geese *B. b. hrota* breeding on Svalbard winter around the North Sea and those breeding in arctic Canada winter mostly in Ireland and stage in Iceland. The majority of Brent Geese in B&I are Dark-bellied Brent Geese which breed on the on the Taymyr Peninsula in the central Russian Arctic.

The population of most concern for primary incursion are the Russian and Svalbard populations. Both have narrow migration routes. The Russian birds migrate through the White Sea, which is a critically important staging area in June and September (BG 2). In autumn, they then move through the Baltic region to the Wadden Sea region in September and October and by November B&I wintering population is back on the wintering grounds (BG 2 & BG 3). Return migration begins in late February and after staging in the Wadden Sea in May, birds return to the breeding areas by June. Within B&I, the Svalbard breeding population is found almost exclusively at Lindisfarne during winter. These birds arrive in September, peak between October and December and move to Denmark by early March to stage before finally migrating to the breeding areas by June.

The Canadian population winters almost exclusively on the coast of Ireland. These migrate from breeding areas via Greenland and Iceland to the wintering areas. Over 75% of the population use Strangford Lough in September and November, before moving to other estuaries further south in Ireland, where they winter, leaving for the breeding areas in April, again via Iceland.

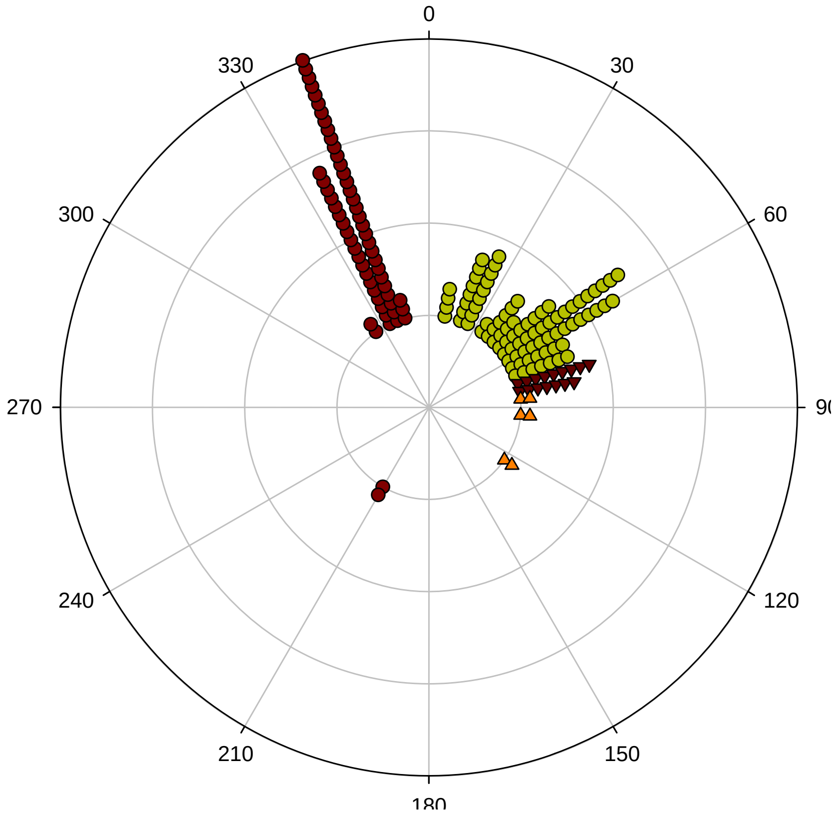
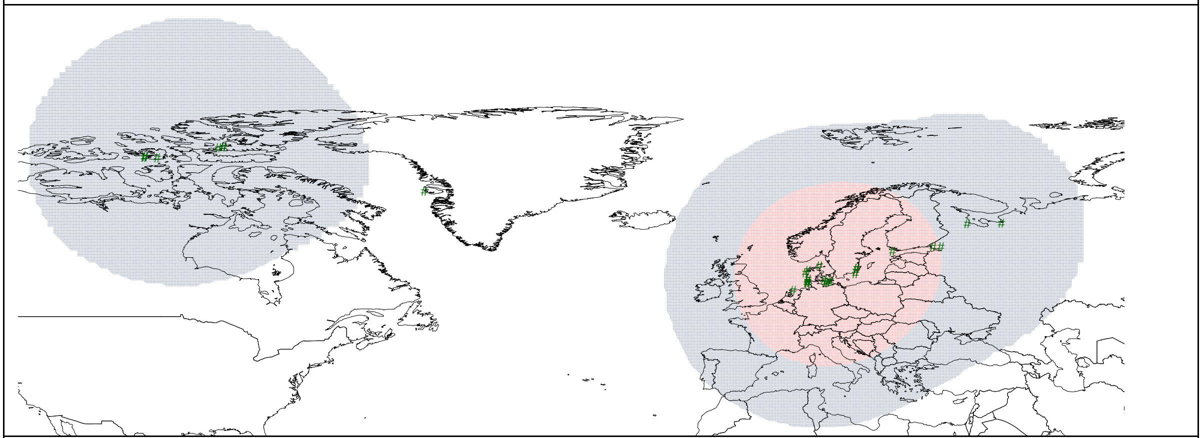
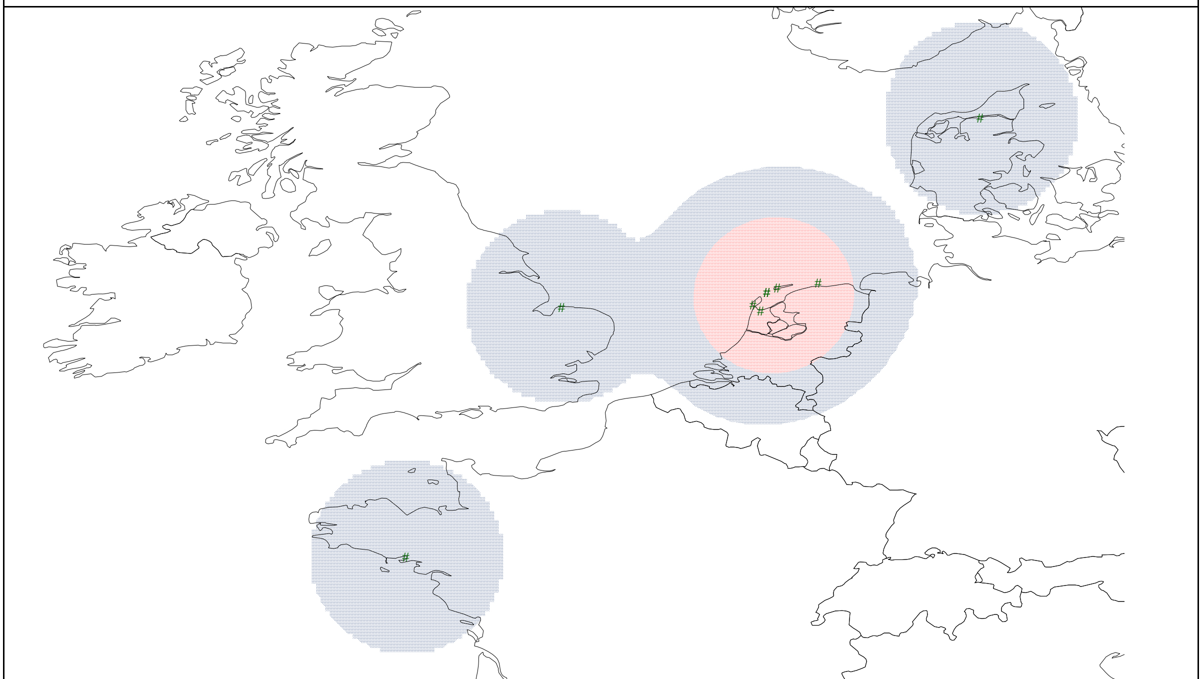


Figure 3.3.4.1 The number of directional movements of Brent Goose to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 121

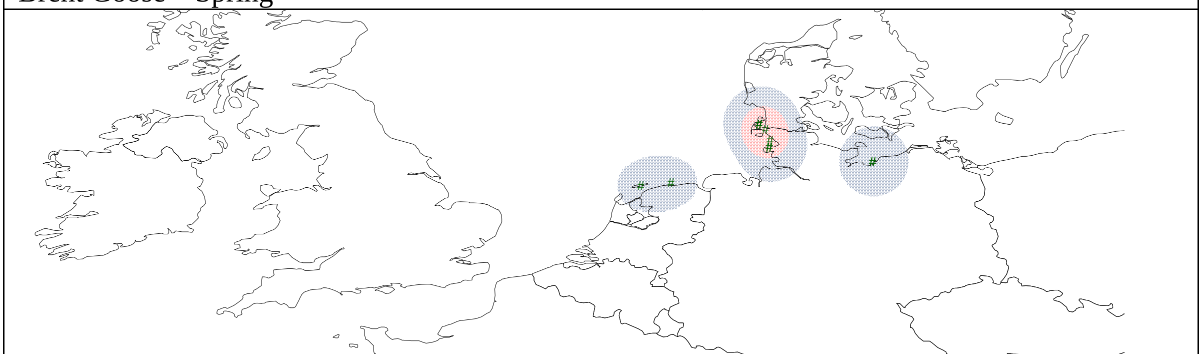
Brent Goose - Autumn



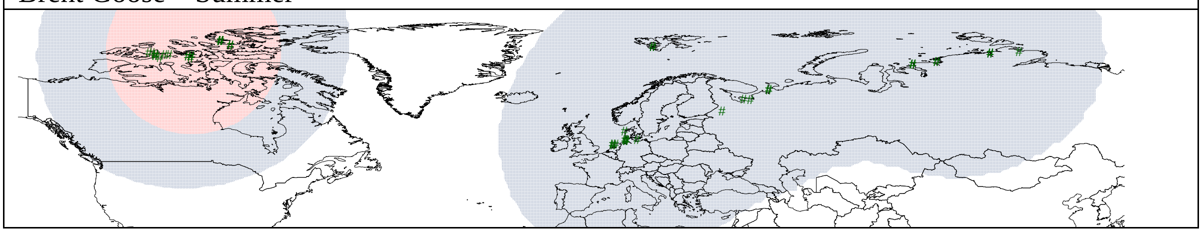
Brent Goose - Winter



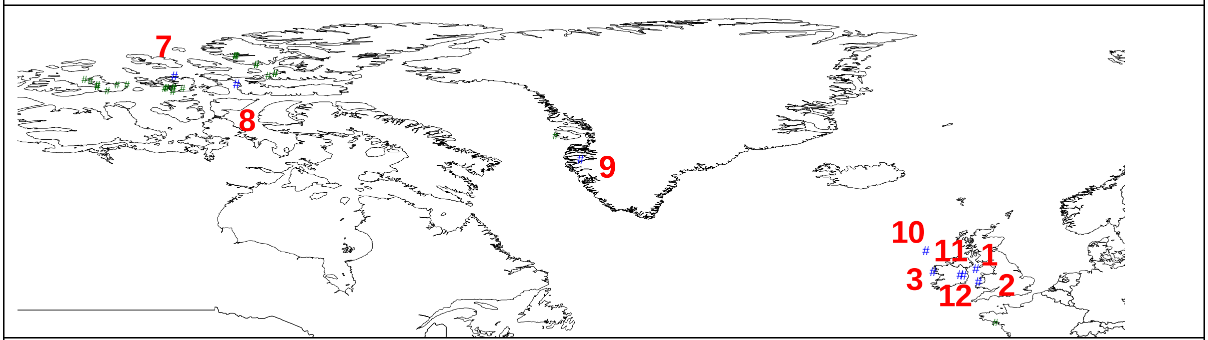
Brent Goose – Spring



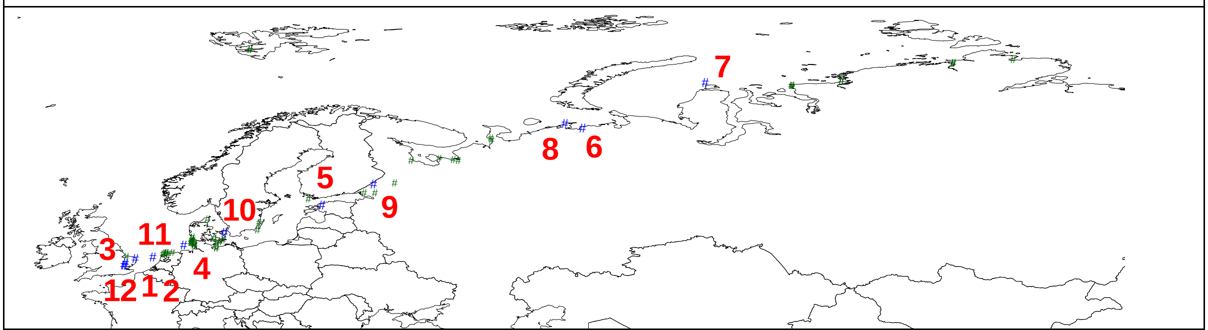
Brent Goose – Summer



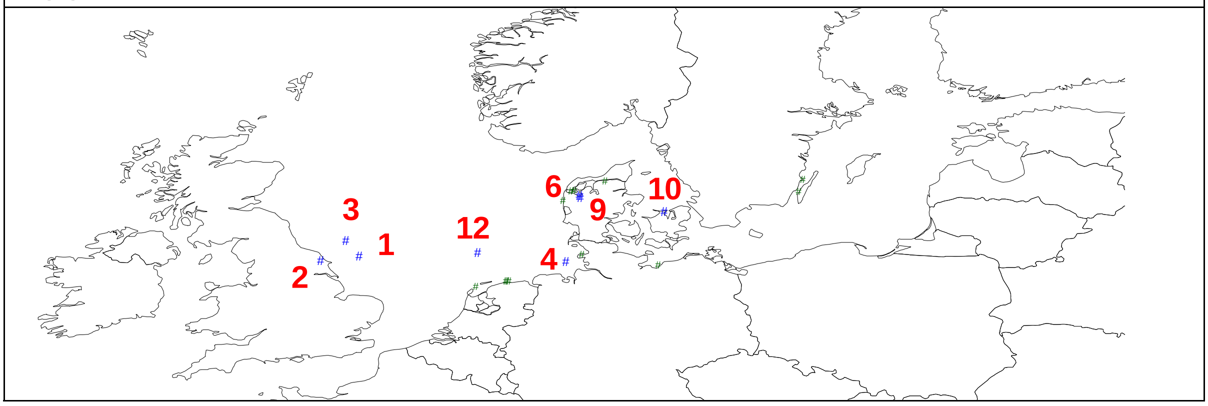
BG 1



BG 2



BG 3



3.3.5 Eurasian Wigeon *Anas penelope*

Wigeon have a northern Palaearctic world breeding range from the B&I to Kamchatka, occurring over sub-arctic and boreal zones south to c. 50º North. In Europe, in winter they concentrate in two main areas, in northwest Europe and the Black Sea and Mediterranean Basin. As with many species of duck, they are a broad front migrant and birds visiting B&I in the non-breeding season are from a wide breeding range, stretching from Iceland, through the Low countries, Scandinavia, central and eastern Europe and central and western Russia. Significant numbers of recoveries are from west of the Urals into the Ob River basin. Spring and autumn recoveries reflect this spread but perhaps show some indication of a loop migration with more recoveries in south-western Russia in spring and more in northwest Russia in autumn. In winter, birds are generally restricted to the North Sea coasts of Denmark to France and the Atlantic coast of France. There are exceptional winter records in southern Spain, and the recoveries on Italy, Greece and eastern Turkey provide evidence of switching between the two main wintering concentrations.

The directional analyses identified five different directional movements. The first shows the north-east to south-west movement of birds breeding in southern Scandinavia and the Baltic states (WN 1_1) and north-west Siberia (WN 1_2). The second type of movement (WN 2_1 and WN 2_2) are more difficult to interpret. The first represents local movements around the North Sea and the second (WN 2_2) a switch in wintering areas to areas around the eastern Mediterranean.

The third type of movement represents local mixing of birds in autumn and winter within B&I and the Channel and Atlantic coastal regions of France (WN 3_1), with some extreme winter movements to southern Spain (WN 3_2).

Apart from some local westerly movements in B&I, the only other directional movement is the movement of birds breeding in Iceland moving into B&I in October before returning to the breeding areas in April (WN 5).

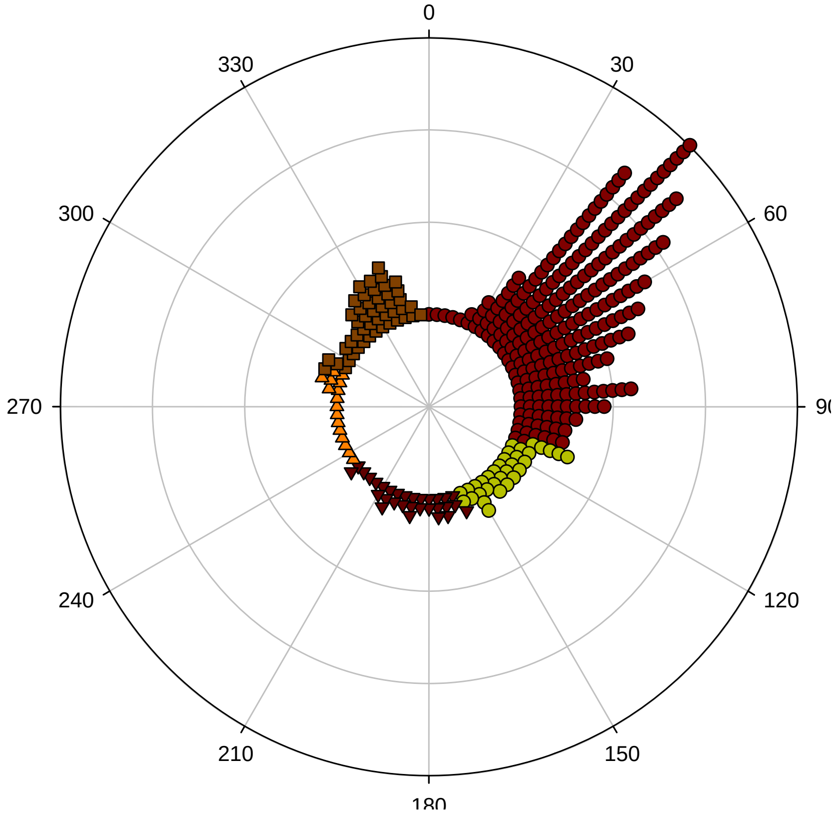
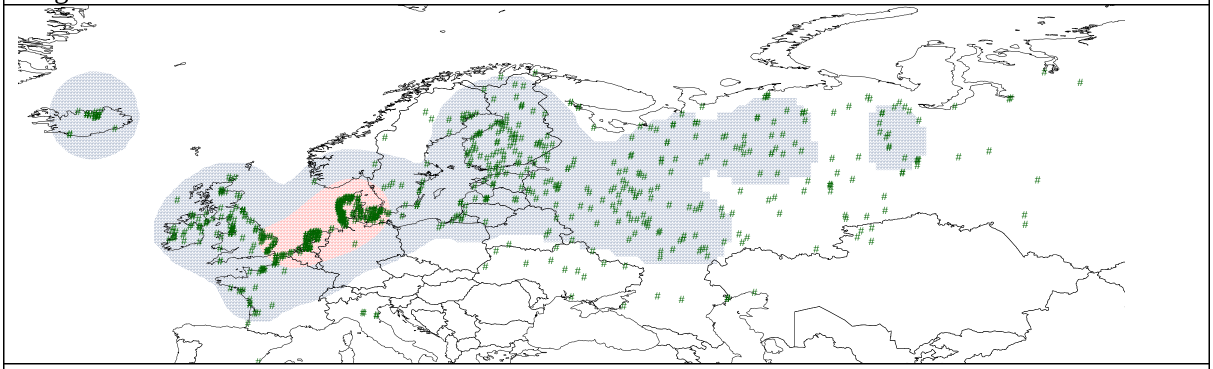
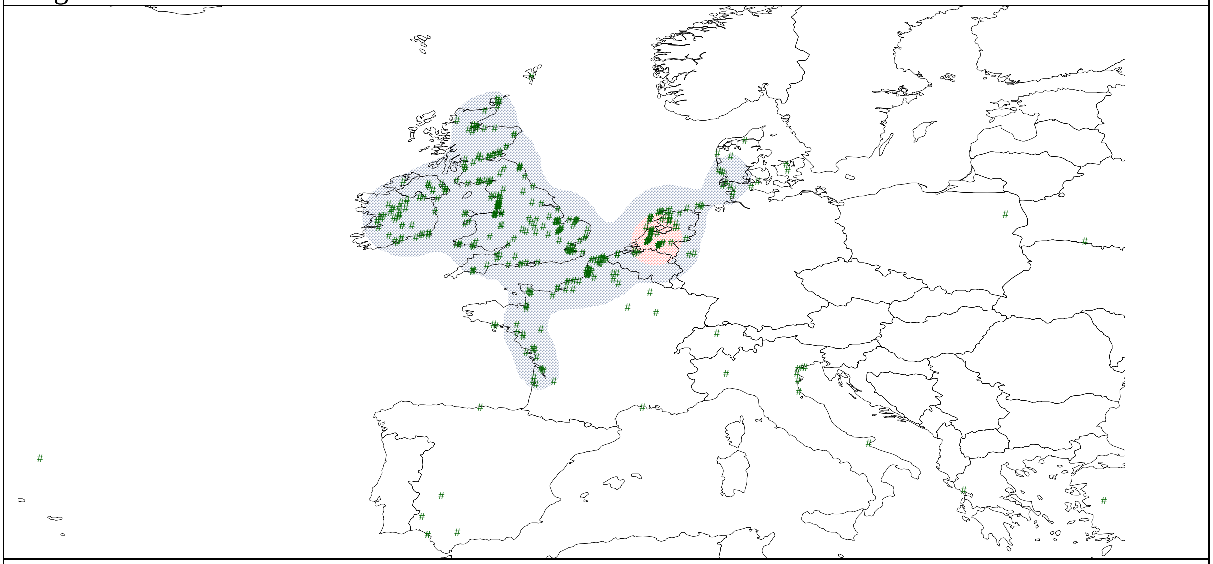


Figure 3.3.5.1 The number of directional movements of Wigeon to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 1969

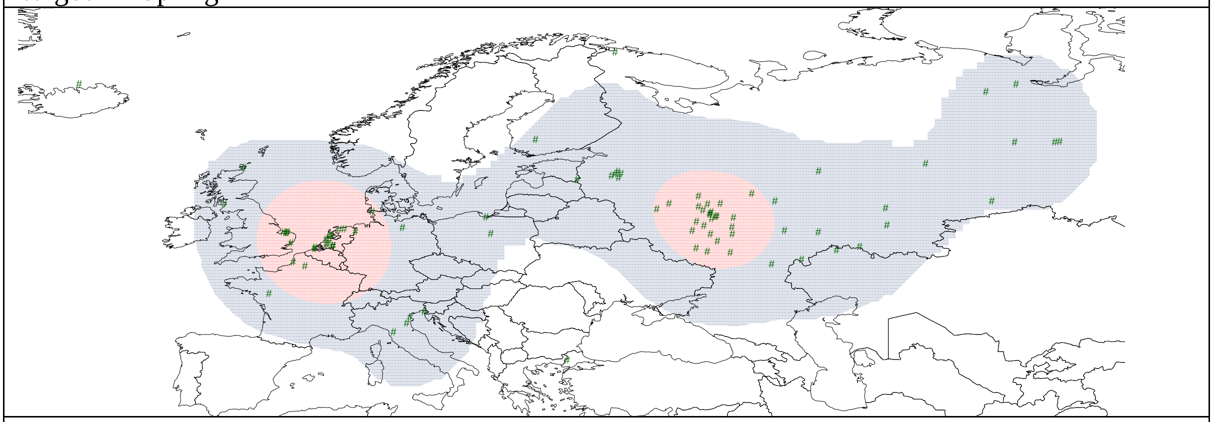
Wigeon – Autumn



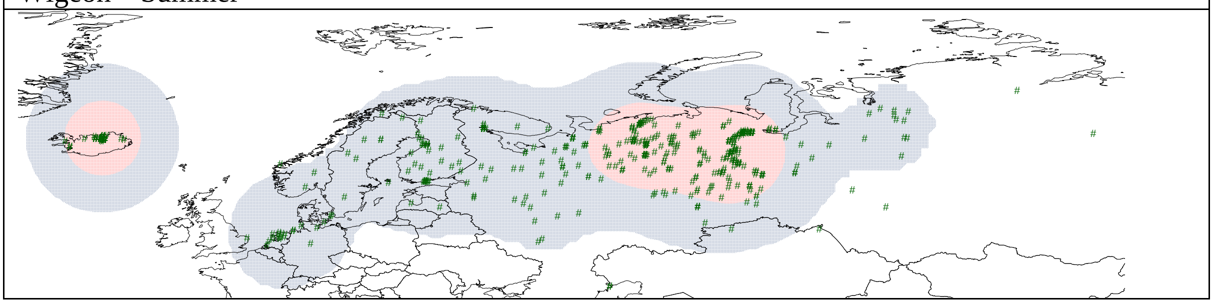
Wigeon – Winter



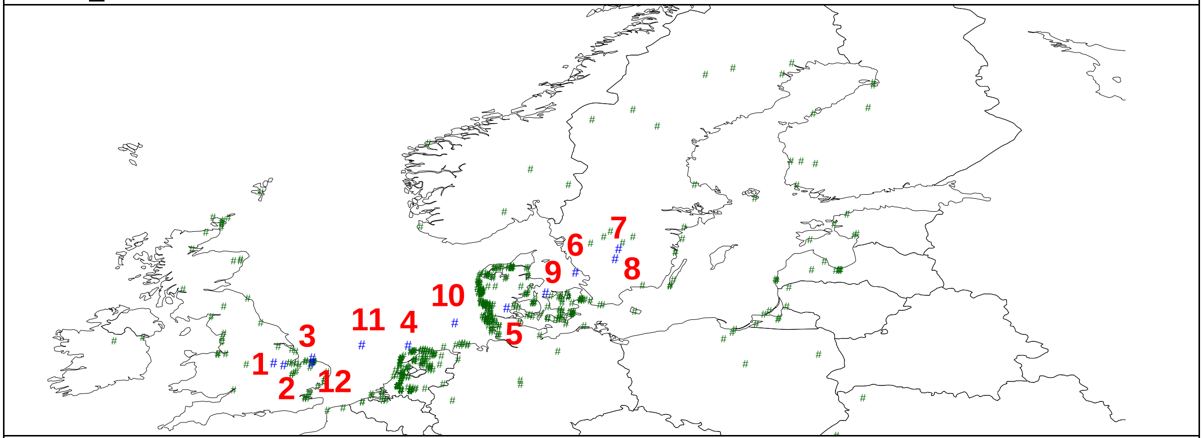
Wigeon – Spring



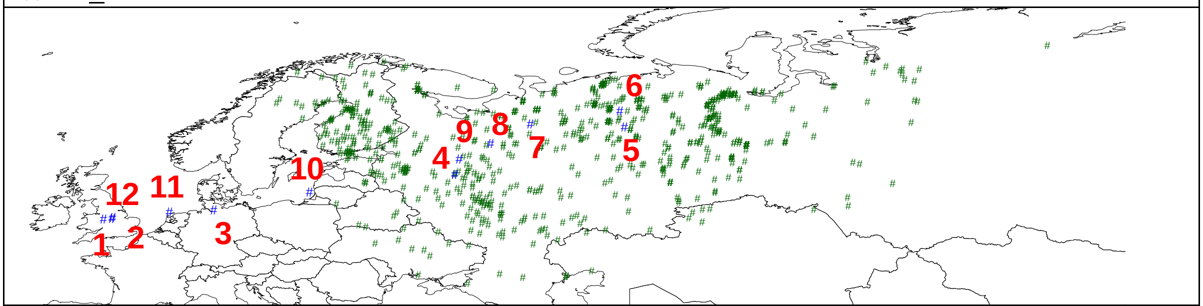
Wigeon – Summer



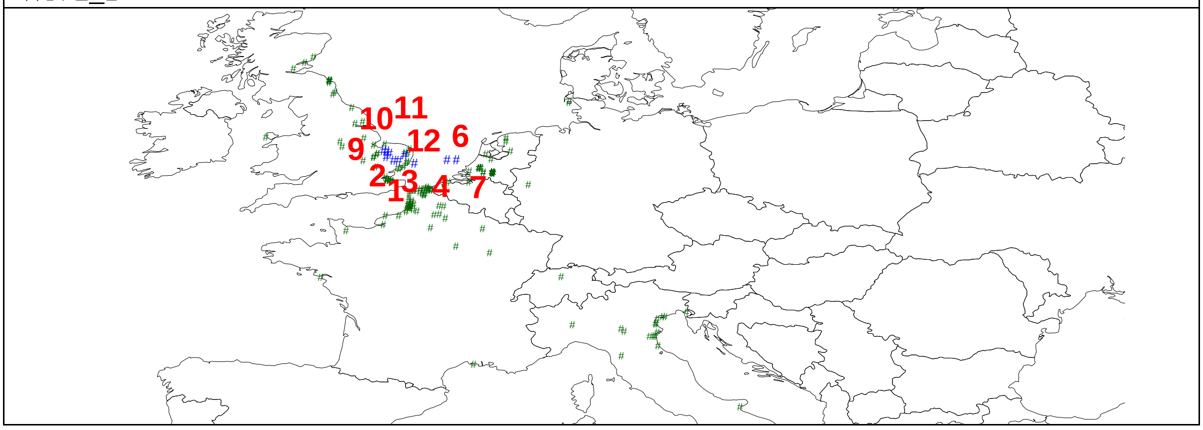
WN 1_1



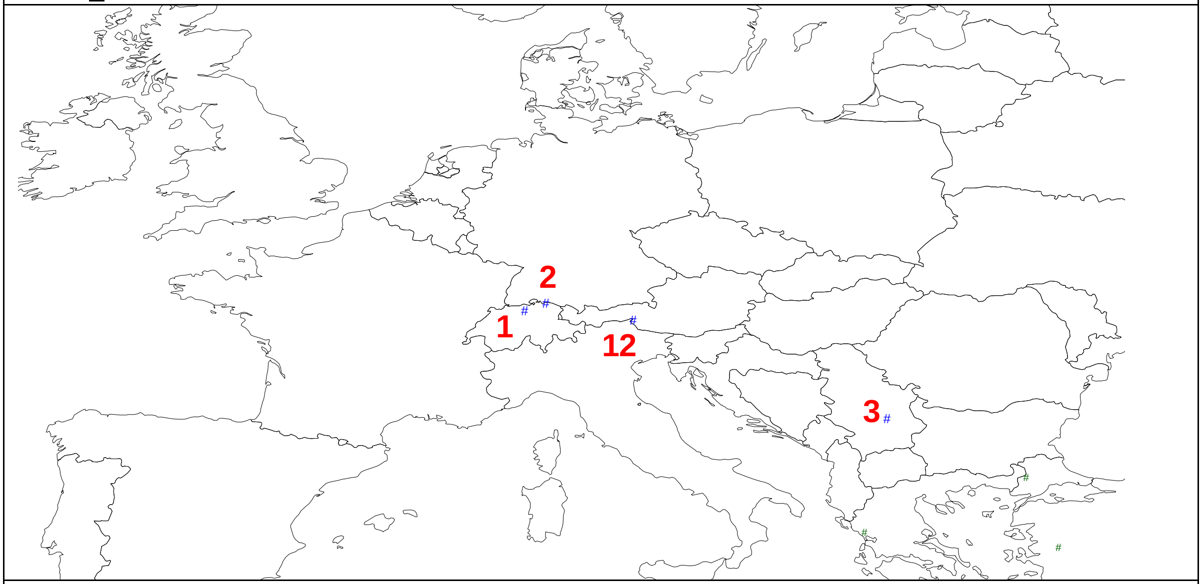
WN 1_2



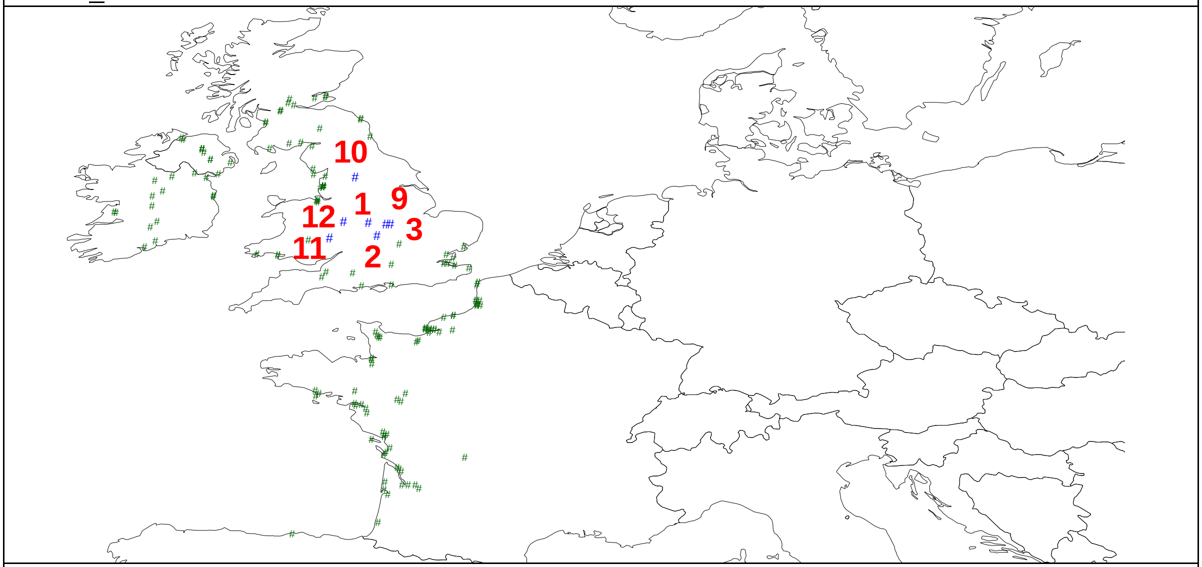
WN 2_1



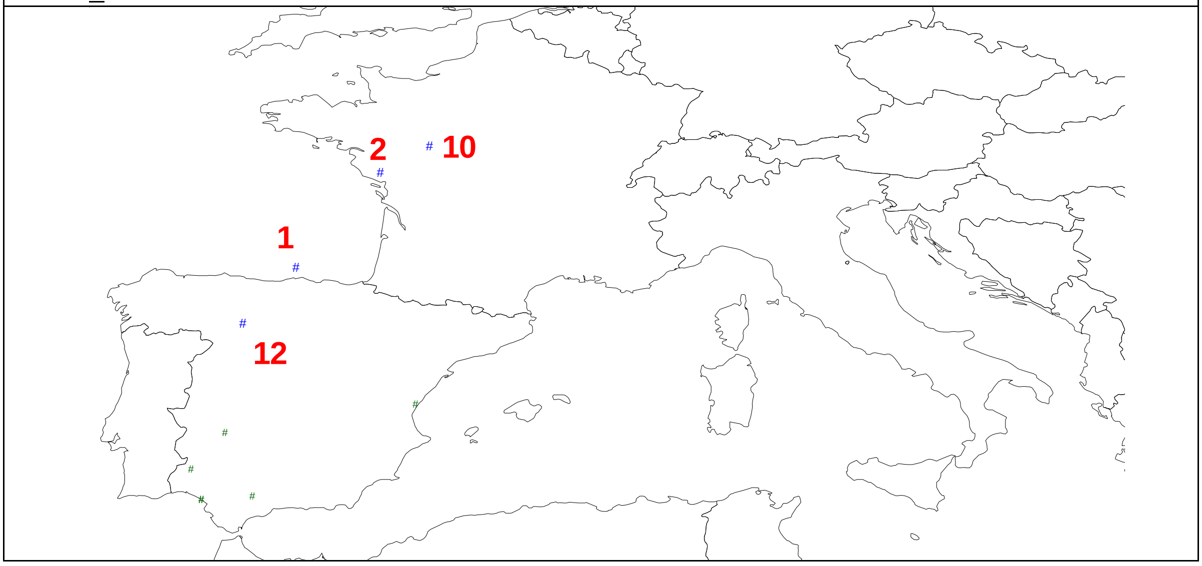
WN 2_2

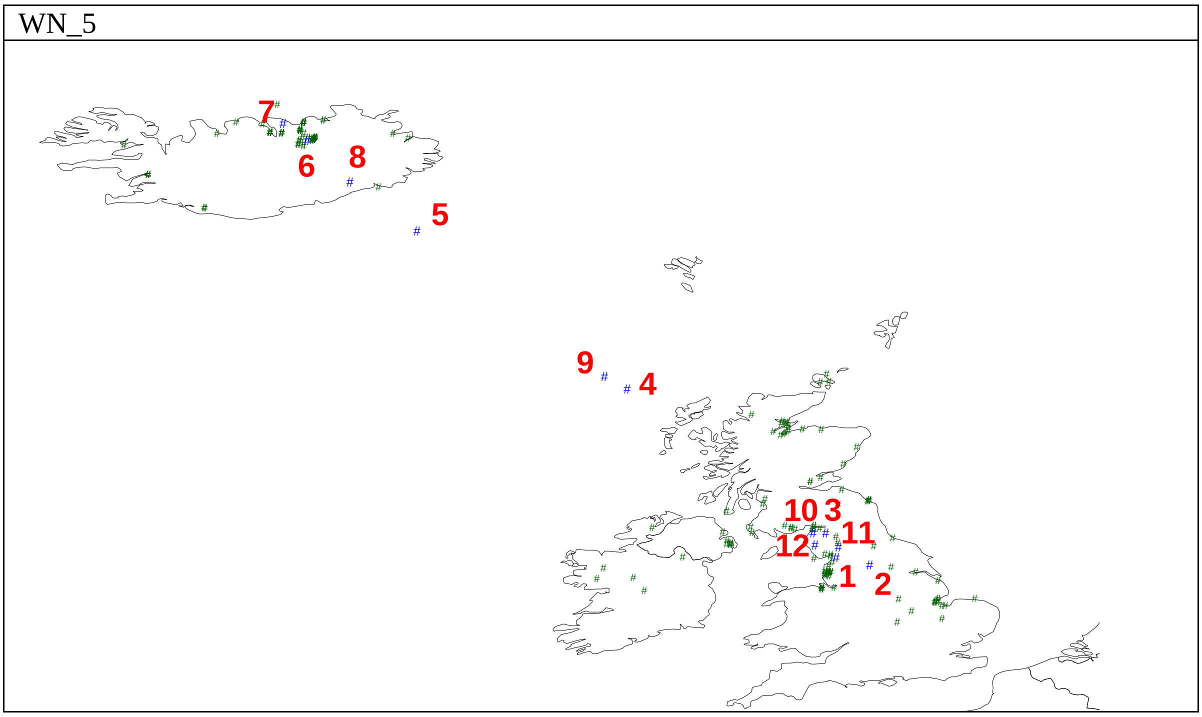


WN 3_1



WN 3_2




WN_5
7
6
8
5
9
4
10
3
12
11
1
2

3.3.6 Eurasian Teal *Anas crecca*

Eurasian Teal are an abundant Holarctic species. In Europe the nominate subspecies, *A. c. crecca*, breeds throughout the middle latitudes of the W Palaearctic in Europe and north Asia.

In winter, recoveries of B&I Eurasian Teal tend to be concentrated in the UK, around the North Sea and along the Atlantic coasts of France, south to Spain. There are a few recoveries further east in Italy, Germany, Eastern Europe and Turkey and Georgia. In spring, there is a concentration of recoveries again in B&I & France but increasing numbers to the northeast in the Baltic States and eastern Russia. The summer distribution shows that birds breed in areas from B&I and northern France west to the Urals and south to approximately 48°N in Western Europe. The largest geographical spread of recoveries occurs in autumn and probably reflects the larger numbers of recoveries during this period, as 95% of recoveries were within a relatively small area covering the UK, Ireland, the North Sea coasts of mainland Europe and the eastern Baltic States. However some of the movements in eastern and southern Europe may reflect either movements between flyway populations.

The turning point analyses identified four directional movements, because Eurasian Teal are an abundant, broad-front migrant, i.e. birds coming to B&I are from a very widespread area. Winter visitors to B&I are predominantly from the Scandinavian and north-western Siberian population and Iceland. Only two recoveries are east of the Urals.

There is a clear northeast/southwest movement (T 1_0), with large concentrations of recoveries in Scandinavia, but also from a much wider area, ranging from the northern Mediterranean to northern Scandinavia and westwards to the Urals. This is a breeding movement and the smoothed line shows that birds in B&I from October to February start to move back to the breeding areas in March, reaching the furthest limit in May and June. Return migration commences in July and by September the smoothed time-line indicated that most birds are back around the North Sea.

The second pattern identified (T 2_0) is more difficult to interpret but essentially is a redistribution of birds from Britain, southwards to the southern and Atlantic coasts of France and Spain. These movements are not clearly temporally defined and probably reflect (a) changing wintering areas between years, cold weather movements and migrants passing through B&I to the continent. Some recoveries are from the summer months and perhaps include breeding birds.

The third pattern was a local east-west movement between B&I and Ireland (not shown) and the fourth (T 4_0) concerns the movements of the Icelandic breeding birds. Birds were back in Iceland by May, remained to breed and were back in B&I by September.

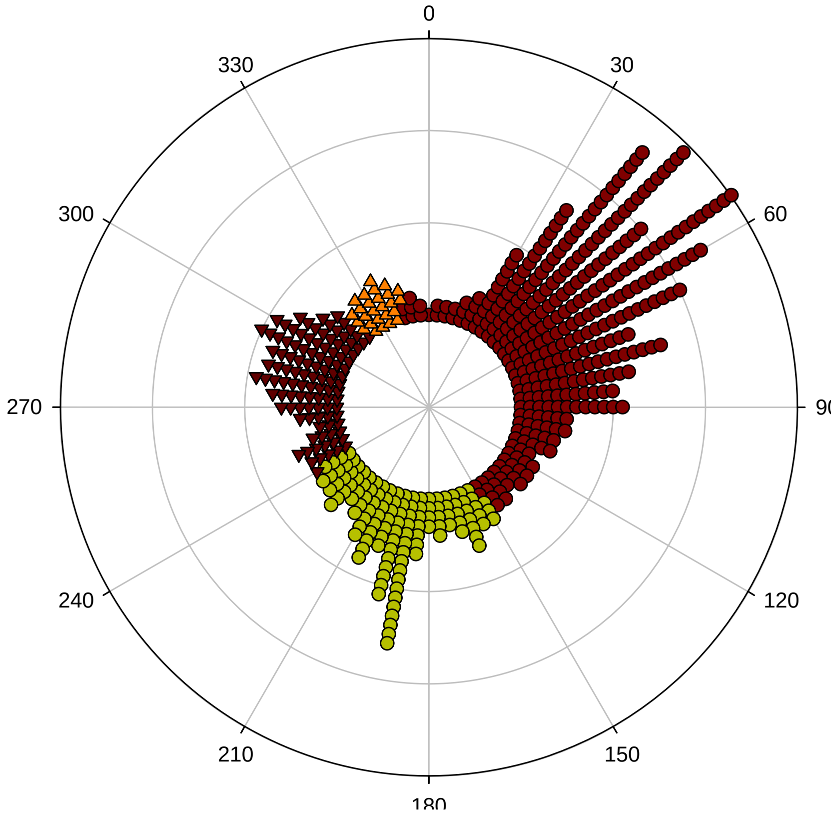
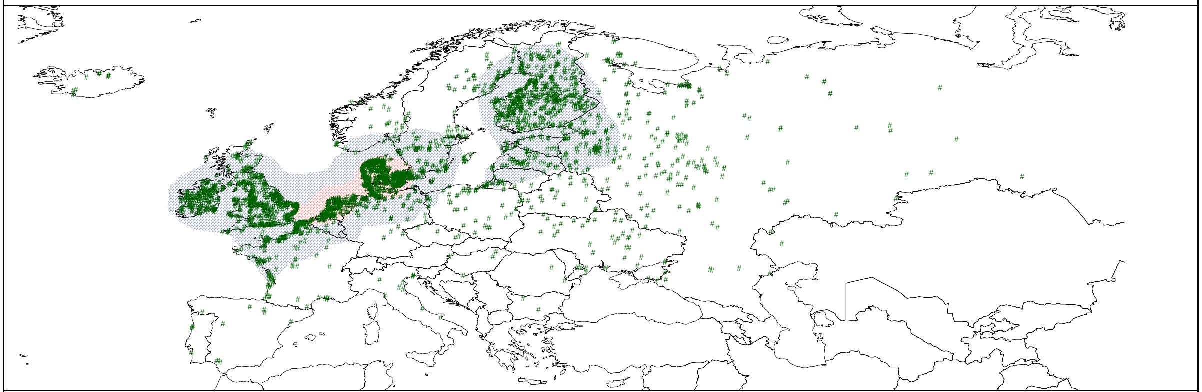
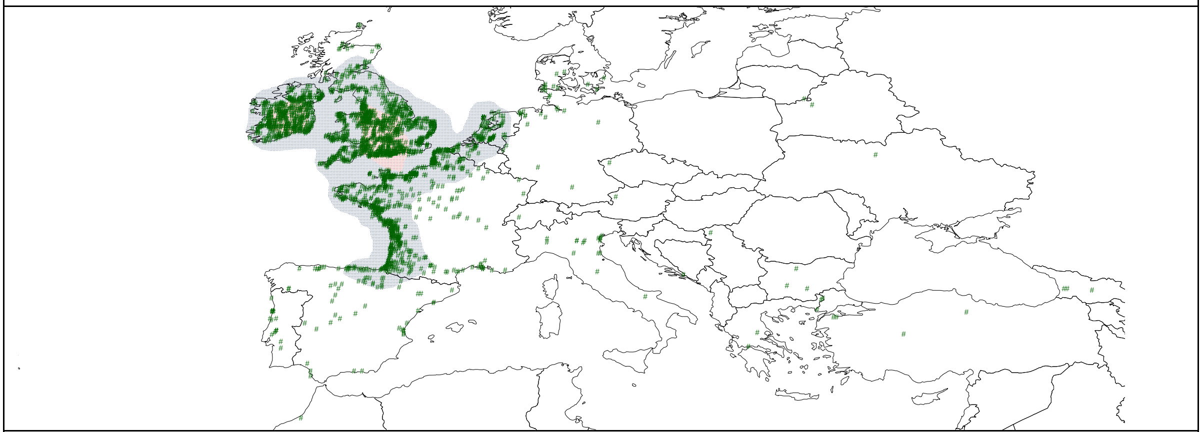


Figure 3.3.6.1 The number of directional movements of Eurasian Teal to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 7595

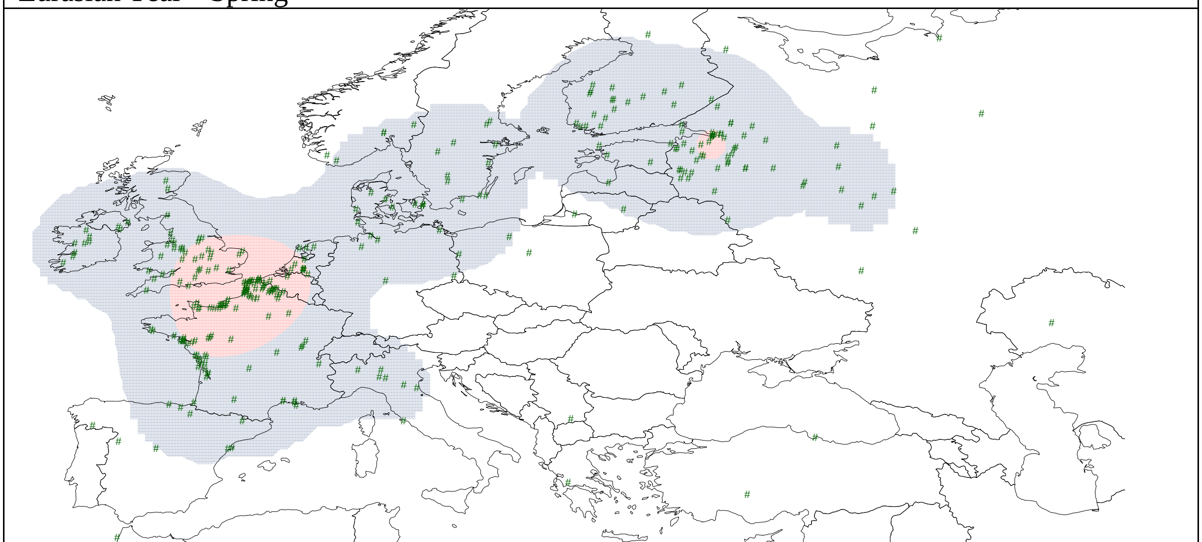
Eurasian Teal - Autumn



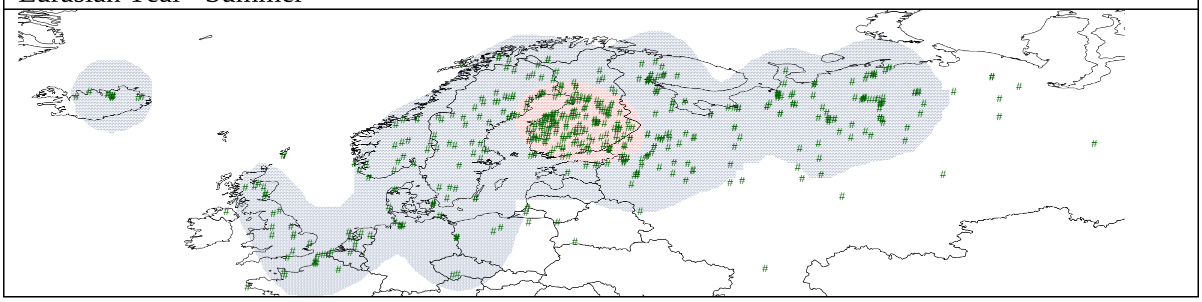
Eurasian Teal – Winter



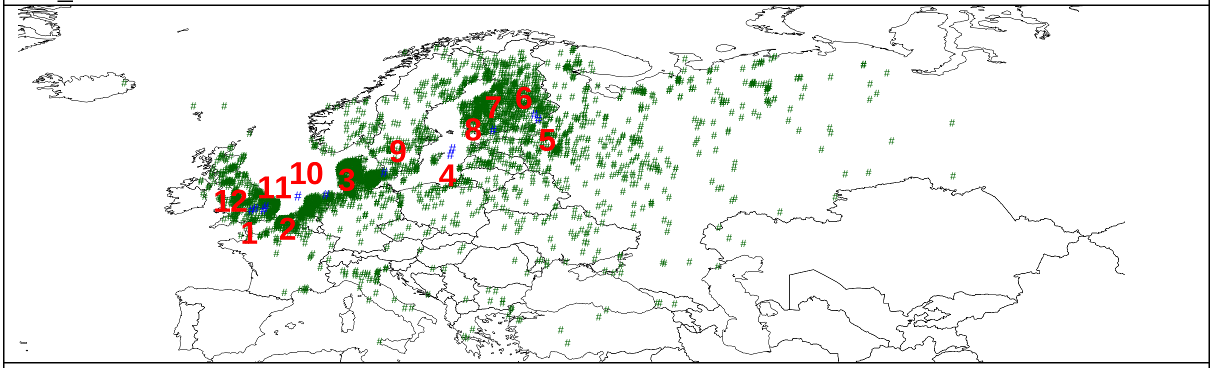
Eurasian Teal – Spring



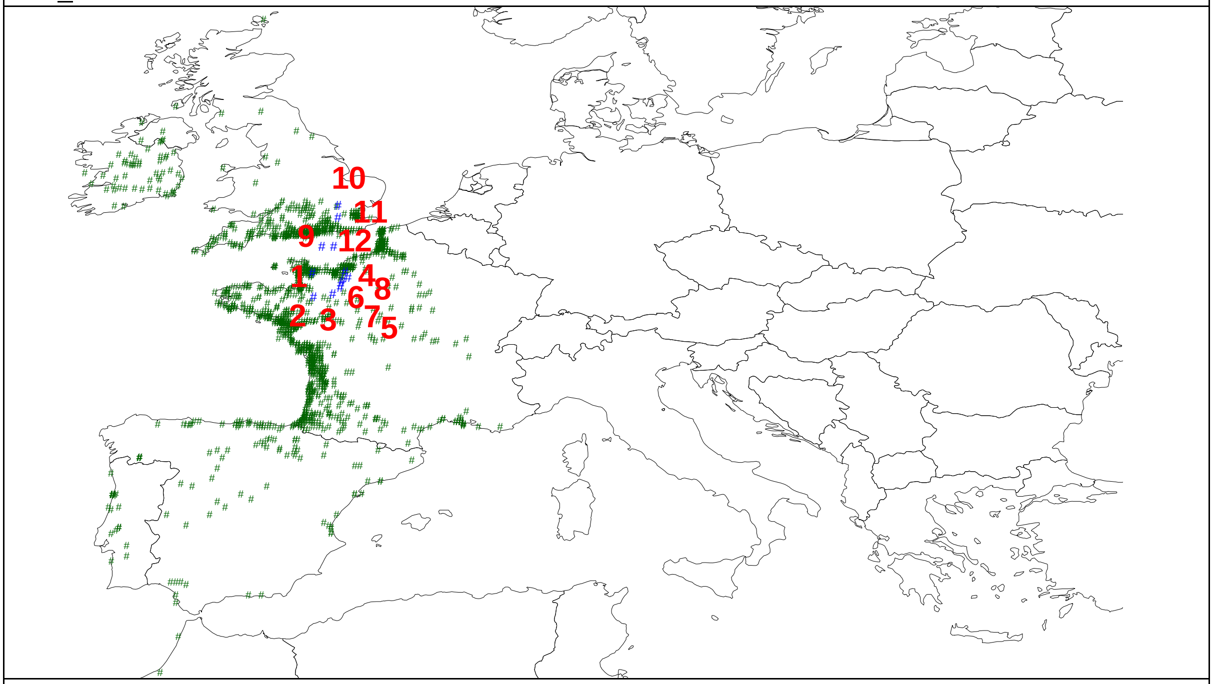
Eurasian Teal - Summer



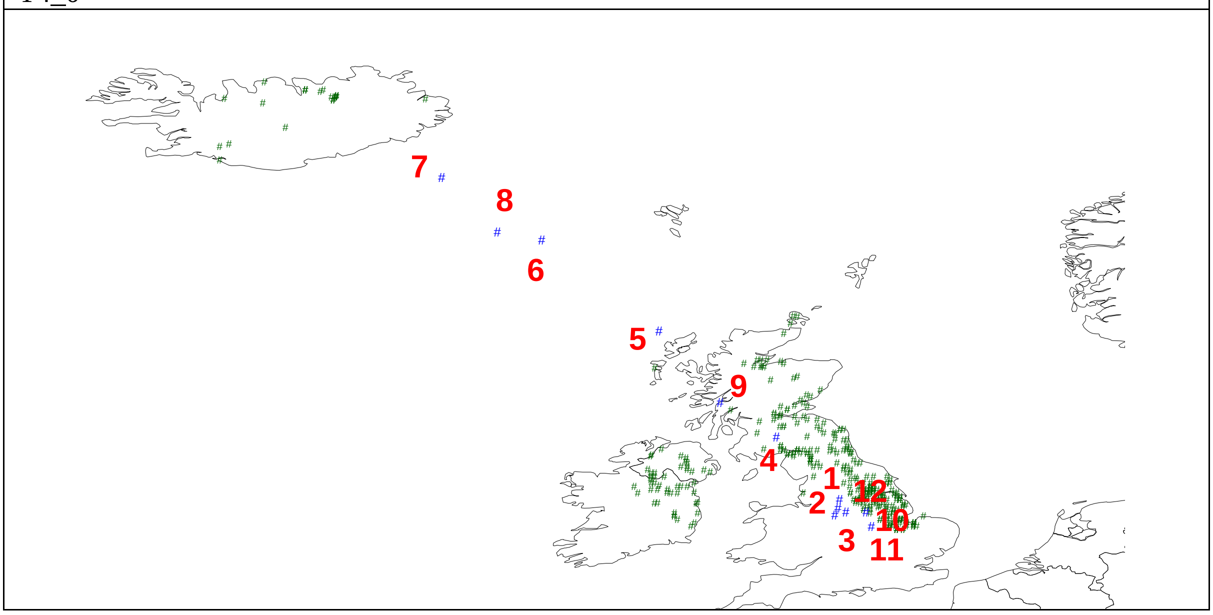
T 1_0



T 2_0



T4_0



3.3.7 Mallard *Anas platyrhynchos*

Mallard are the most widespread duck in B&I. Apart from resident birds, numbers are swelled by migrants from continental Europe in winter. The birds are from north-west Europe, including southern Norway, Sweden and Finland to western Russia and south to Poland, Germany, the Low Countries and northern France (summer distribution maps). Most recoveries are from the autumn and reflect the summer distribution as birds move into their winter quarters. In winter, birds ringed or found in B&I are generally from a limited area stretching from the Low Countries through to the Atlantic coast of France.

The analysis identified 4 main directional movements. The first (MA1_0 and MA1_1) describes the movement of birds from wintering areas in B&I to breeding areas in north-west Europe, across to western Russia. There are two extreme easterly recoveries in central Russia (MA 1_0). Although immigrants can be found in B&I across the autumn and winter months, most birds are in B&I for a relatively short time during December, January and February before moving back to the continent in March. The second movement in a south-west direction also reflects birds leaving B&I in winter to breed in north-eastern France (MA2_0). The third type of movement (MA 3_0) is more difficult to interpret and probably reflects recoveries of birds in continental Europe in autumn, summer and winter. The fourth type are within B&I movements and show no particular temporal pattern (MA4_0)

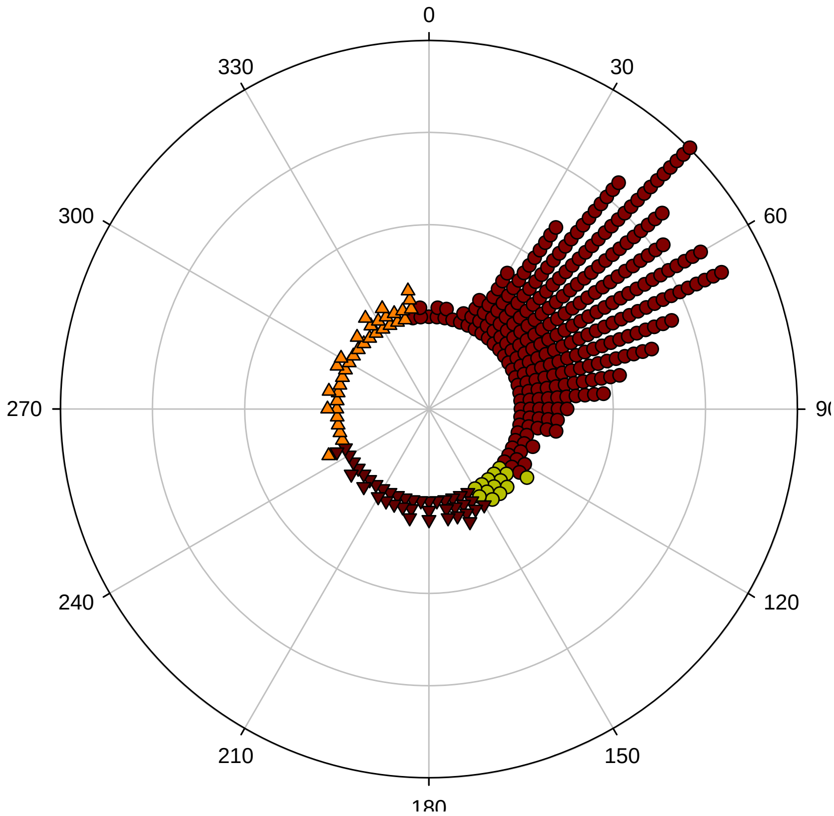
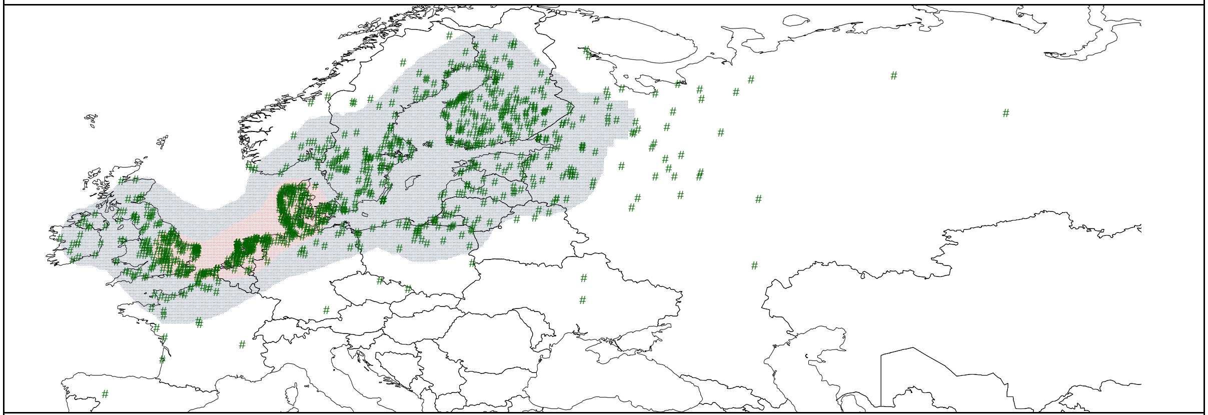
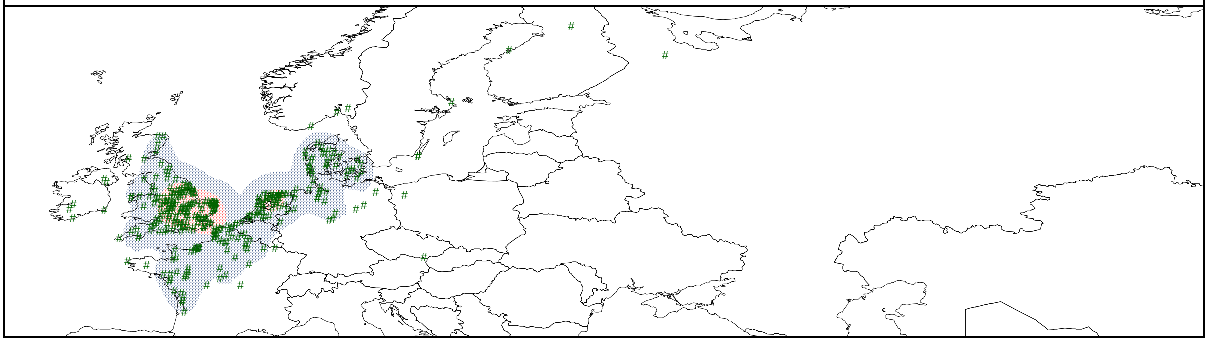


Figure 3.3.7.1 The number of directional movements of Mallard to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 4432

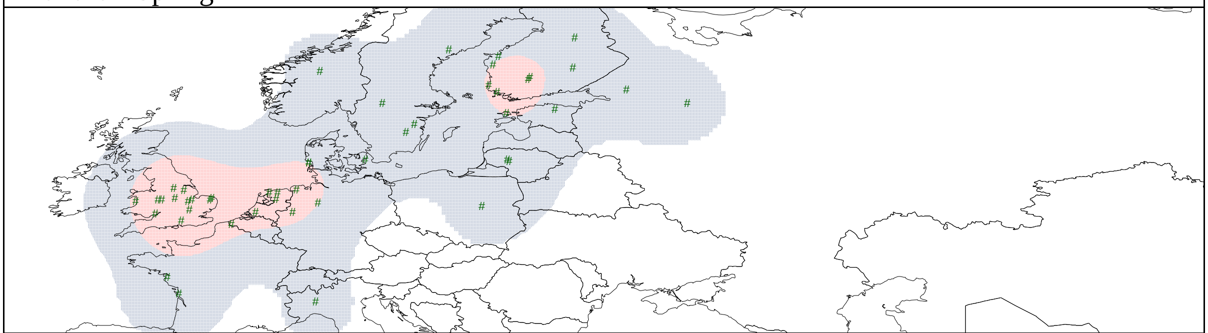
Mallard - Autumn



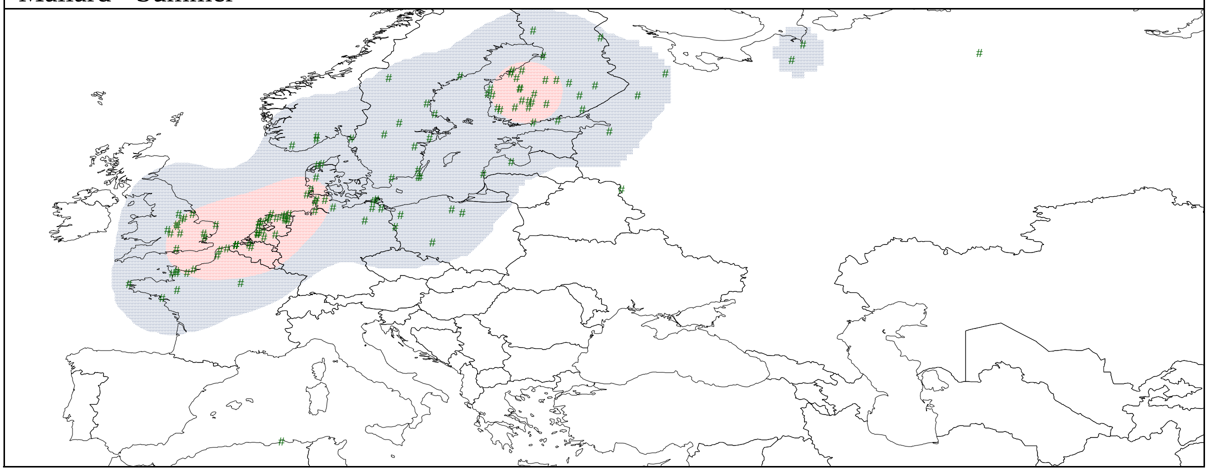
Mallard - Winter

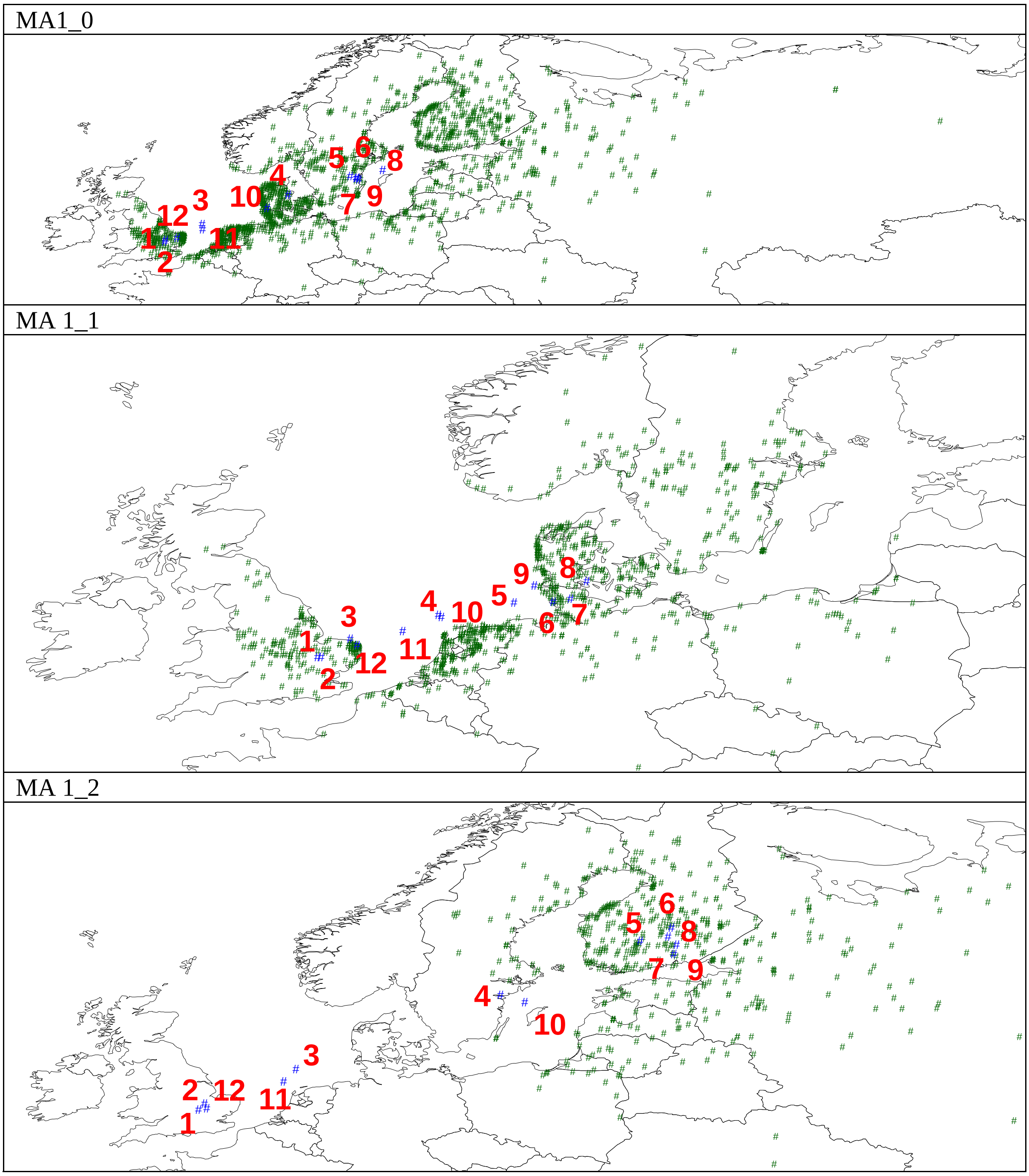


Mallard - Spring

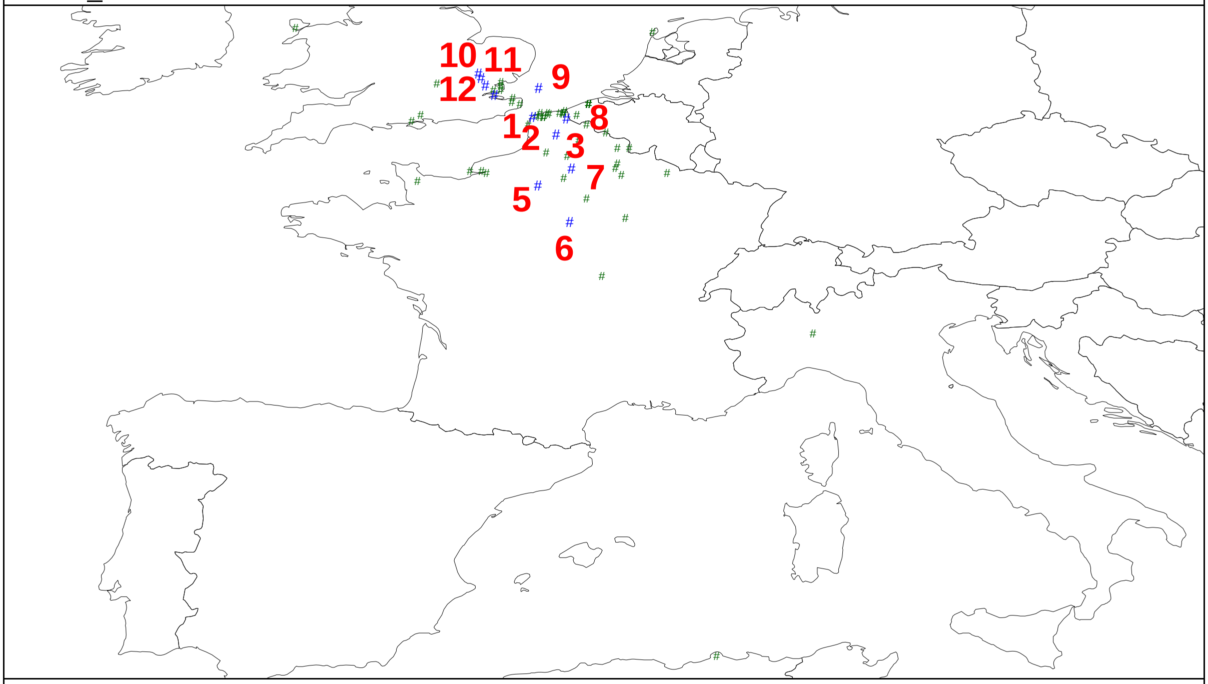


Mallard - Summer

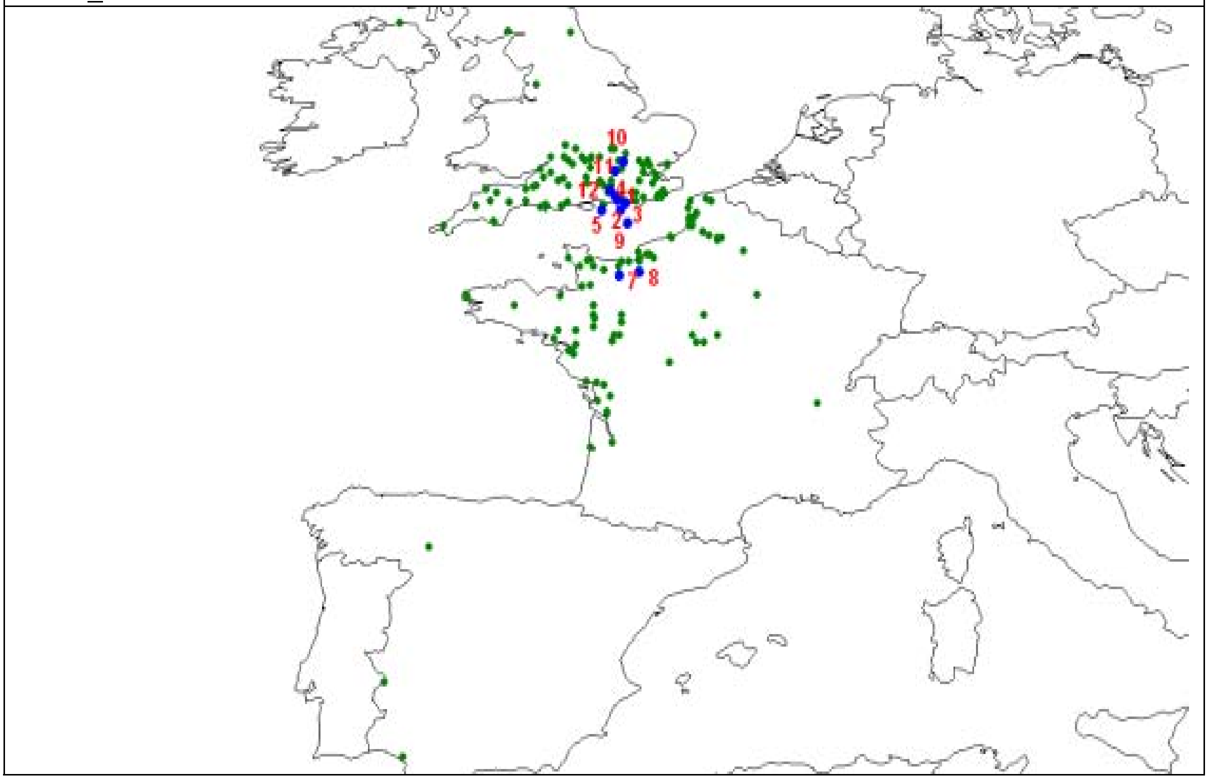



MA1_0
MA 1_1
MA 1_2

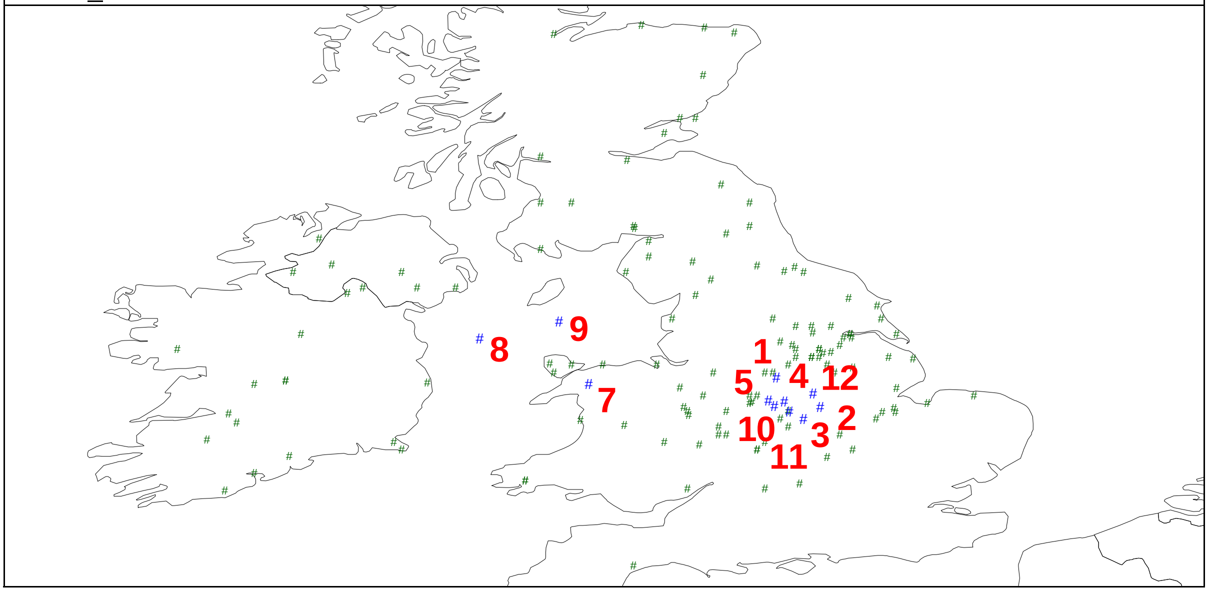
MA 2_0



MA 3_0



MA 4_0



3.3.8 Northern Pintail *Anas acuta*

The distribution of the Northern Pintail covers northern and temperate regions of Europe, Asia and North America occurring from the European Arctic to c. 40°N. Summer recoveries show that the birds visiting B&I in winter are predominantly from the Fenno-Scandinavian and west and central Siberian population, and also from breeding areas in Iceland. In autumn, it appears from the recoveries that birds take a narrow route through the Baltic States and along the North Sea coasts of France and the Low Countries to B&I. In winter birds are concentrated around B&I, the Low Countries and northern and eastern France, with a few recoveries as far as southern Spain.

The first directional movement (PT 1_0) shows the movement of birds breeding in Fenno Scandinavia and west and central Siberia moving through the Baltic in spring and autumn to wintering areas in the UK. They remain from November to February before moving back in March. The remainder provide an indication of the routes of migrants to and from B&I (via France & the Low Countries PT 2_1) and winter movements to the Atlantic coast of France and Mediterranean coast of Spain (PT 3_1, PT 3_2 & PT4 (not shown due to sparseness of data). The final movement type (PT 7_0) documents the movement of birds breeding in Iceland moving into B&I for the winter months, October to March. No recoveries were available for April and May and the first recoveries appear in Iceland in June. Birds first appear back in B&I in September.

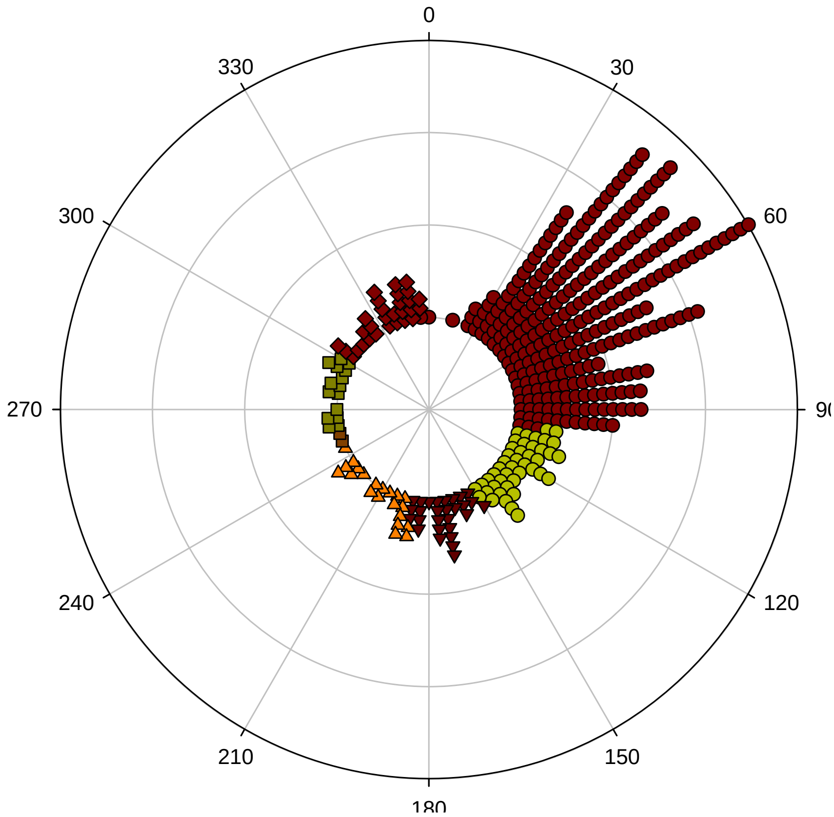
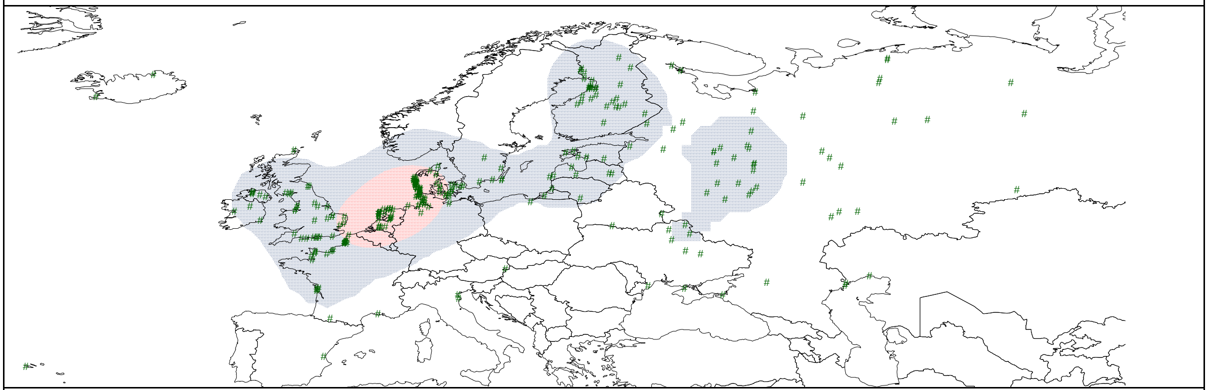
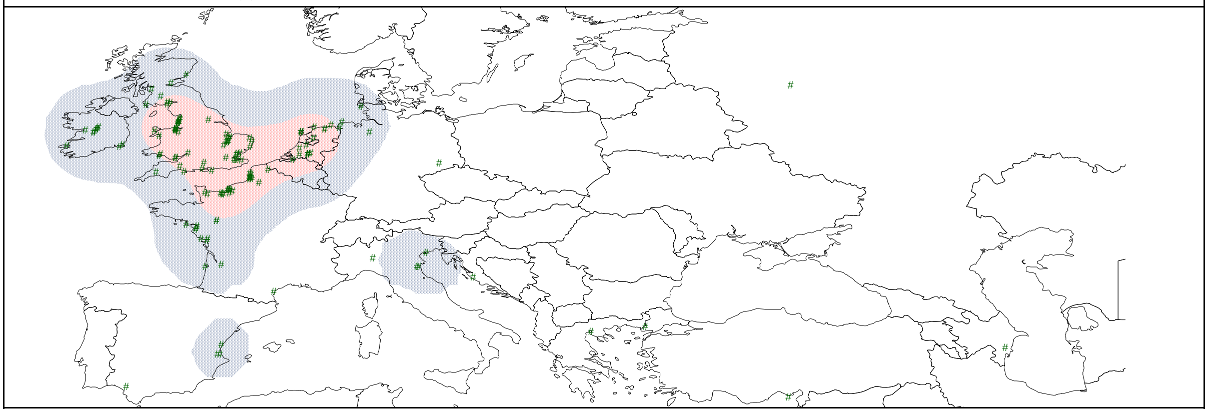


Figure 3.3.8.1 The number of directional movements of Northern Pintail to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 649

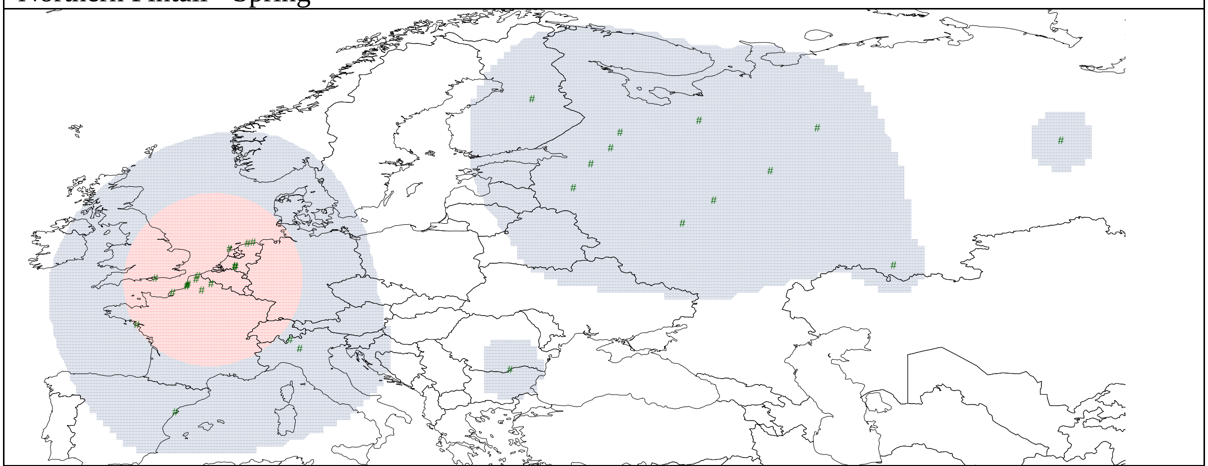
Northern Pintail - Autumn



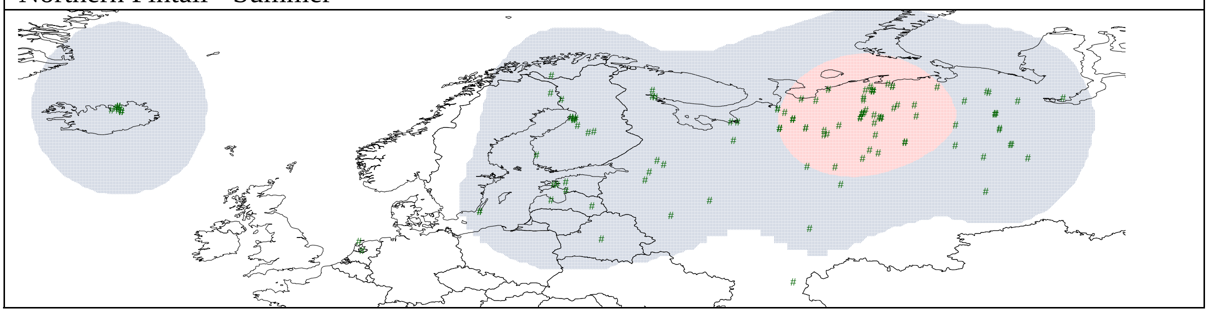
Northern Pintail - Winter



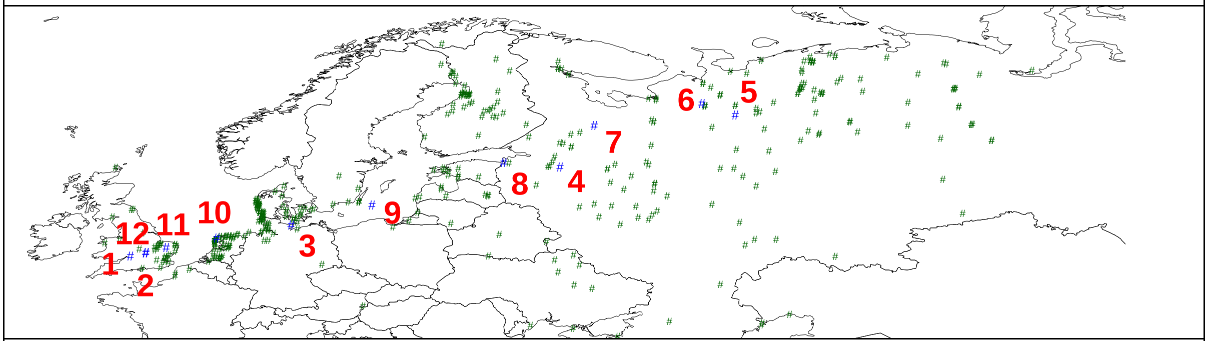
Northern Pintail - Spring



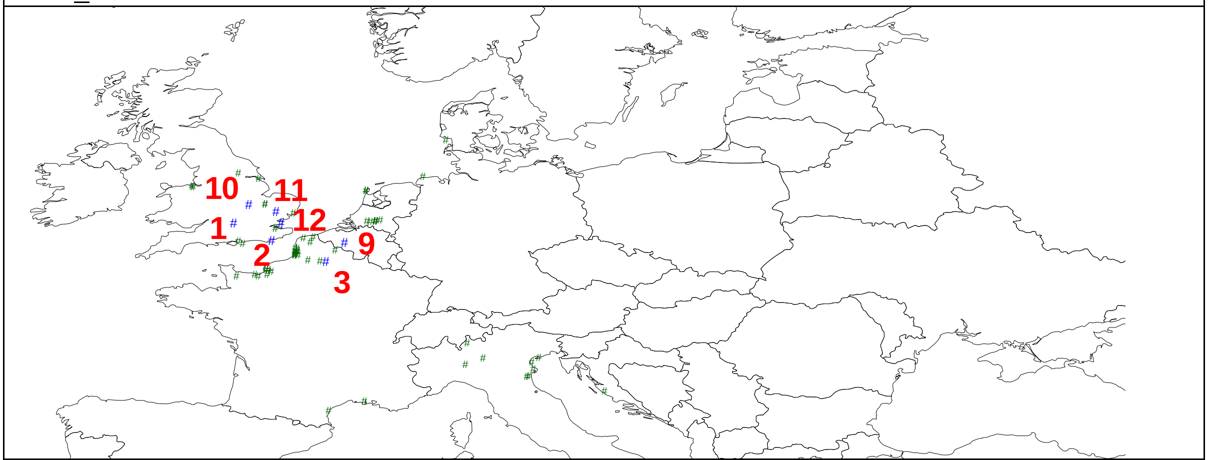
Northern Pintail - Summer



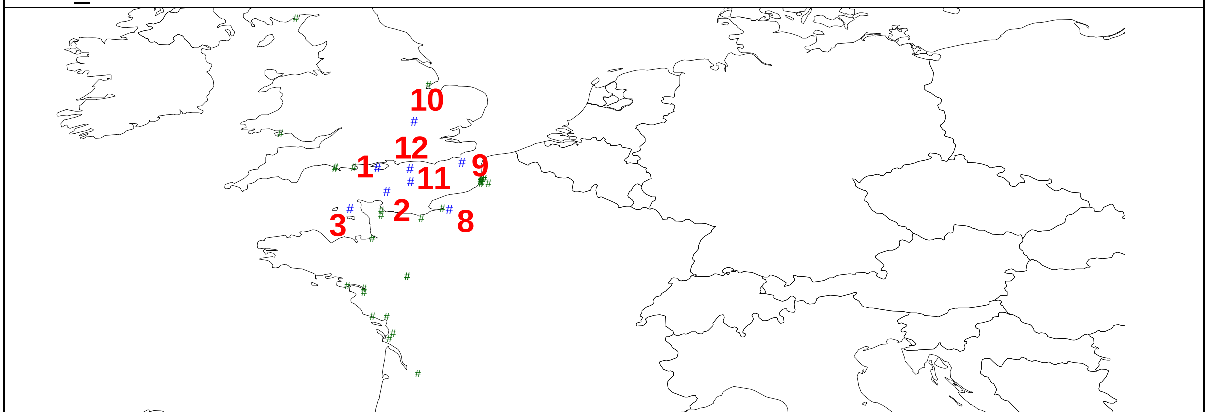
PT 1



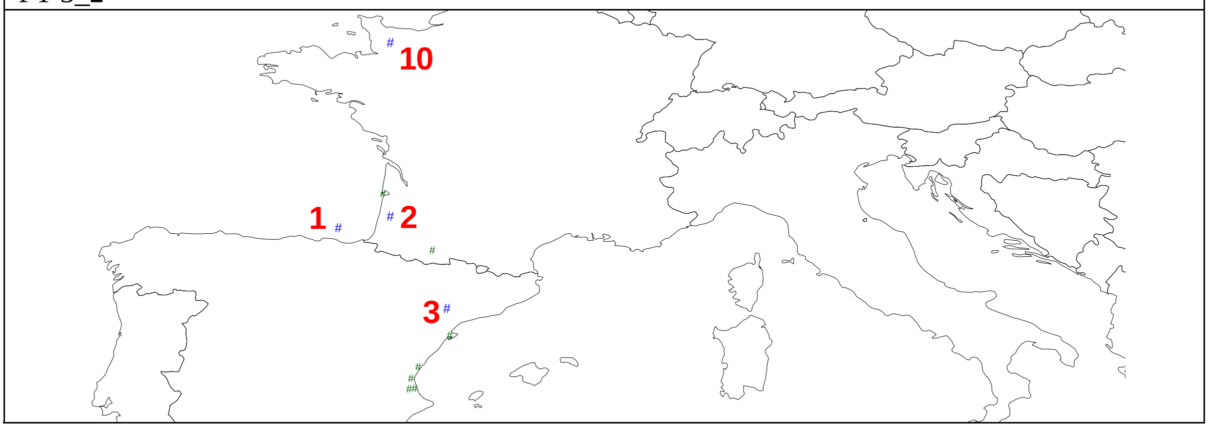
PT 2_1



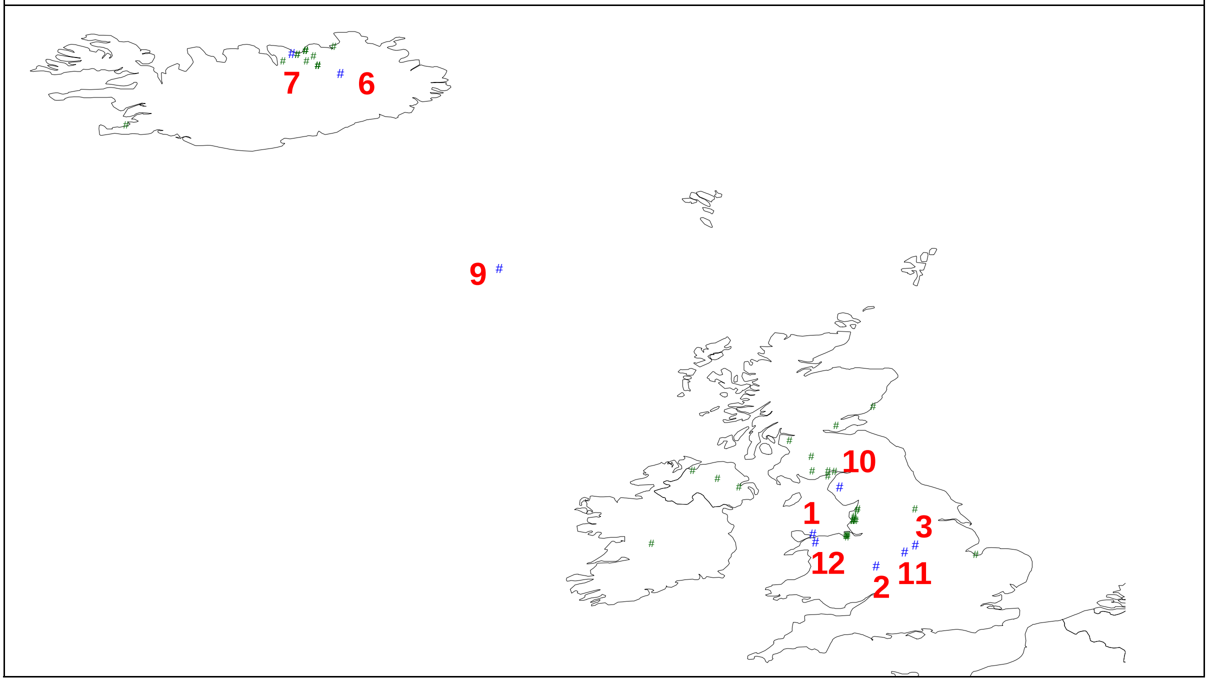
PT 3_1



PT 3_2



PT 7



3.3.9 Common Pochard *Aythya ferina*

Common Pochard is a Palaearctic diving duck breeding from the Lake Baikal region in the east to Iceland, Ireland and Spain in the west, mostly between 45 and 60°N. Isolated populations occur in northwest Africa and Turkey.

The recovery maps reflect this large breeding range. Common Pochard are a broad front migrant. Summer recoveries are concentrated in central and eastern Europe and just to the west of the Urals, partly in the Ob river basin. Easterly breeding birds move west in autumn and recoveries are spread over their wider area from the Asian part of Eurasia west to Ireland. In winter, B&I birds are generally restricted to B&I, France, the Low Countries and Germany. A small hotspot of recoveries is found on the Black Sea coast and may represent a change in wintering areas, or a moult migration.

Five main directional movements were identified. The first three types of migratory movement show the birds breeding across a large part of central, western and eastern Europe to areas as far west as the Urals and moving to winter in the UK. The first directional movement identified is essentially an east-west movement. Two clusters of points were identified and clearly show that birds from Germany to Russia (PO 1_1) and western and central Russia (PO 1_2) undertake a movement to B&I in winter. The shorter distance migrants occur in B&I in November and remain until February. In March they move through the Low Countries and northern Germany and reach the breeding grounds in April and May. They then remain there until August and then return to B&I in winter. The longer distance migrants essentially follow the same route but there is an indication that they arrive later in B&I in December and reach the breeding areas in May, where they remain until September, presumably moulting near the breeding areas.

The second directional movement identified is that of birds found in summer in B&I and the Low Countries (2_1), Poland and the Czech Republic (2_2). The movement of birds to the Black Sea region (2_3) does not include birds being recovered in May and July and possibly relates to a moult migration. In the case of 2_2 and 2_3, birds are mostly recovered in B&I in December to February.

The third directional movement refers to birds breeding in northern France (3_1) and central eastern France and Switzerland (3_2). These have tended to be found in B&I in January-March.

The remaining movements are essentially within and between winter movements. Movement type 4 describes a few recoveries that were in a southerly direction to France (4_1) and to Spain (4_2). The westerly movements of 5_1 and 5_2 reflect redistribution within B&I and most likely refer to birds passing through B&I after being in Ireland in autumn.

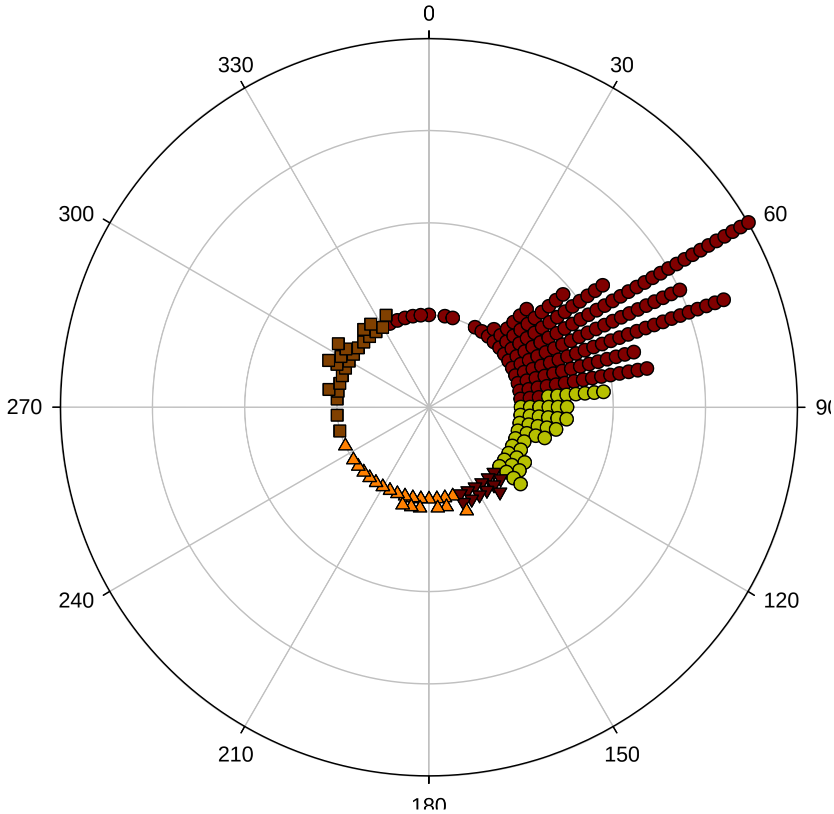
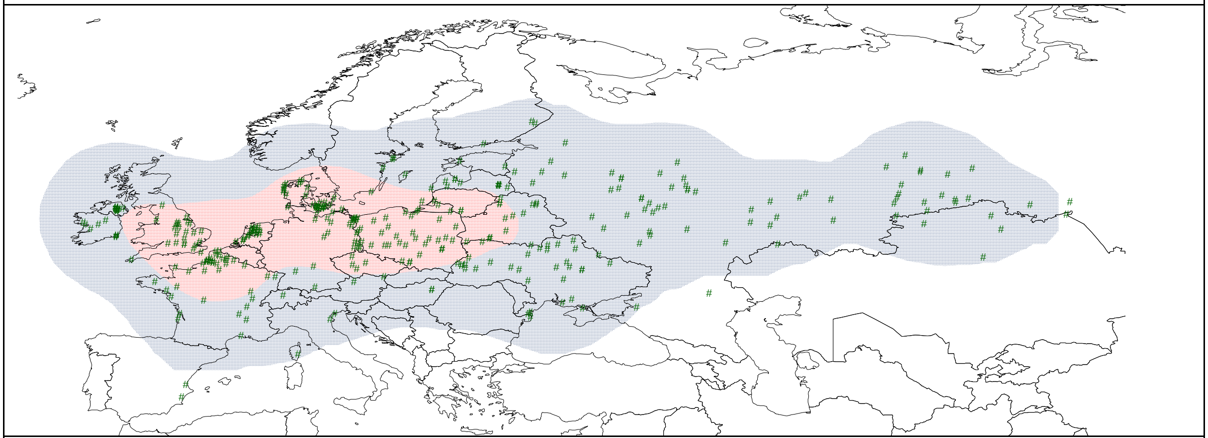
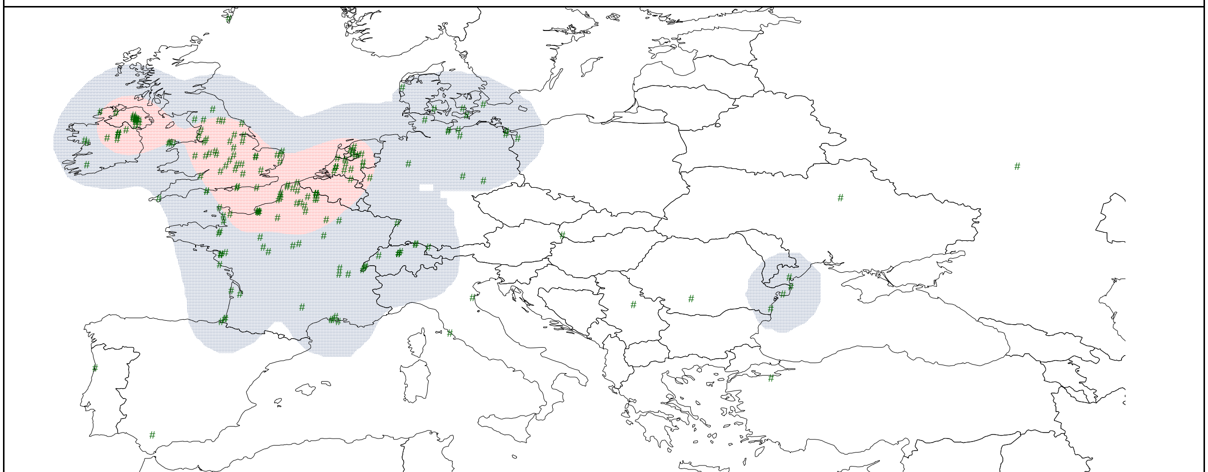


Figure 3.3.9.1 The number of directional movements of Common Pochard to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 989

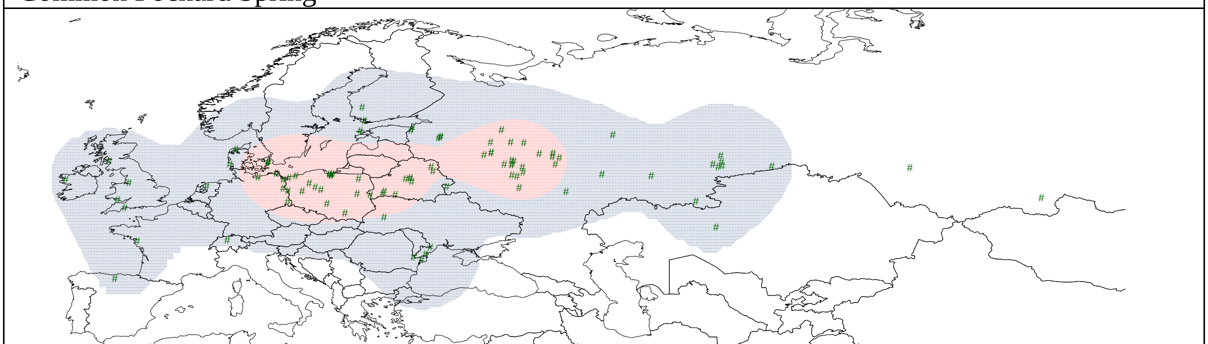
Common Pochard Autumn



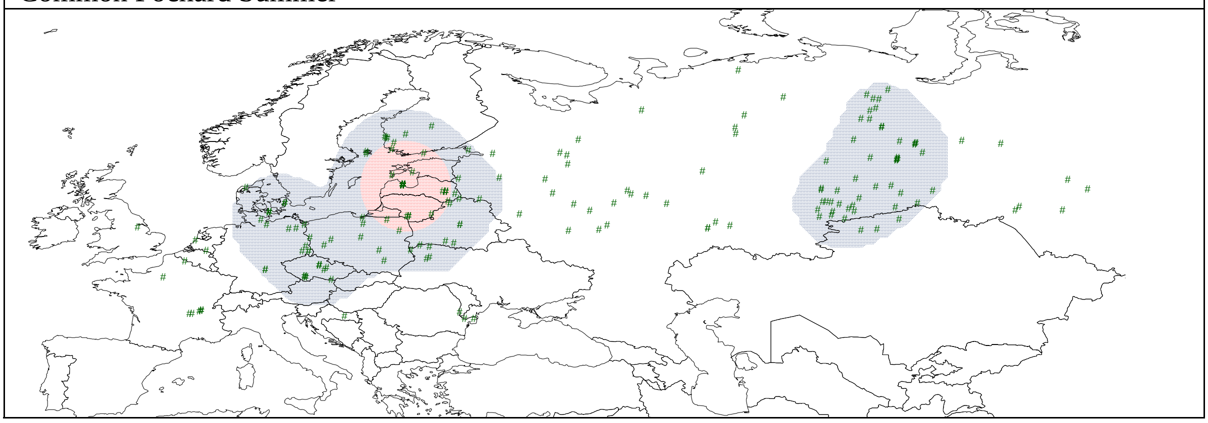
Common Pochard Winter



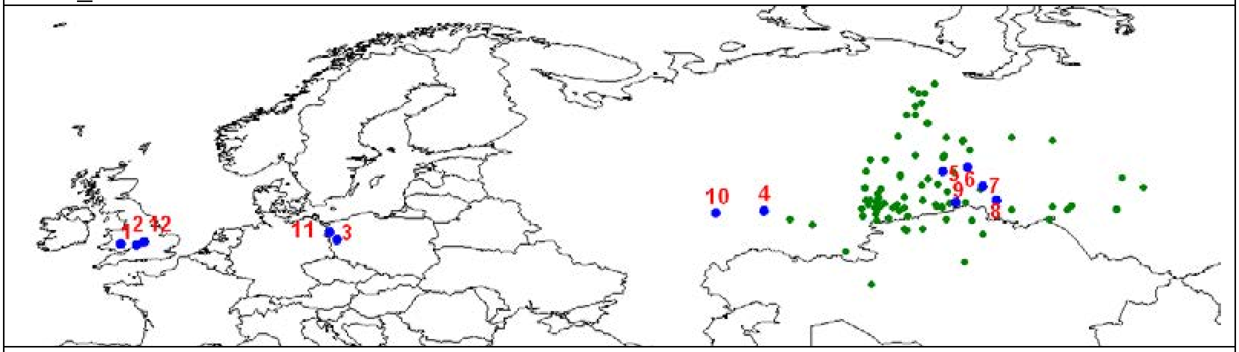
Common Pochard Spring



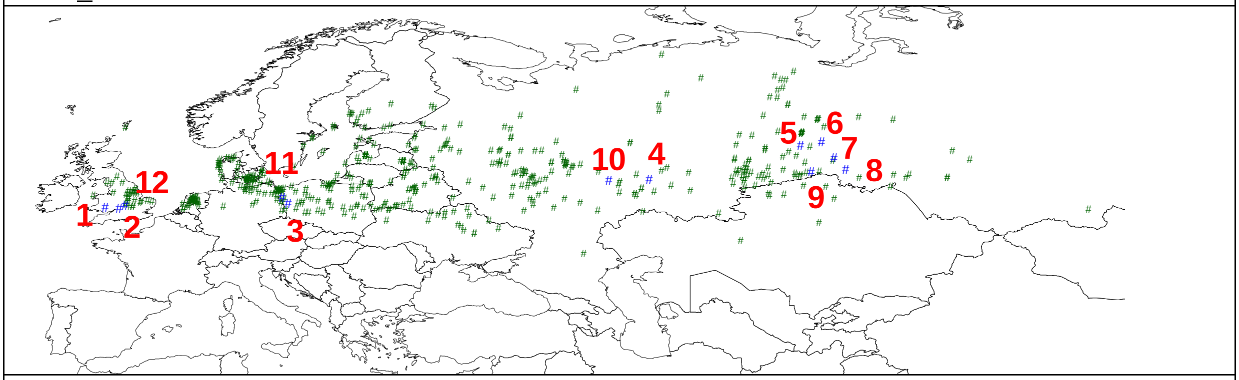
Common Pochard Summer



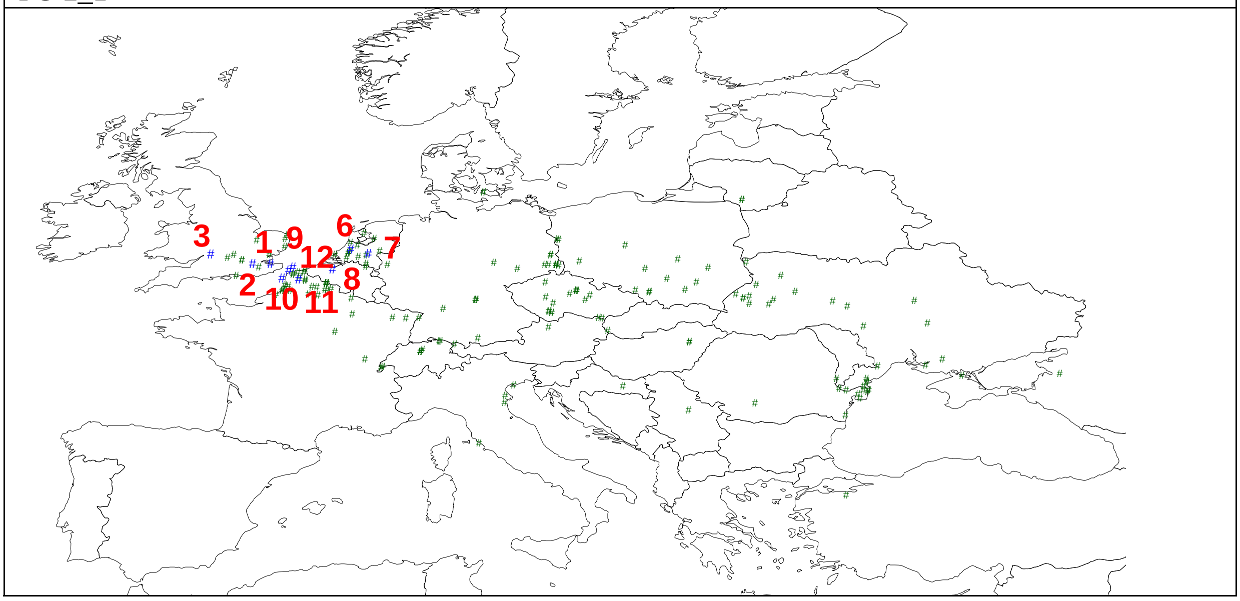
PO 1_1



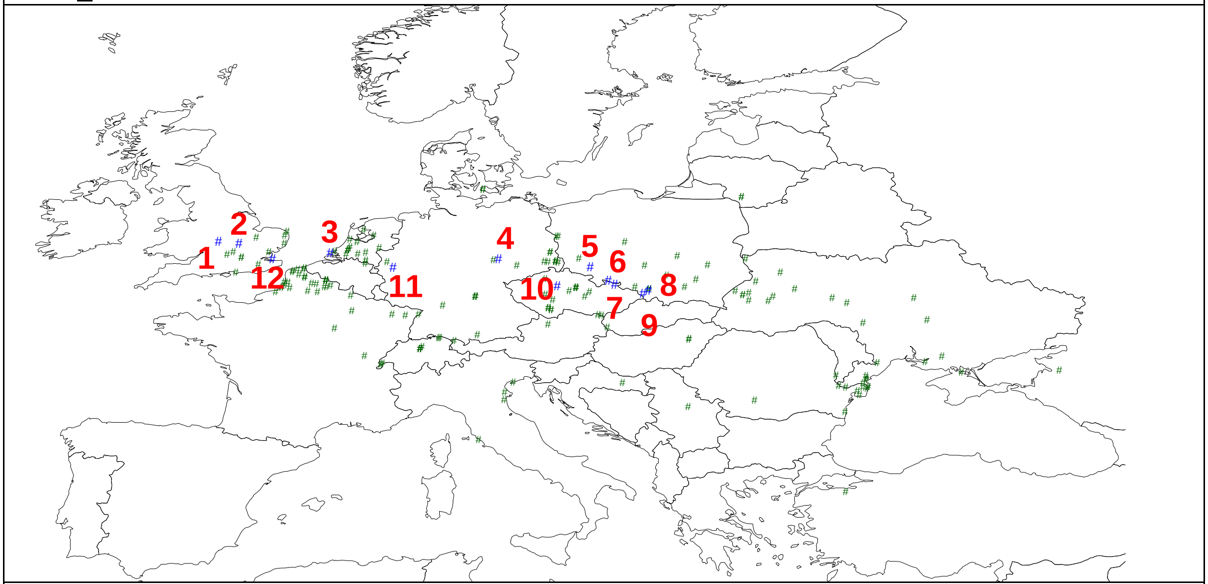
PO 1_2



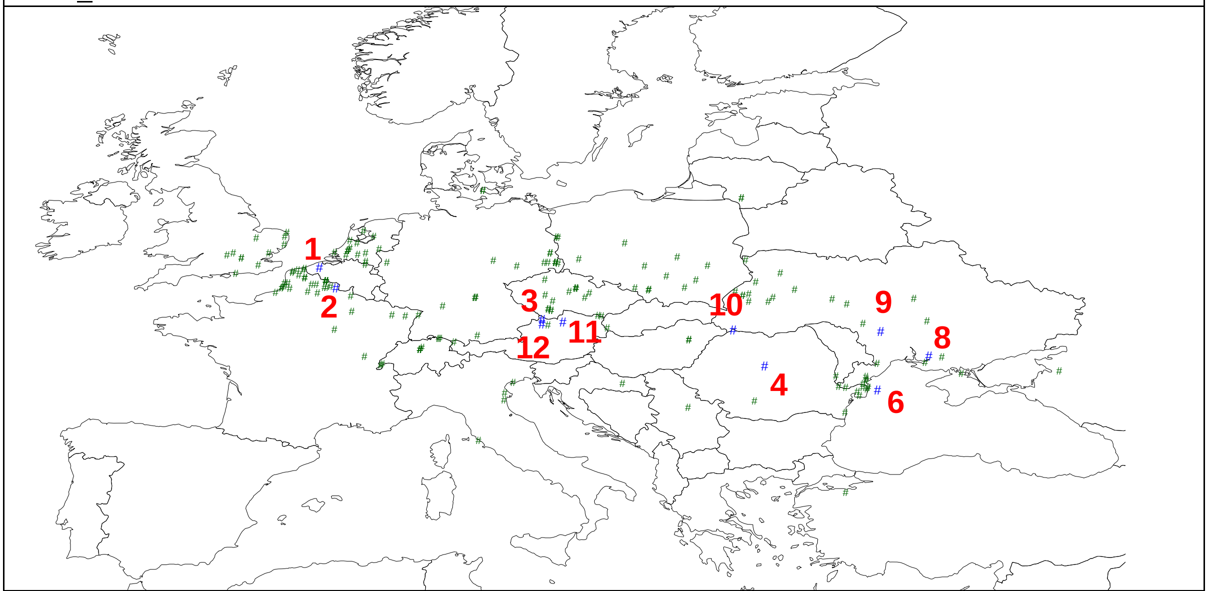
PO 2_1



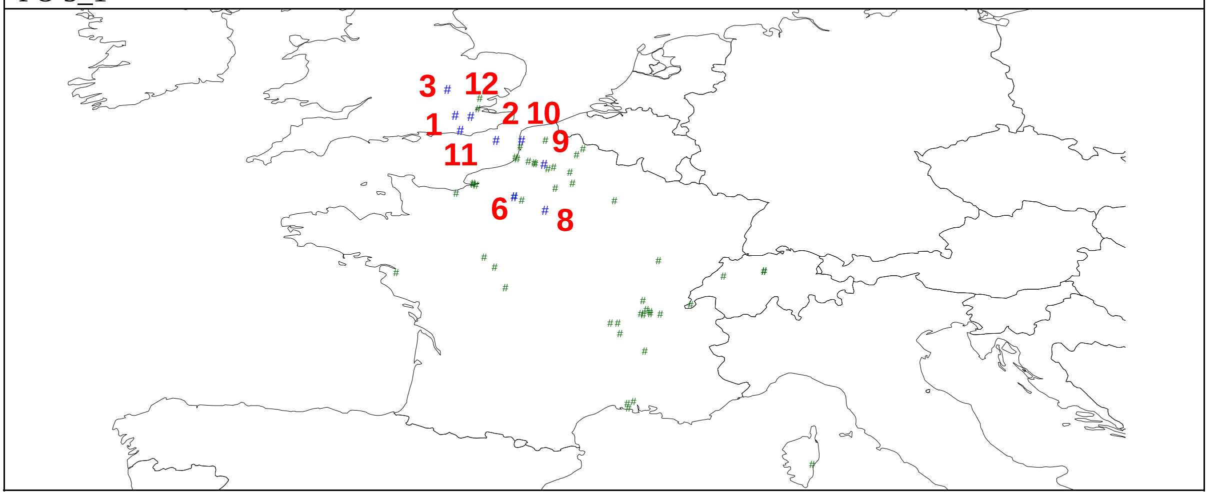
PO 2_2



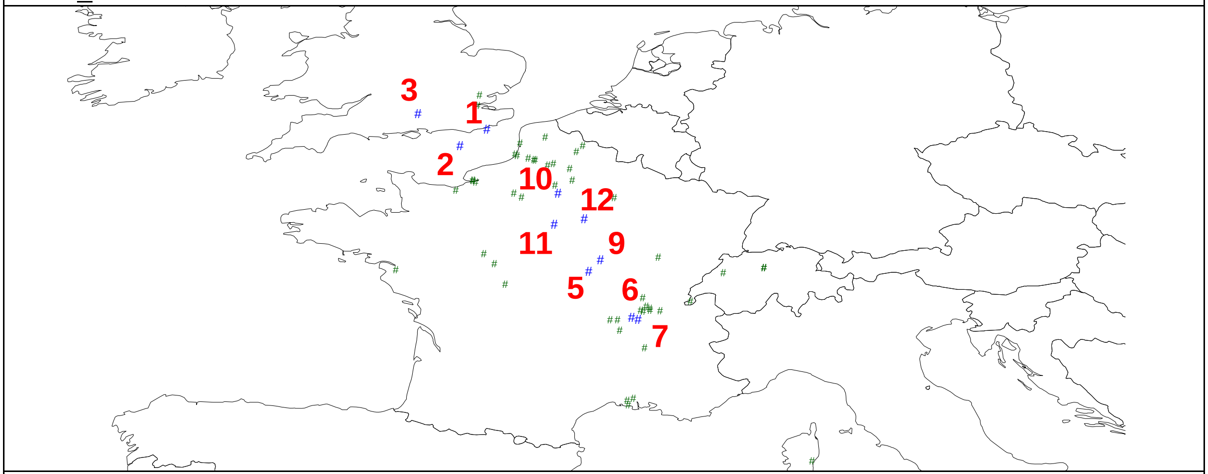
PO 2_3



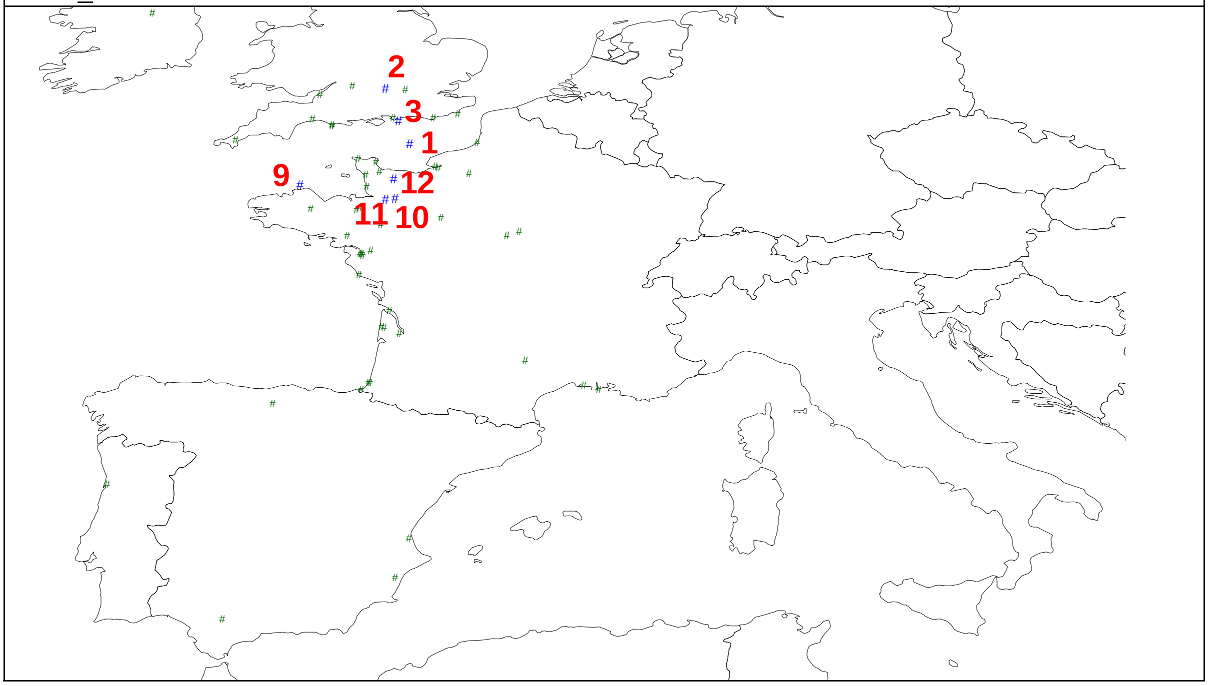
PO 3_1



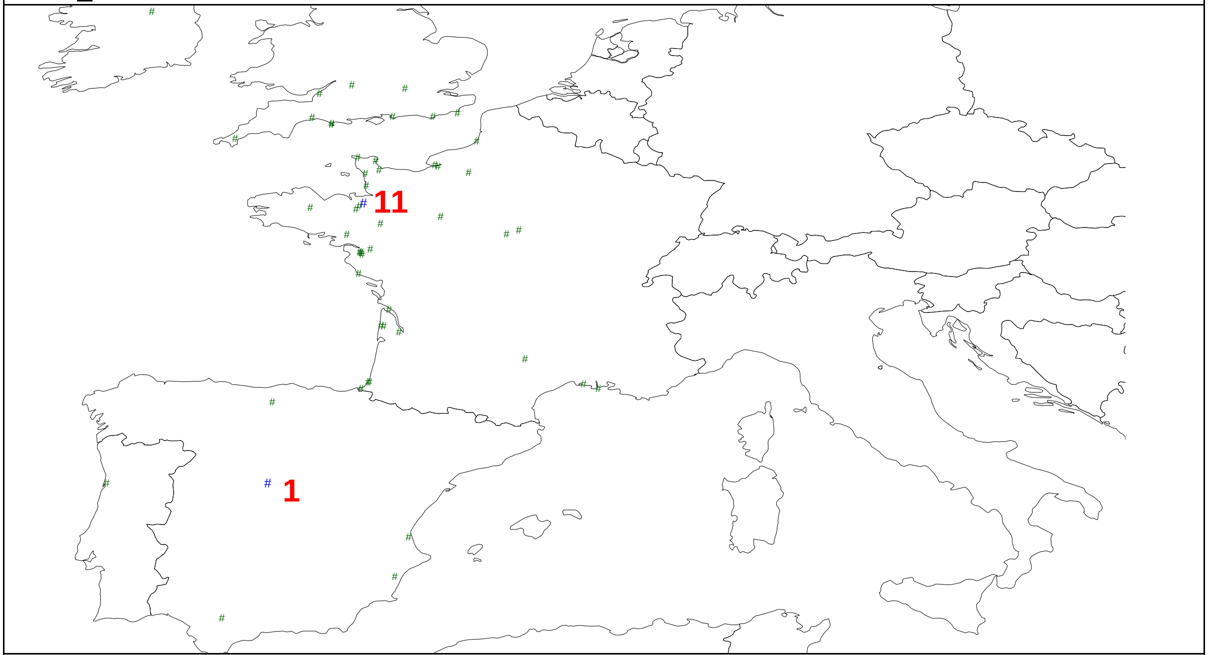
PO 3_2



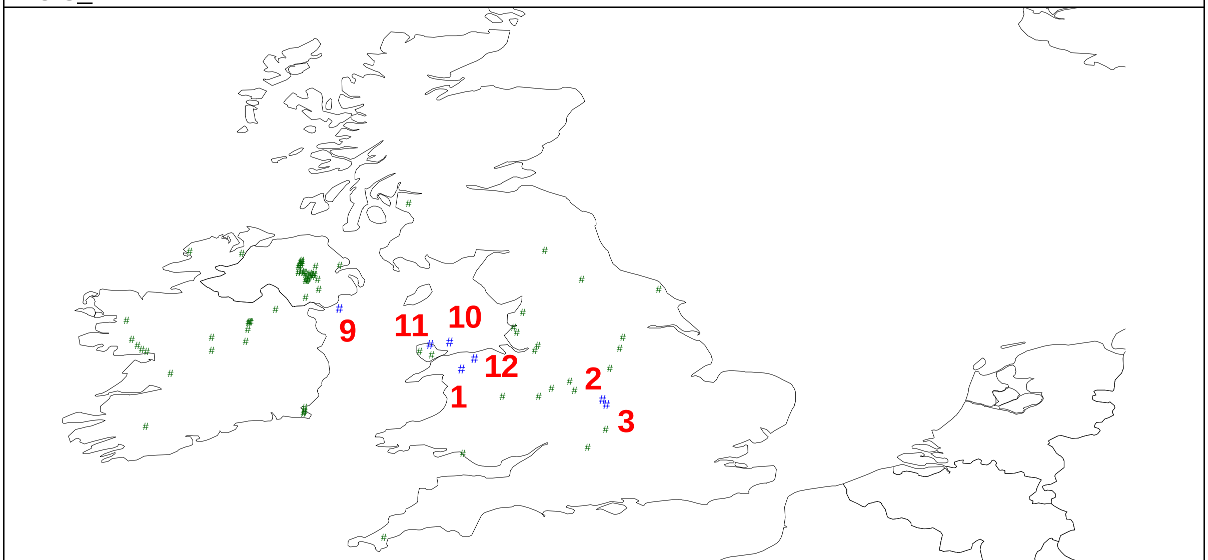
PO 4_1



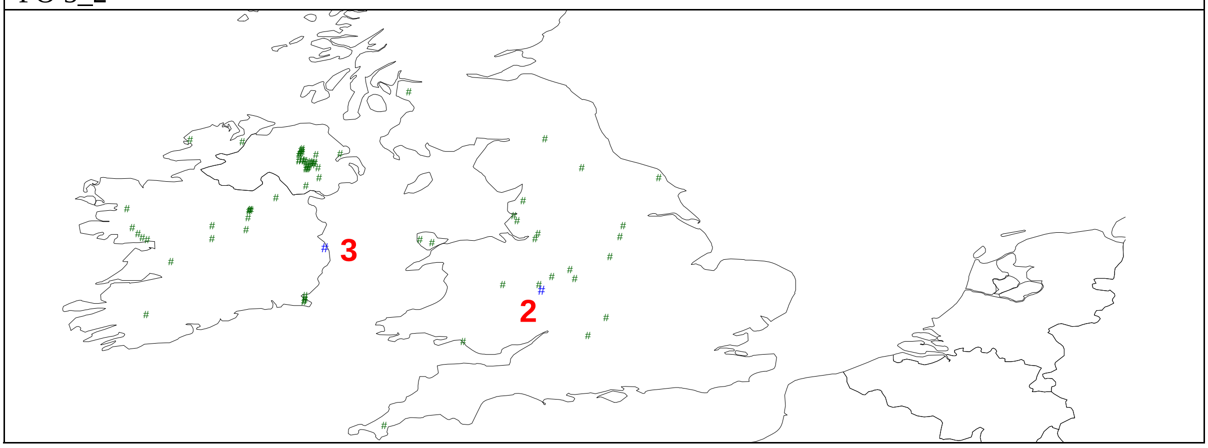
PO 4_2



PO 5_1



PO 5_2



3.3.10 Tufted Duck *Aythya fuligula*

Tufted Duck are a trans-Palaearctic breeding species, nesting in the boreal, temperate and steppe climatic zones. Its extensive breeding range extends to 70° North in Norway and parts of Siberia and reaches 45°N in southern Europe, but the majority of the population is concentrated in Finland and Sweden.

The birds visiting B&I in winter are likely to be a mix of local breeders and those from continental Europe & Iceland (summer distribution map). The recoveries are spread from the base of the Yamal Peninsula and the Ob River delta in the east to Iceland in the west. In Europe, most recoveries are from Baltic States, south to Switzerland and northern France.

Five directions of movement were identified (TD1 contained no relevant data points). The first covered the extensive Scandinavian and western and central Siberian population (TD 2_0). Within this group, three clusters were identified which referred to the breeding populations in the Low Countries (TD 2_1), Scandinavia and western Siberia (TD 2_2) and central Siberia (TD 2_3). Timings of movement were similar between these groups, with most birds being in B&I for three midwinter months December, January and February. The south-easterly movement identified by TD 3_0 is slightly more difficult to interpret as the smoothed movement trajectory points are very close together, implying that there is little relationship between the month of recovery and location. The fourth type of movement shows the movement of birds breeding in B&I moving to central and southern France in winter, before returning in April and May (TD 4_1 and TD 4_2). TD 5_0 shows the south-westerly movement of birds breeding in the northern part of B&I and TD 6_0 the westerly movement of birds in southeast England into Ireland in winter.

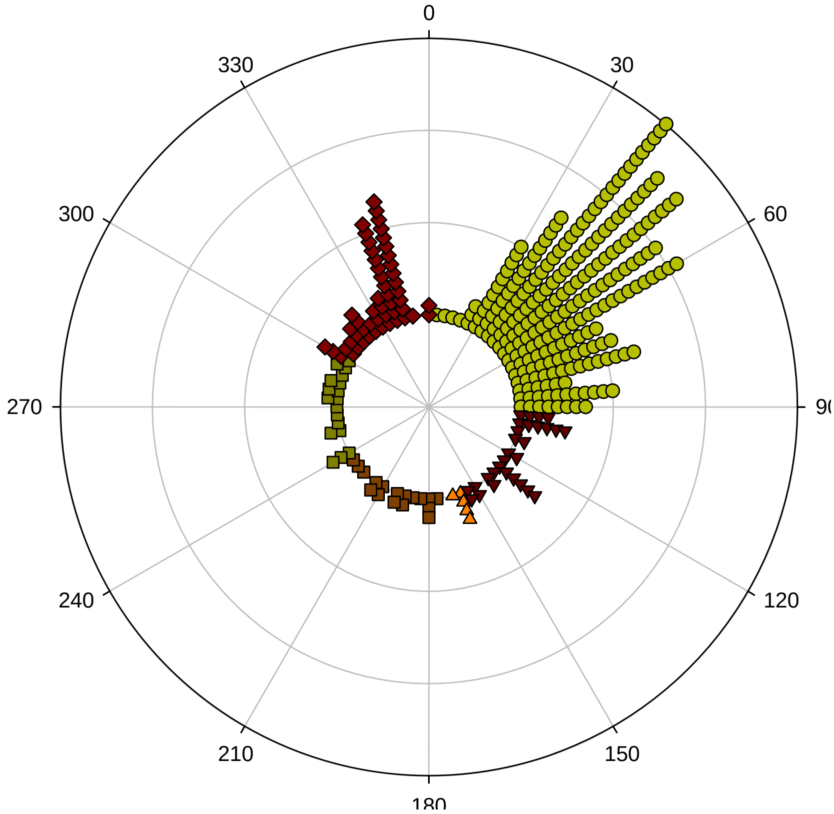
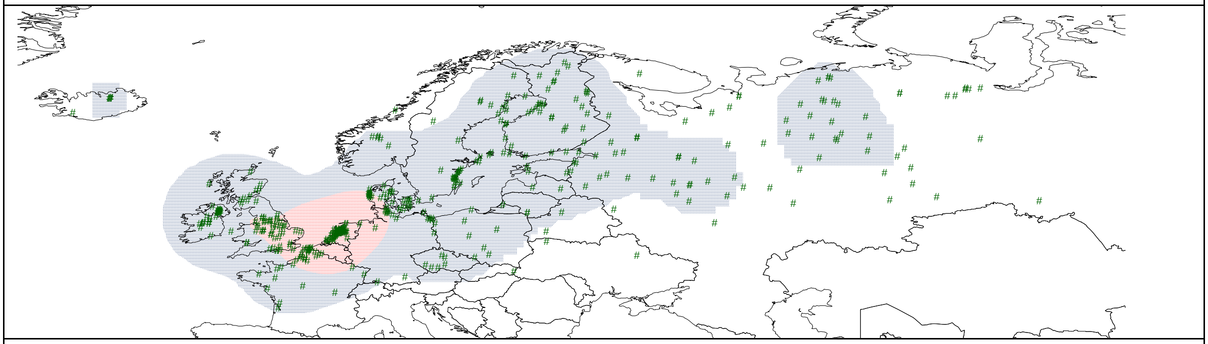
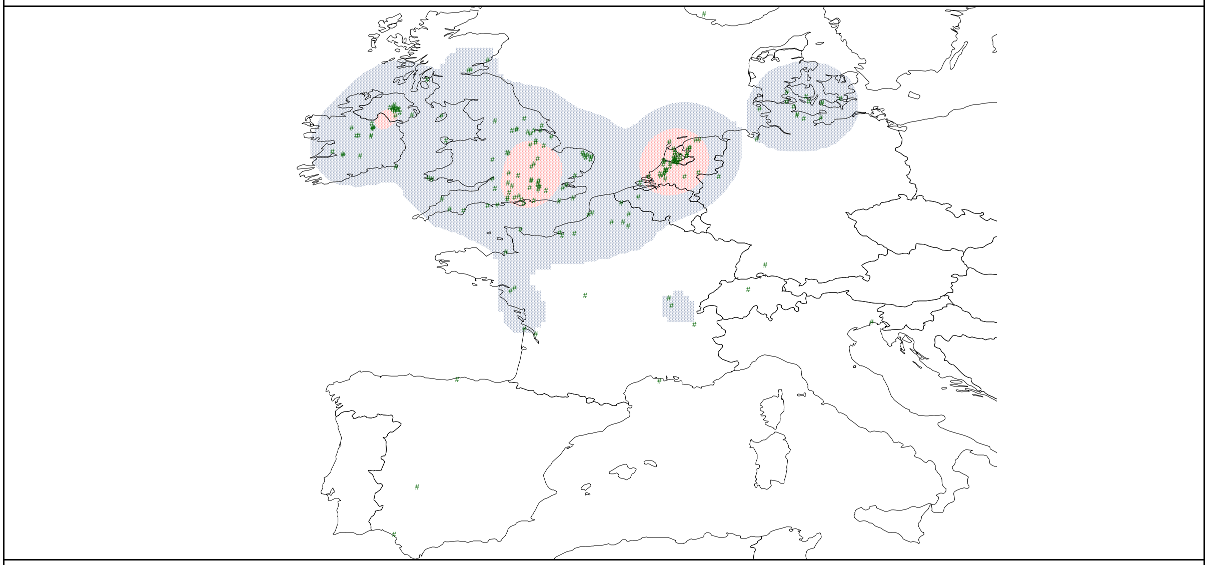


Figure 3.3.10.1 The number of directional movements of Tufted duck to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 1103

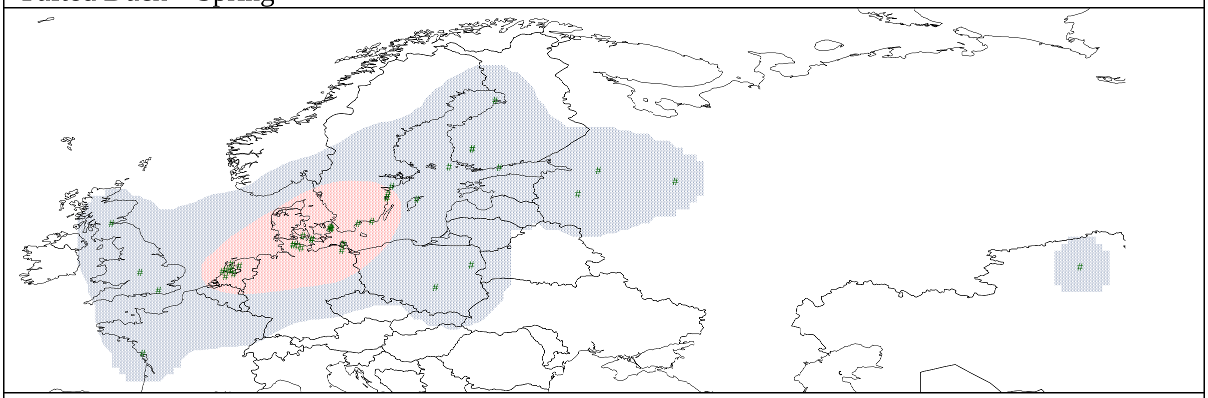
Tufted Duck – Autumn



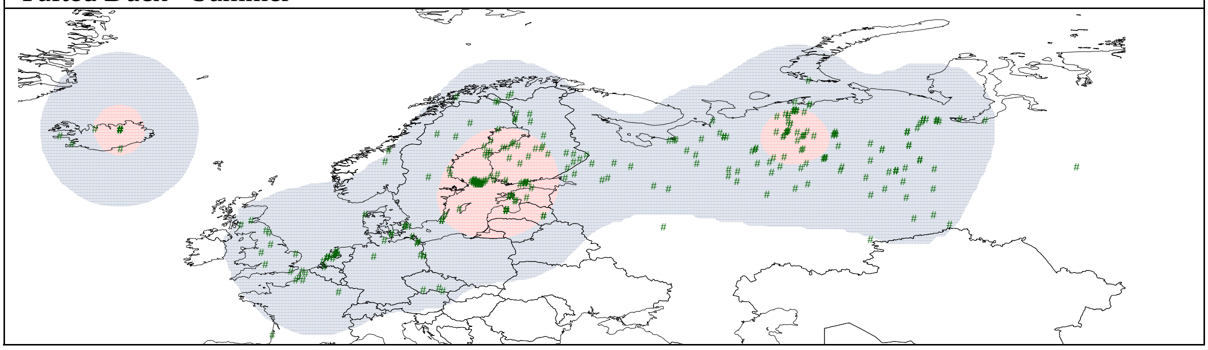
Tufted Duck – Winter



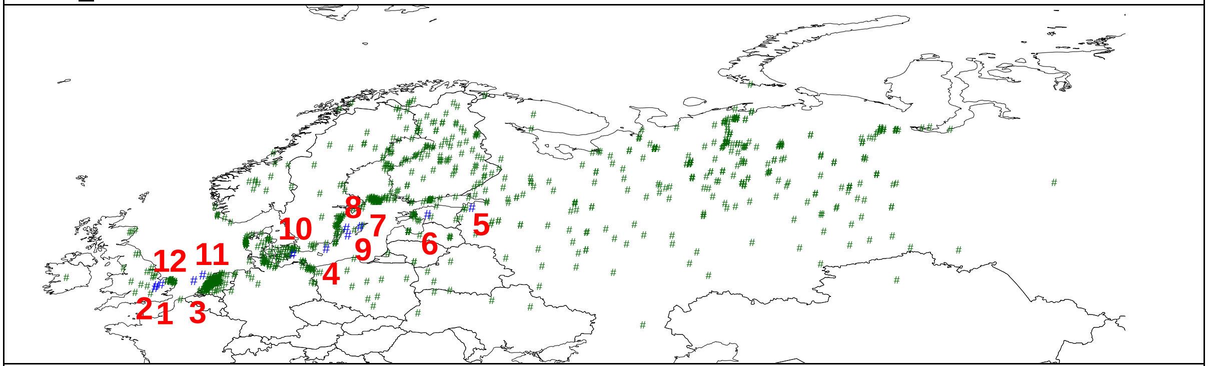
Tufted Duck – Spring



Tufted Duck - Summer

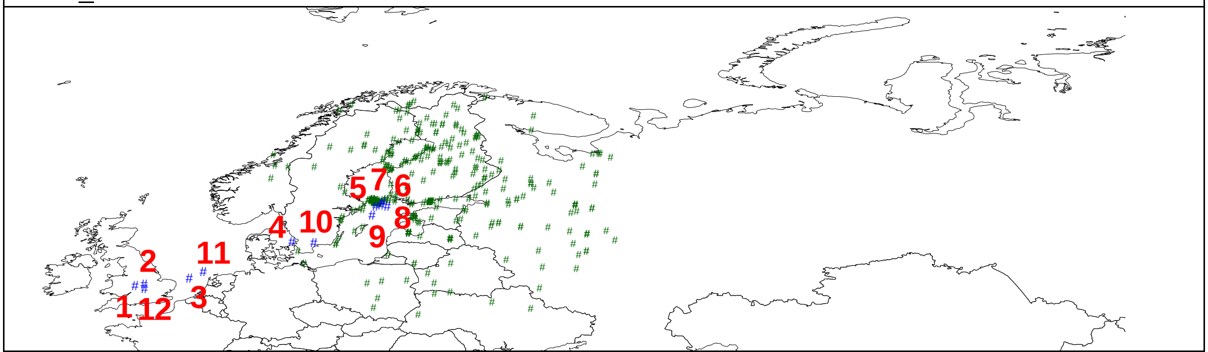


TD 2_0

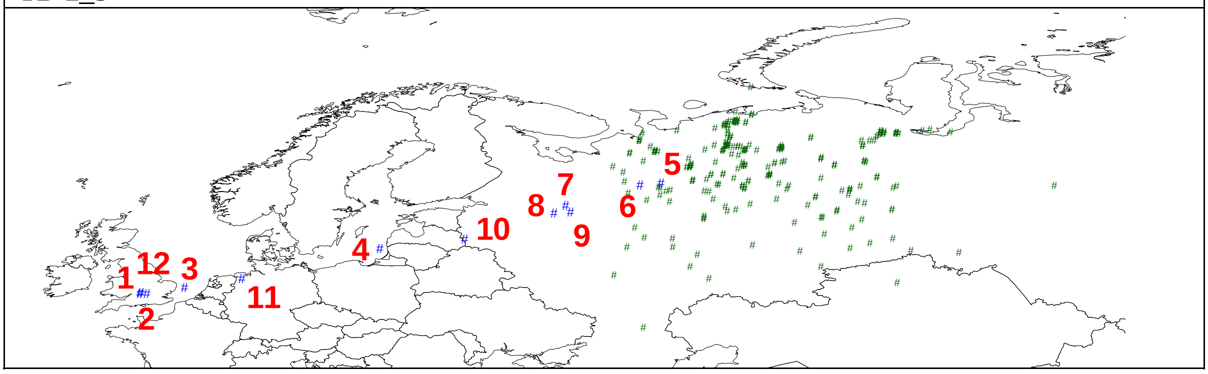


TD 2_1

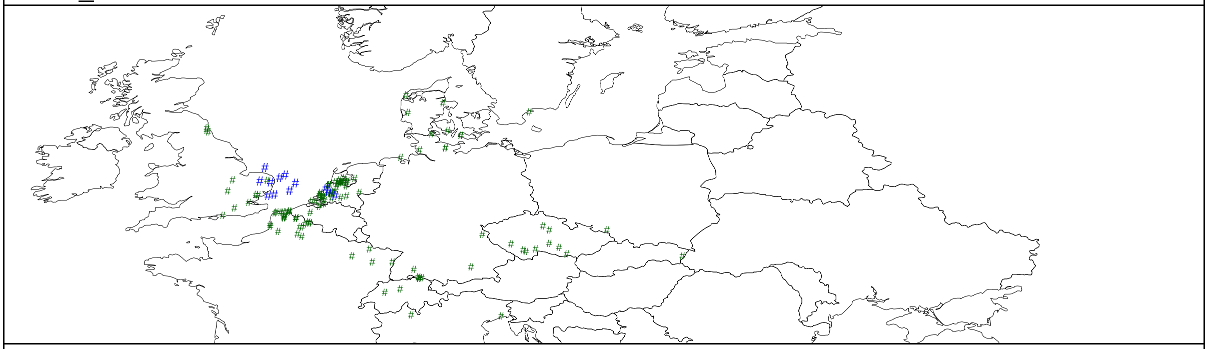
TD 2_2



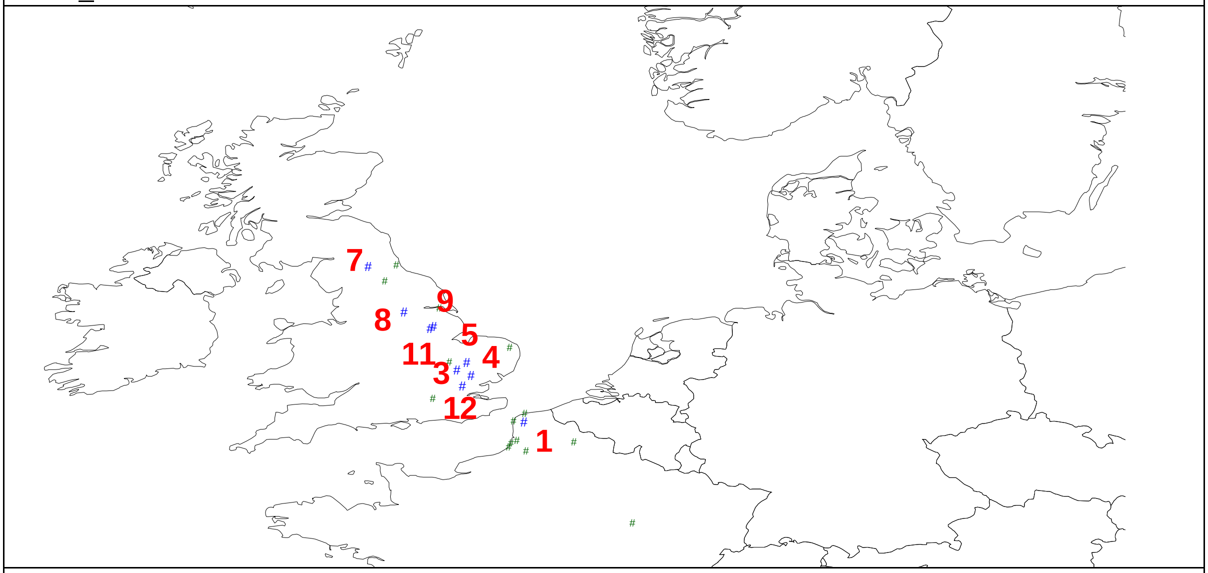
TD 2_3



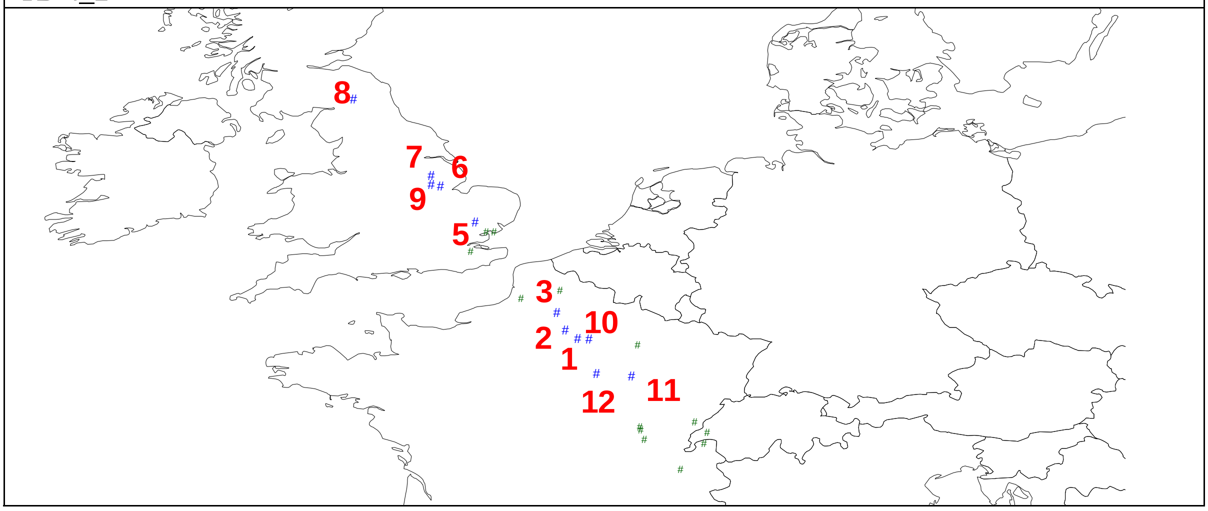
TD 3_0



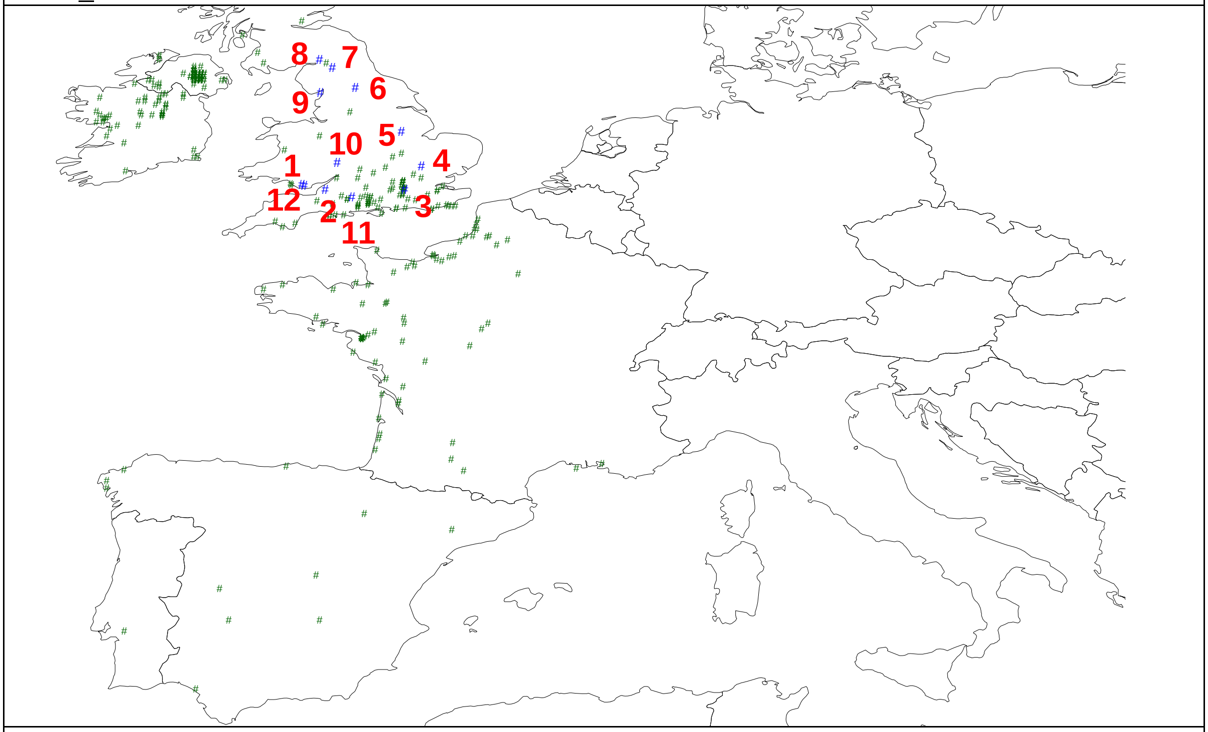
TD 4_1



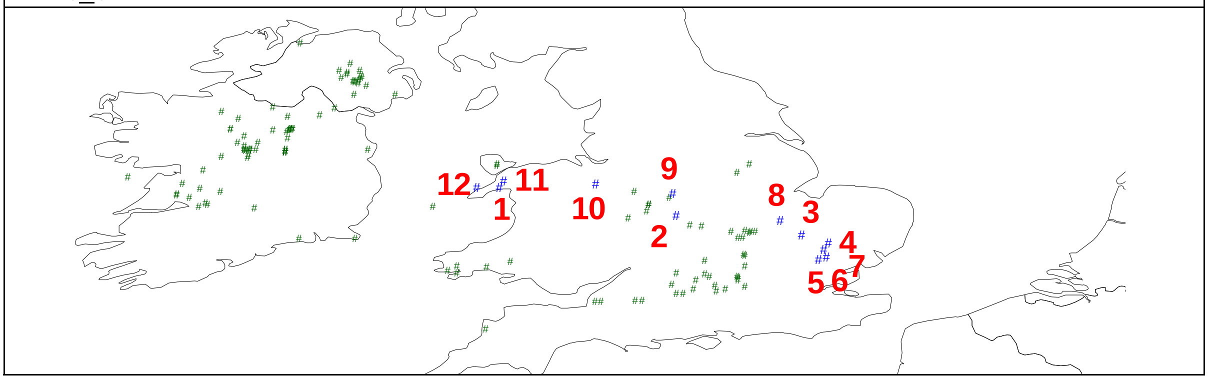
TD 4_2



TD 5_0



TD 6_0



3.3.11 Northern Lapwing *Vanellus vanellus*

The Northern Lapwing is widespread across the western Palaearctic and breeds across most of Europe, to North Africa and east to China. In winter, many thousands of Northern Lapwing migrate south and westwards from the continent and winter in the UK. The majority of Northern Lapwing ringed in B&I were chicks and the initial filtering (restricting the analysis to birds in B&I in October to March) will have removed many of these birds.

The summer recoveries are concentrated in an area from the Low Countries to Germany bounded in the north by southern Norway, Sweden and Finland and to the south by Germany and Switzerland. There are a few recoveries to the west of Poland. In autumn birds are spread from the breeding areas to B&I and a few recoveries to the Iberian Peninsula. In winter there is a strong westerly bias with a clear movement of birds moving from B&I through France to Spain and Portugal. These will be recoveries of birds caught on migration in the UK, birds changing winter quarters between years or a response to cold weather. There is some evidence that birds returning to the breeding areas in spring may take a more southerly return route, given the SE Europe recoveries in spring.

The directional movements can be broken down in to breeding (L1, L2, L3, L4) and wintering movements (L6 and L7). The first four show the migration between breeding and wintering grounds in Norway (L1), Denmark, Sweden and Finland (L2), Denmark, the Low Countries and Eastern Europe (L3) and the Low Countries (L4). The timing of migration is very similar across these three types. Northern Lapwing remain in B&I from October to March before moving back to the breeding areas in April.

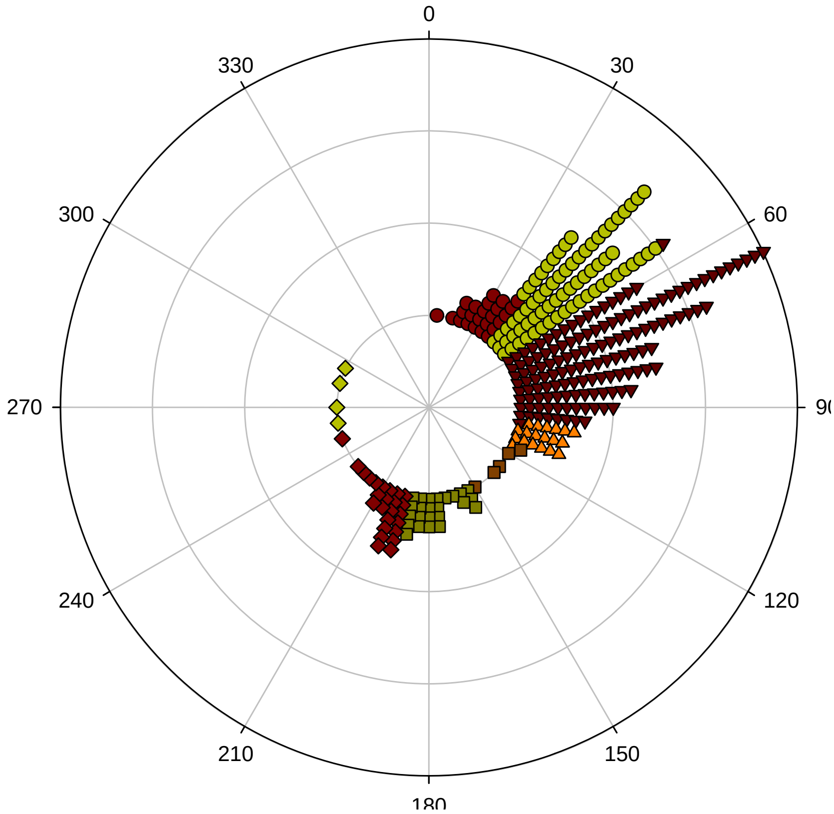
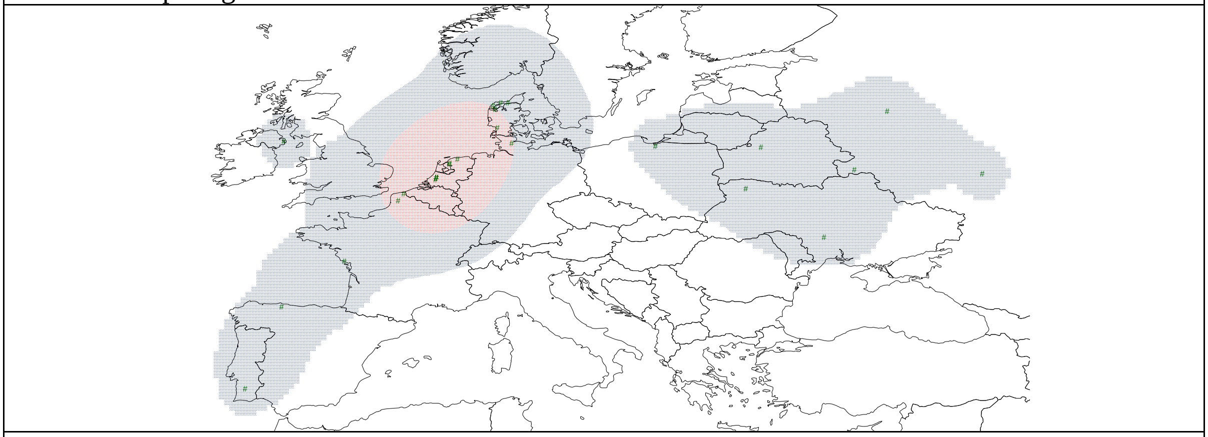
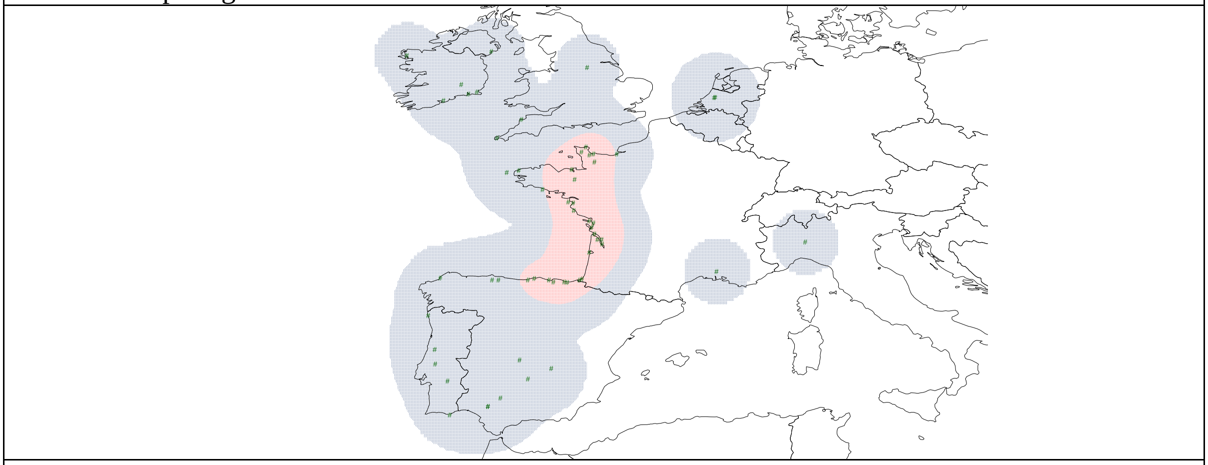


Figure 3.3.11.1 The number of directional movements of Northern Lapwing to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 421

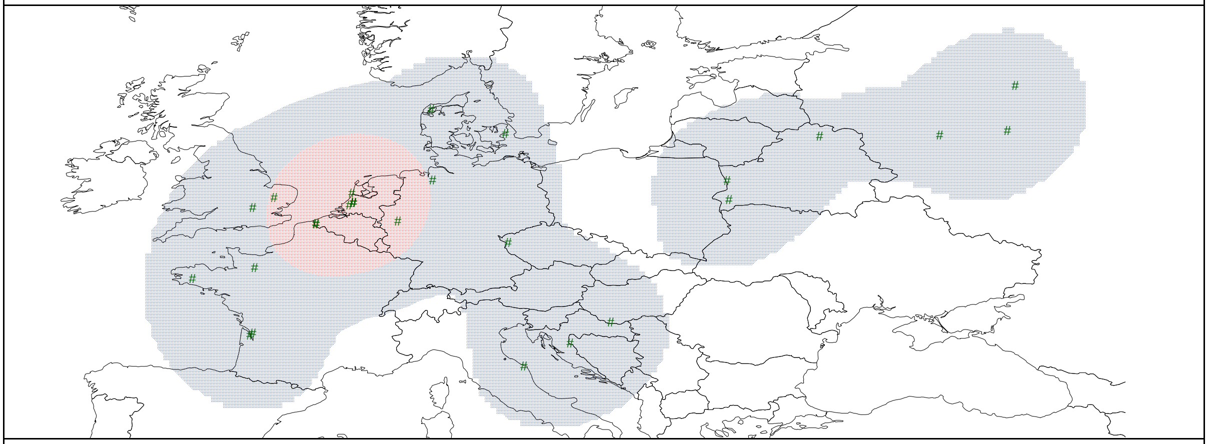
Northern Lapwing - Autumn



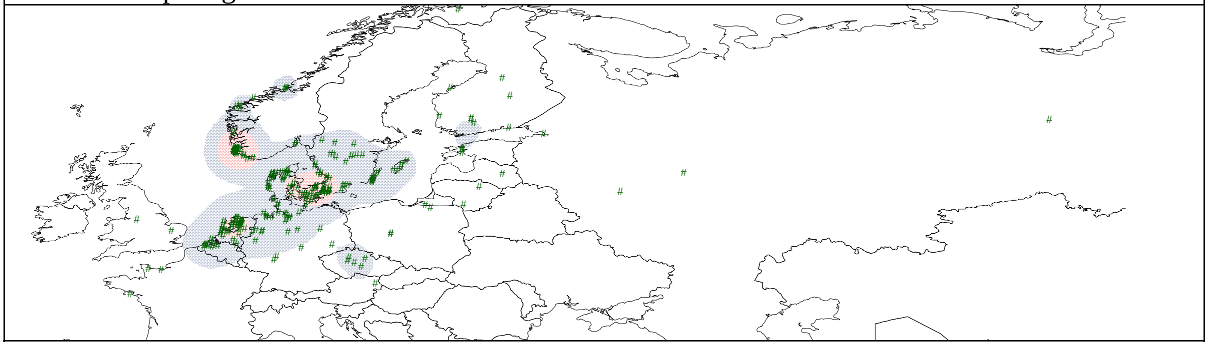
Northern Lapwing – Winter

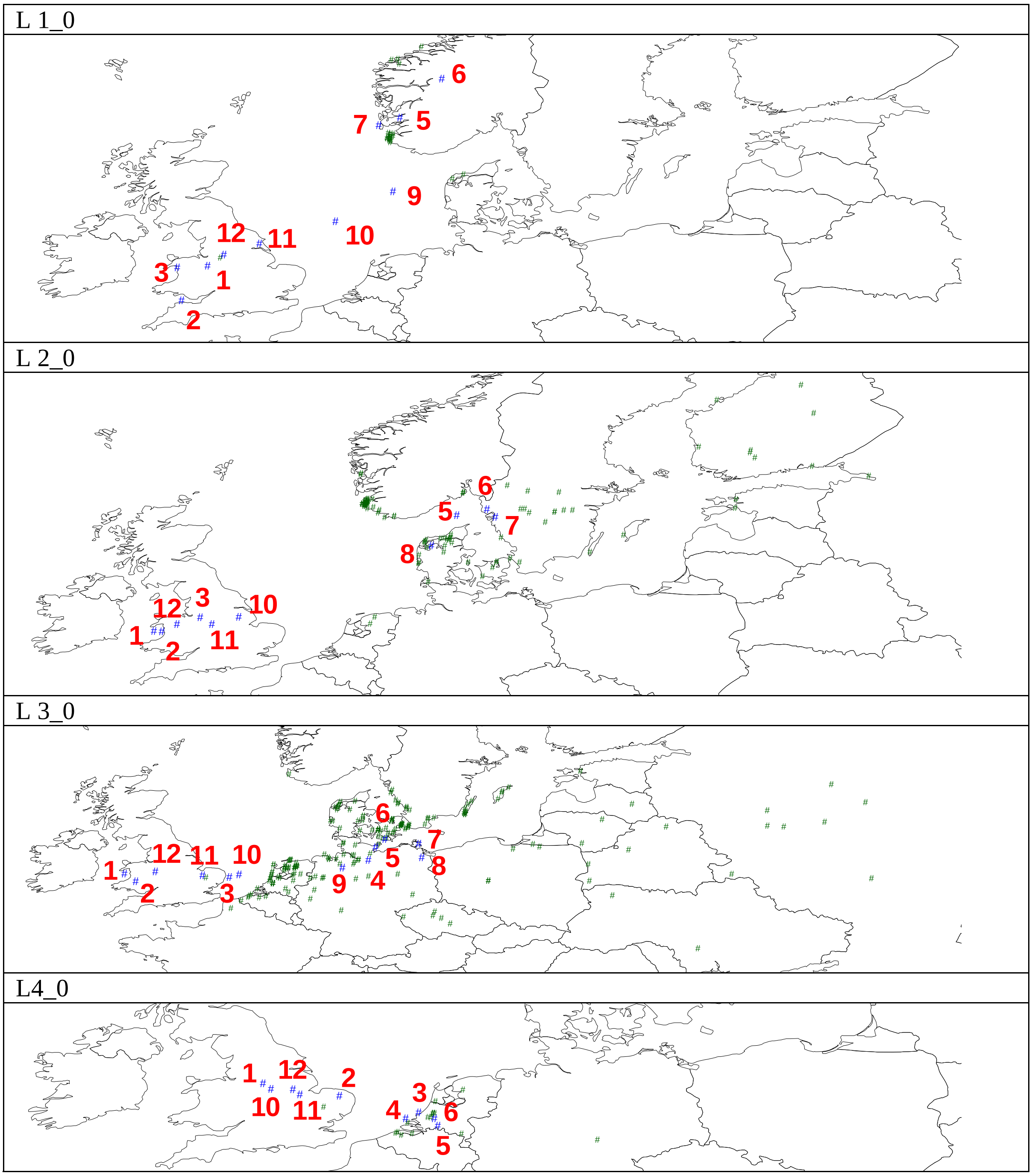


Northern Lapwing – Spring



Northern Lapwing - Summer




L 1_0
6
7
5
9
12
11
10
3
1
2
L 2_0
6
5
7
8
12
3
10
1
2
11
L 3_0
6
7
12
11
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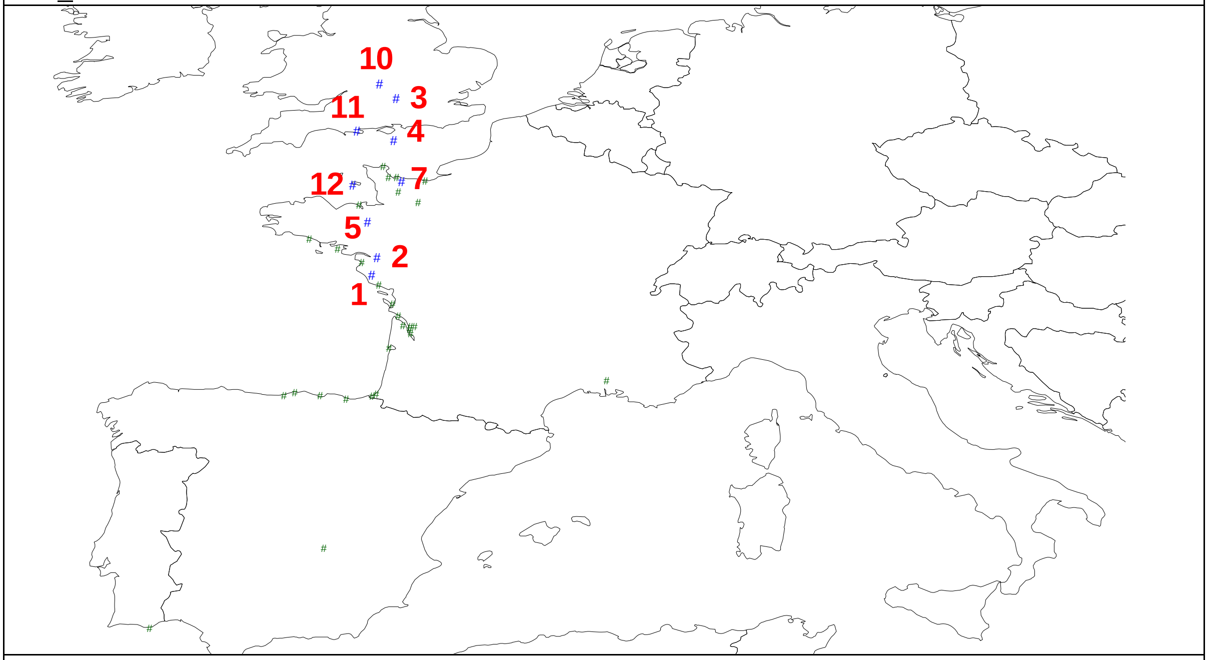
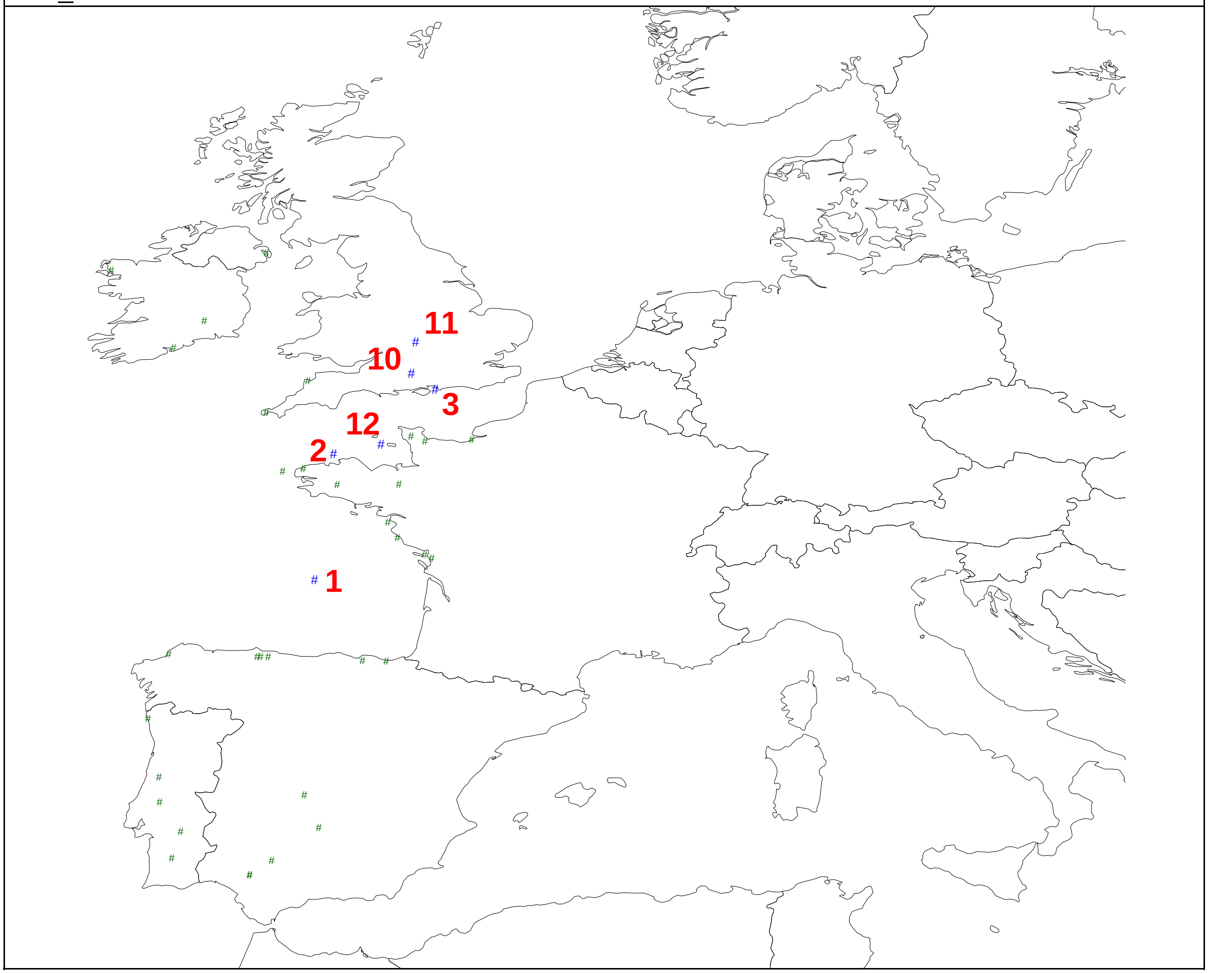
4
6
5

L 6_0



L 7_0



3.3.12 Black-headed Gull *Larus ridibundus*

Black-headed Gull breed throughout the Palaearctic, from Kamchatka to the Atlantic, ranging between 70 and 37°N. Black-headed Gull populations are migratory, partially migratory or dispersive. The birds wintering in B&I are from breeding areas stretching from the Low Countries, the Baltic coast, Finland and inland areas in central and Eastern Europe, with a few records in western Russia (seasonal maps). In general, easterly populations move south and westwards in autumn and, by winter, birds are concentrated in B&I and around the North Sea coasts of the Low Countries and Denmark.

The directional analysis identified five major types of movement, three of which were movements between wintering and breeding areas. Black-headed Gull breeding colonies are widespread across Europe and the directional movements reflect this. Movement types BH 1_1 and BH 1_2 show the movements between Norway, Sweden and Finland and B&I. The two clusters identified show very similar timings. Black-headed Gulls are in the B&I from November to February and start moving to the continent in March. By May they are on the breeding areas and remain there until August when they start their return migration to B&I.

The second movement type (BH 2_1 and BH 2_2) contained two clusters and represents birds breeding across a large area from south-western Scandinavia, Finland and the Baltic states. The timing of movements is very similar to the first movement type, and birds remain in B&I from November to February, before reaching their breeding grounds in May. Return migration starts in July and August.

The final breeding movement is BH 5_0, and shows the link between the breeding population in Iceland and the wintering population in B&I. The first recoveries appear in Iceland in June, somewhat later than mainland Europe, reflecting the more northerly distribution.

Two types of southerly movement were identified (BH 3_1 and BH 3_2) and these represented a winter movement, one of which was a redistribution of birds within B&I and near continent, which showed no particular seasonal movement (BH 3_1) and a winter movement to France and Spain, possibly in response to cold weather (BH 3_2).

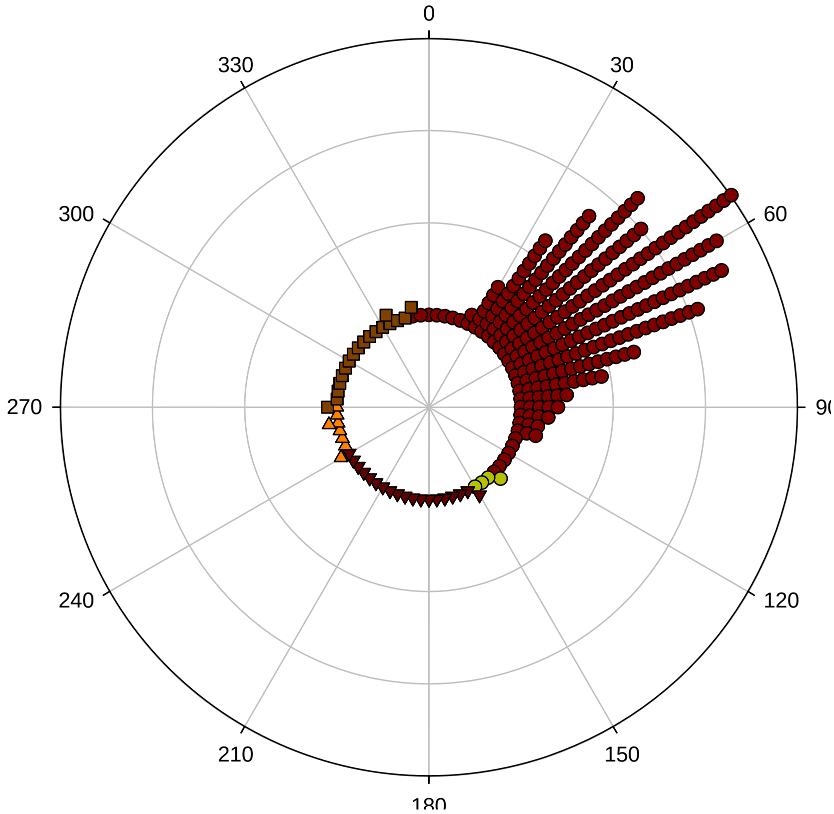
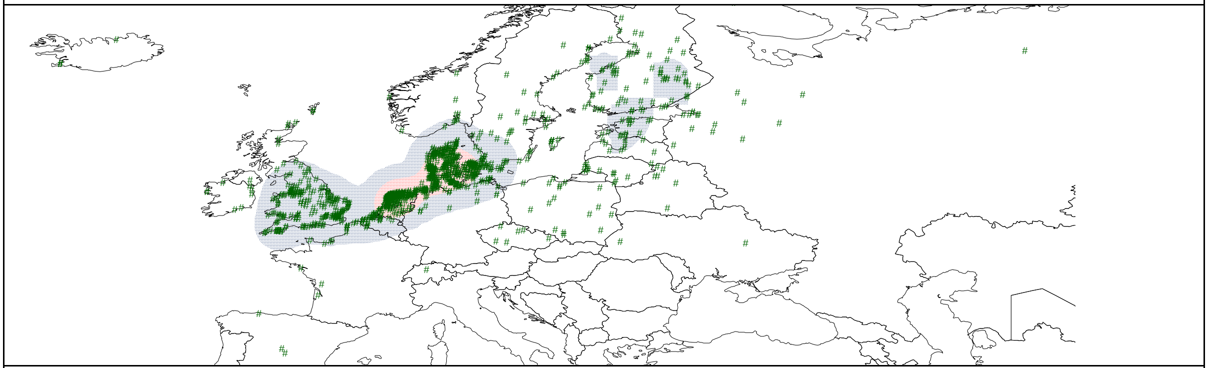
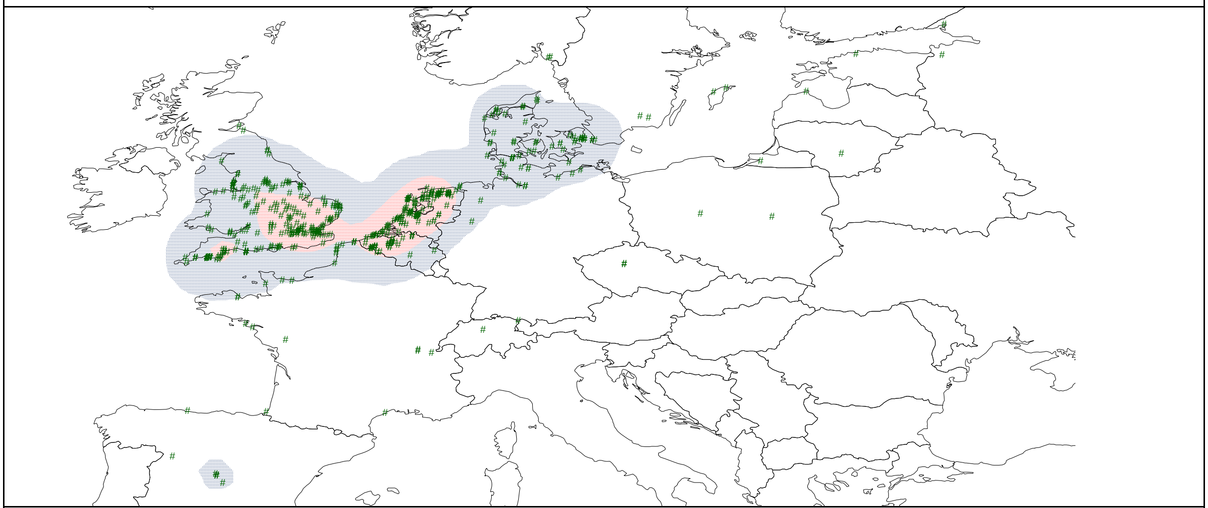


Figure 3.3.12.1 The number of directional movements of Black headed gull to and from B&I in 15 degree segments. Key (*NB not all movement types occur in each species*): Directional movement 1 – brown circles; 2 – green circles; 3 – brown triangles; 4 - orange triangles; 5 – brown squares; 6 – green squares; 7 – brown diamonds; 8 – green diamonds. Sample size = 8269

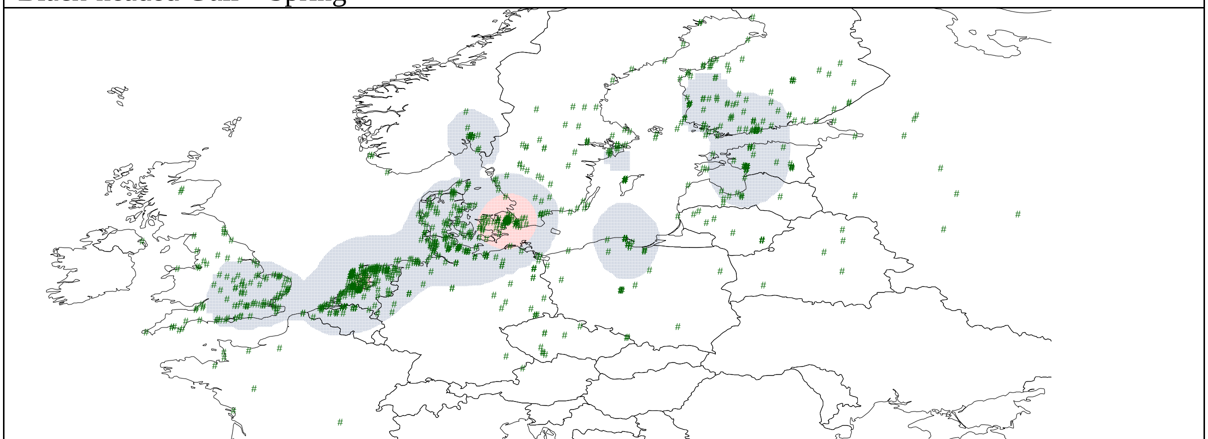
Black-headed Gull - Autumn



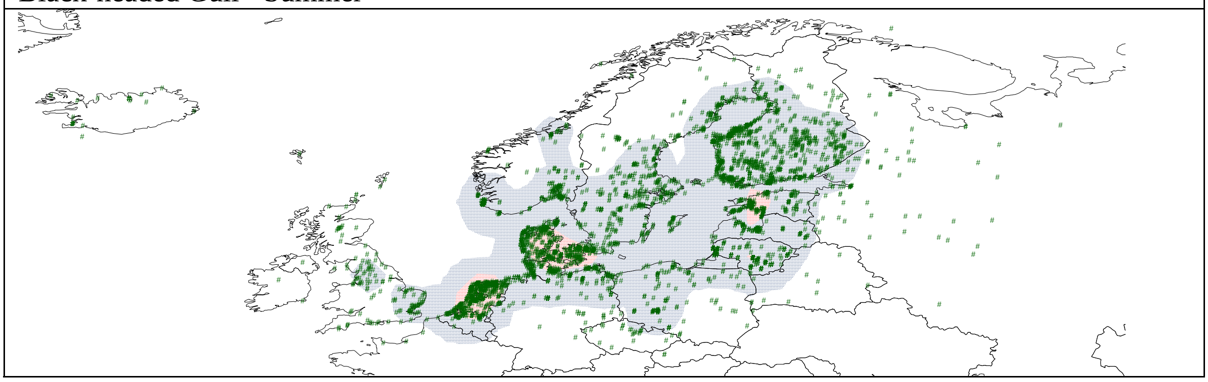
Black-headed Gull – Winter



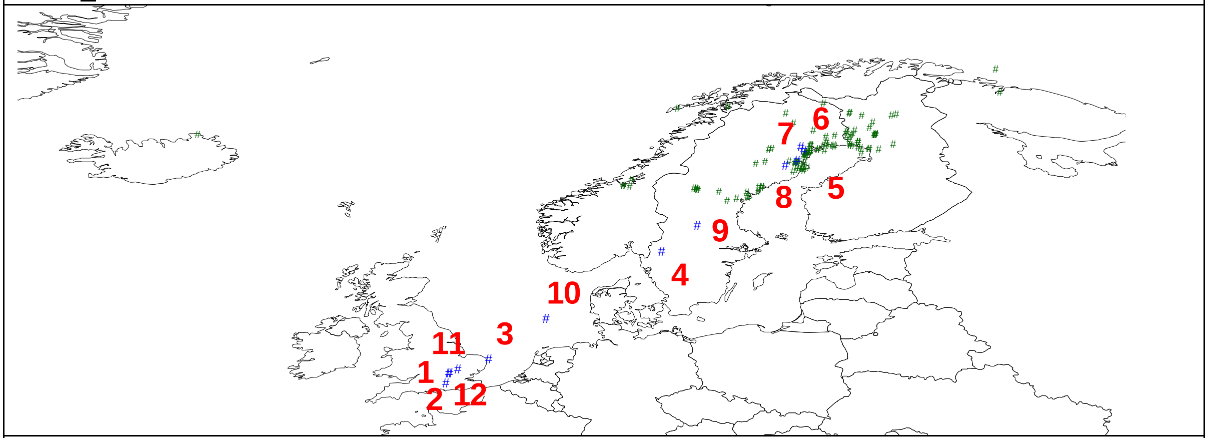
Black-headed Gull – Spring



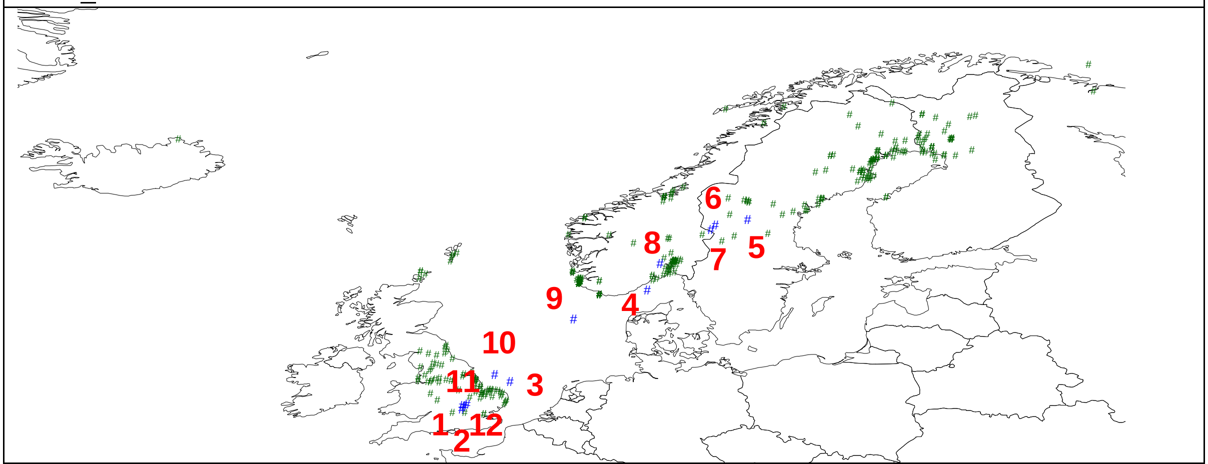
Black-headed Gull - Summer



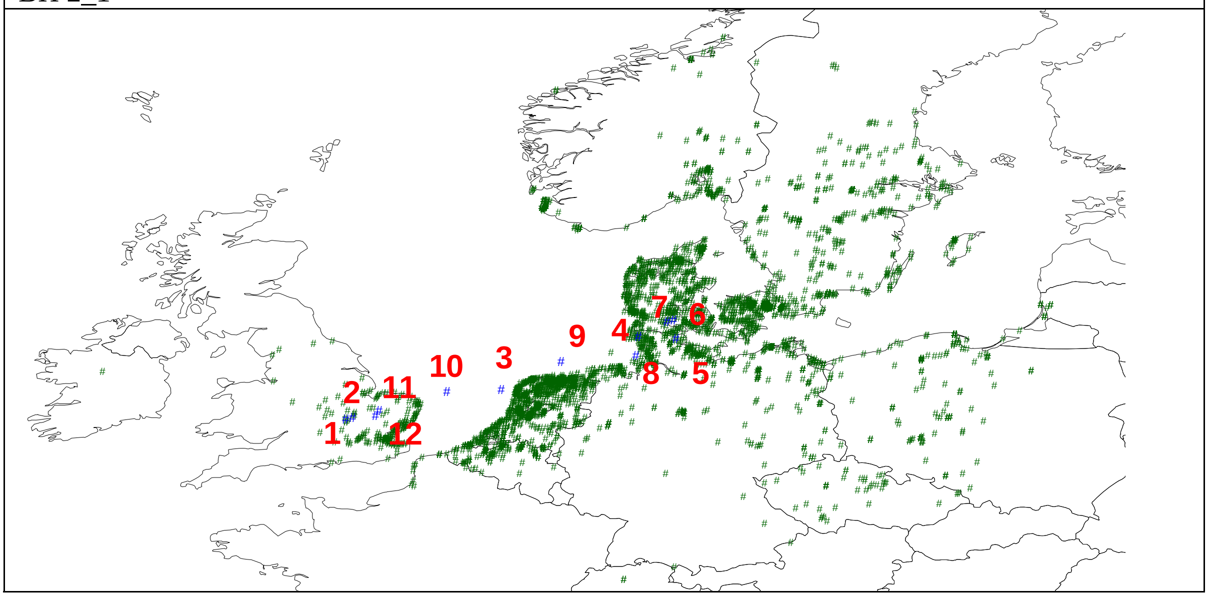
BH 1_1



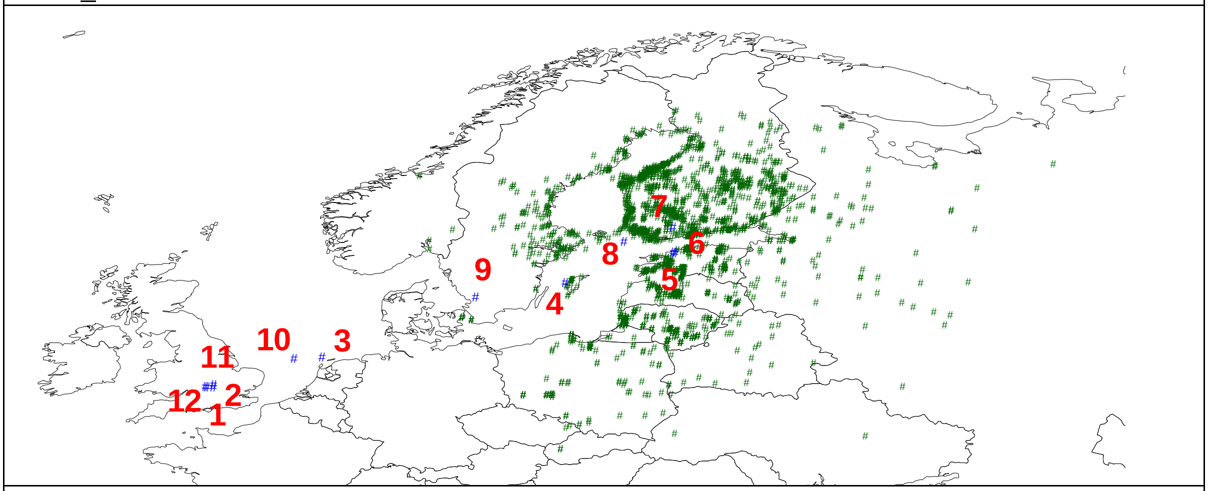
BH 1_2



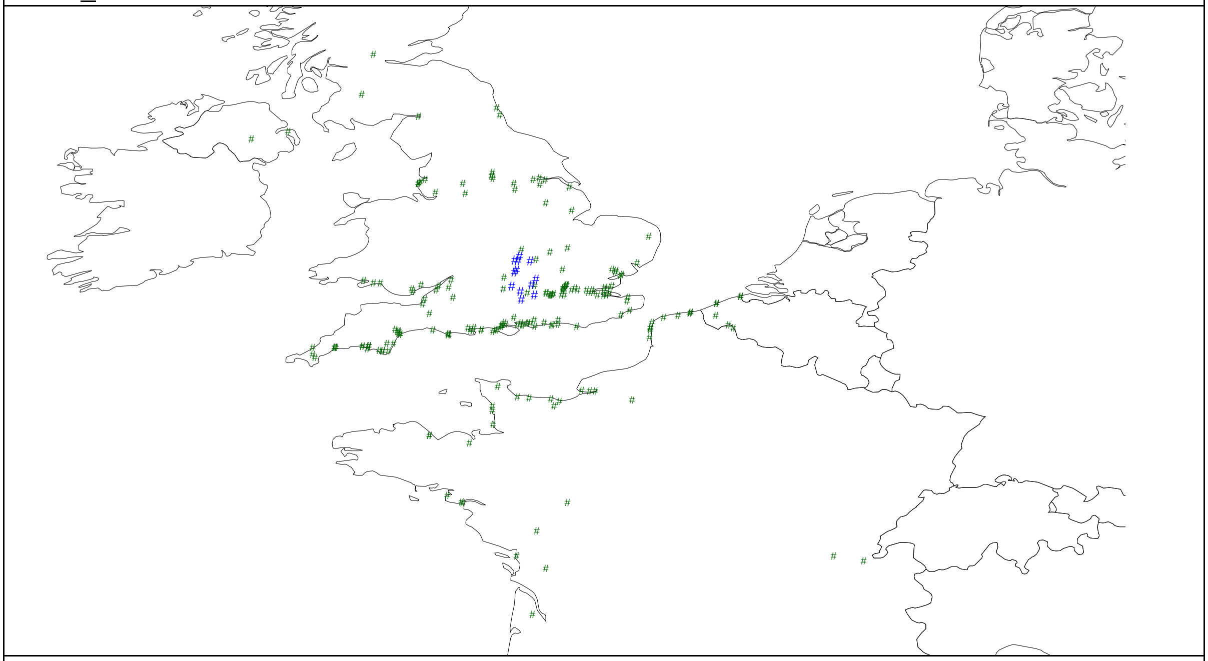
BH 2_1



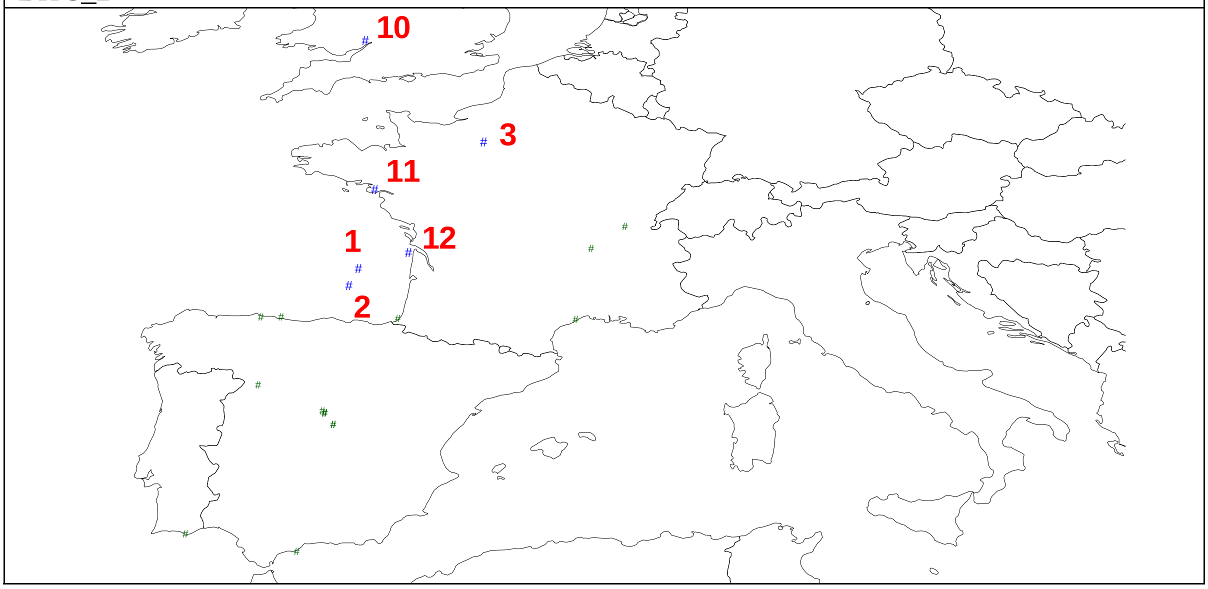
BH 2_2



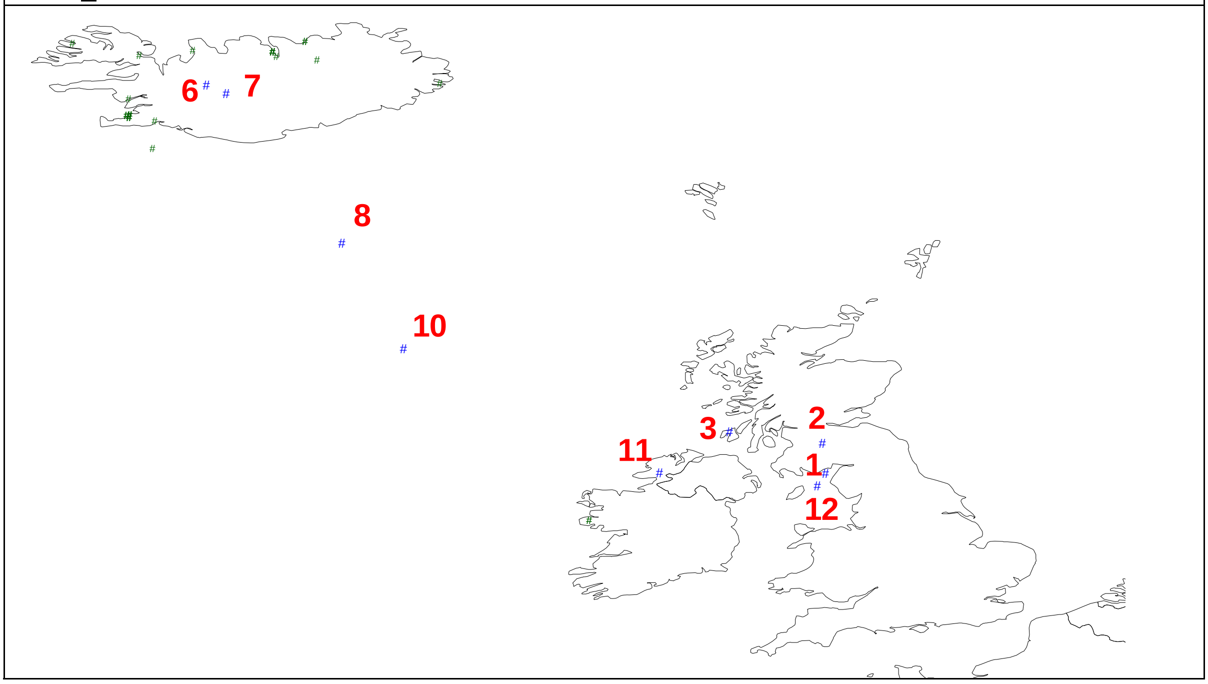
BH 3_1



BH 3_2



BH 5_0



3.4 DISCUSSION

The results presented in this report represent a major improvement in the analysis of the movement of marked birds. Even relatively recently, Wernham *et al.* (2002) were largely limited to presenting dot maps, with lines linking individual ringing and finding locations. This could sometimes give a very misleading impression of the pattern of bird movements, since birds tend not to move in straight lines, but rather follow, for example, geographical features. By combining sophisticated statistical smoothing techniques with the capabilities of geographic information systems (GIS) we have been able to present a much more accurate pattern of bird movements. In particular, we have been able to represent in readily interpretable way, the seasonal pattern of movement of different populations of each species. This allows, for the first time, the annual migration paths of specific populations to be plotted, allowing a much more reliable assessment of the pattern of distribution outside Britain and Ireland for populations that occur here at only certain times of year.

The analysis presented here draws on the large database of movements of birds ringed or recovered in Britain and Ireland held by the BTO. This database represents the result of many thousands of hours of efforts from both ringers and members of the public who have marked or found the birds included. It represents the primary data source for the analysis of movements of birds occurring in Britain, however, interpretation of the data should be subject to a number of caveats, as the data do not represent an unbiased sample of all bird movements. However, providing appropriate caution is used, the analyses of movement presented here do provide an informative and relevant picture of the pattern of movement of British birds.

3.4.1 Biases in sampling

In the following, we provide a brief outline of some of the major sources of bias present in the data, and how this affects their interpretation, for more details we refer the reader to Wernham & Siriwardena (2002) who discuss these issues at some length.

The number of recoveries of marked birds reported to the BTO from a particular area will depend on:

a. The number of ringed birds that go there.

b. The number of ringed birds that die there, which will reflect spatial variation in mortality risks, e.g. through adverse weather conditions, or hunting pressure.

c. The chances that a dead bird will be found and reported to the BTO. This is likely to depend on habitat and climate (e.g. how quickly corpses decay, or are scavenged), the species (large, brightly coloured species are more readily found), the density of the human population, and the level to which they are educated about the presence of ringed birds, and how to report them.

3.4.1.1 Representativeness of samples

The number of birds that are ringed while travelling to a particular location is a function both of the total number of birds that go there and also on the geographical variation in ringing effort. Clearly, in order to draw inferences about the movements of a particular group of birds, one needs to mark a representative sample of individuals. For most species ringing effort may be biased spatially (e.g. most ringers live in the south and east of Britain) or temporally (e.g. different relative effort may be made in different seasons and there may be changes through time between years). This clearly applies not just to ringing in Britain, but also throughout the area from which birds are likely to occur. Unfortunately, information on ringing effort outside Britain has not been synthesized, so the comments below are restricted to Britain. Where it is known that changes in ringing effort outside Britain may affect the interpretation of a particular species' movements, this is noted in the species text (e.g. Whooper Swan, 3.3.2). In practice, for most species, the number of species found bearing a ring from another country is relatively small (c. 1,000 for all species, i.e. less than 10% of all birds found)

For wildfowl, ringing effort tends to concentrate on situations where large numbers can be reliably caught, either in duck decoys or by cannon-netting flocks of birds. Consequently, effort tends to be greatest in winter, when wildfowl gather in large flocks, and relatively low during the summer months, when most birds are breeding, both because many species occur in relatively low numbers during the breeding season (they breed elsewhere in Eurasia) and they tend to be relatively dispersed. However, when considering incursion of AI in Britain, it is likely that such winter flocks represent the greatest risk, and recoveries from the winter period only were considered in this report. This is primarily because of the large numbers of immigrant birds into Britain, and because breeding individuals (particularly of wildfowl and some wader species) tend to be relatively sedentary. Thus, ringing is targeting the most relevant populations in the current context.

Sampling is also biased spatially, with fewer birds being ringed in the north and west of Britain (particularly Scotland) and more in the south and east. Similarly, wildfowl ringing tends to focus on areas with the greatest concentration birds. However, in the present context of assessing risk of incursion of AI into Britain, neither of these presents a serious problem, since (i) numbers of wildfowl occurring in northern and western areas are generally lower and (ii) they are far less likely to come into contact with poultry, due to a lower density of poultry units and also (iii) large concentrations pose the greatest threat simply through the numerical likelihood of such a concentration including an infected individual.

Over the period of operation of the ringing scheme, there have been changes in the methods available to ringers to trap birds, with the advent of mist- and rocket-nets in the 1950s, in particular, greatly expanding the scope of feasible locations for trapping birds. Consequently, there has been a marked expansion in the locations of bird ringing, with ringers having much more flexibility in terms of where, and when, they can catch birds. There has thus been a trend towards catching more representative samples of bird populations through time. However, as we are not considering trends through time in this analysis, but rather all data over the period of ringing, this should pose little problem for the analysis of overall extent of movements.

Thus, although ringing of birds is subject to some spatial and temporal biases relative to the populations of birds occurring in Britain, which make quantitative assessments of relative risk difficult, they do not compromise our ability to assess qualitatively the risk of incursion of AI into Britain.

3.4.1.2 The importance of recovery type

Marked birds may be ‘recovered’, that is found, either alive or dead following their initial marking. Because of the very different nature of the finding circumstances, the biases associated with each are different, and we outline these here. However, by using both types of recovery we will ‘smooth’ the effect of these biases to a certain extent.

Birds found alive tend to be either caught by another (or the same) ringer, or seen in the wild because they bear individual marks that can be identified at a distance (usually by some combination of coloured leg or neck rings). Amongst the species considered here, two (Bewick’s Swan and Brent Goose) have been the subject of large-scale studies involving colour marks, so a large proportion of marked birds have been re-sighted alive. In contrast, for most of the other species, live re-sightings (or recaptures by ringers) make up a fairly small proportion of the database. The Whooper Swan, being large and with a tendency to occur in areas with large numbers of birdwatchers, has a higher proportion of re-sighted individuals. For waterbirds, many dead birds are reported shot by hunters, particularly for wildfowl, which tend to be popular quarry species (Table 3.4.3.1). However, for the two swan species considered, a significant proportion of marked birds were recovered as a result of collision with man-made structures, mostly power-lines.

Clearly, the extent of bias in finding location associated with the different recovery types will differ. The frequency of re-sightings of live birds will depend on human population density (more specifically, the density of bird-watchers, or, at least, informed members of the public), while the frequency of birds found dead will depend, on the frequency of hunting, particularly for quarry species, such as most wildfowl. There is thus a greater likelihood that marked birds from western Europe will be reported than from areas further east, where human population densities are lower (and knowledge of English with which to read the ring is less). Having said that, most hunters will operate in areas where birds congregate, thus recoveries should be received from many of the most important areas inhabited by birds. This may be particularly true in eastern Europe and countries of the former Soviet Union, where hunting is more popular and species protection laws tend to be less stringent. This may be exemplified by reference to the map of recoveries of Tufted Duck (see 3.3.10), with concentrations of recoveries (though in small numbers) along the floodplains of the Ob and Pechora rivers. Spatial biases in other forms of reporting (e.g. collision with power lines) will also exist, though for many of the species considered here they are much less important numerically (Table 3.4.3.1), so have less effect on the broad-scale analyses presented here.

Thus, although analysis of ringing recoveries cannot provide quantitative information on the likelihood of movement of birds from particular areas, for qualitative assessments the extent of occurrence is broadly informative. Clearly, however, when examining the maps in the context of AI incursion risk, one should bear in mind their general, indicative, nature, particularly in areas of eastern Europe and Asia, and (where appropriate) Africa, since the reduced number of recoveries means that the extent of occurrence cannot be mapped in as great a detail as in western Europe. The kernels define broad areas of likely occurrence, but do not imply that birds encountered outside those areas will not migrate to Britain in some cases, though clearly, the likelihood of them doing so will decrease with distance from the mapped kernel, which will reflect the central areas from which birds arrive.

3.4.1.3 Summary: usefulness of ringing data

Above we have summarised the major biases to be considered when interpreting the maps, namely that:

a. That there may be biases in ringing location, both in Britain and elsewhere. Though those in Britain, in general, should not unduly affect these analyses, the effects of variation in ringing effort elsewhere are less clear, and will vary between species.

b. There is spatial variation in the risk of mortality (and of being re-sighted). Though it is possible to broadly outline this, it will affect interpretation of the maps presented here, particularly in areas away from western Europe.

c. There is variation in reporting rate. This will be confounded with (2) above, since with increasing distance from western Europe (through Asia and Africa) levels of education and knowledge of English generally decline.

However, in terms of qualitatively assessing areas from which birds are likely to occur, these maps will accurately reflect broad patterns. A further complication, not considered here, is that migration routes are flexible over time, and will evolve and adapt in relation to changing environmental circumstances, e.g. climate change (Robinson *et al.* 2005). Such changes, though, tend to occur on rather longer time-scales than are being considered here, so are probably not of immediate concern, though they should be noted in strategic, long-range planning.

The database of recoveries analysed here represents an invaluable resource for assessing broad-scale patterns of bird movement, despite its shortcomings. However, its utility could be greatly improved by:

a. Conducting a detailed analysis of the pattern of ringing and finding locations to assess the full extent of these biases and, potentially, establish a (semi-) quantitative index against which estimates of movement for particular species can be judged. For greatest effectiveness, this analysis should be carried out at a Europe-wide scale, incorporating the recoveries held in the EURING DataBank (EDB), since this is the geographic scale of bird movements of most interest here.

b. Further encourage the establishment and operation of ringing schemes in the countries of the former Soviet Union (particularly the western half), since this could greatly increase our knowledge of bird movements to and from this area as the number of recoveries so far is so limited. This is particularly relevant in an AI context, as AI Is endemic in at least some of these areas (Olsen *et al.* 2006).

c. Raising awareness, and education about, ringing schemes in general in areas of eastern Europe, Asia and Africa to increase the likelihood that marked birds found dead, shot, or re-sighted alive are reported appropriately.

3.4.2 Risk of AI incursion into Britain

In order to assess fully the risk of AI incursion into Britain, given the occurrence of infected individuals in a particular area at a particular time of year, one needs to know the following:

a. The number of birds occurring in the given area at the time of year

b. The proportion of birds in that area that migrate to Britain at some point in their life-cycle

c. The behaviour those birds when in Britain

Of these, (a) is beyond the scope of this section, addressing as it does, initial risk of incursion into Britain, however, it is addressed in other sections of this report (Sections 2 & 4). Thus, by combining the pattern of movements presented here with data on bird numbers in particular areas, it should be possible to develop an index of the relative likelihood of AI spreading to Britain and Ireland, given an outbreak in a particular area.

Developing a risk figure for the incursion of AI in Britain, given the occurrence of infected individuals in a particular area at a particular time of year, is perhaps best done on a reactive basis, since the scale of the geographical area, and the species to be considered (in terms of likely cross-species infection) will depend on the nature of the outbreak in question. Additionally, other factors particular to the circumstances may need to be considered. These factors combine to make a generic assessment of risk across all species and areas problematic.

Mid-winter (January) counts for most water bodies in Europe are conducted under the aegis of the International Wildfowl Census (IWC) co-ordinated by Wetlands International. The census involves annual site-based counting of waterbirds, based on a standardised methodology. Most observers are members of enthusiastic, often voluntary networks, with professional co-ordination at national level. Counts at other times of year are only available for a limited number of sites away from Britain and the near continent, compromising our ability to assess the risk of spread of AI.

Indicative information on movements of birds between areas can be obtained from the maps presented in this section. However, as discussed above, this information is largely qualitative in nature and, in many cases, we do not have detailed knowledge of where birds from given regions move to or from, particularly in more remote areas, where marking efforts have necessarily been limited. In particular, estimating proportions of birds that migrate between a particular area and Britain is very difficult and, in many cases, likely to be annually variable in response to, for example, local weather conditions or food shortages. Ideally this analysis would be carried out at a European scale, and involve analysis of the EDB, which is hosted by the BTO, and which includes information on recoveries of birds all over Europe, allowing a more robust analysis of the pattern of movements at this scale.

To arrive at a more detailed, though still qualitative, estimate, one could combine the information on these maps with expert interpretation and the IWC counts database. In principle, it should be possible to use the information from recoveries presented on the maps to assess, for a particular region, the relative numbers of birds present at a particular time that might arrive in Britain. This could be done on a five-point scale:

0. Significant numbers of birds unlikely to arrive in Britain
1. Fewer than 25% of birds likely to arrive in Britain
2. Fewer than 75% of birds likely to arrive in Britain
3. Most birds likely to arrive in Britain

Such a scoring procedure would need to be subject to appropriate peer review, to ensure its robustness, and a qualitative level of uncertainty (perhaps on a three point scale) might be usefully attached to each estimate to give an assessment of the underlying of confidence in the scoring. A major consideration in developing such an assessment would be in delineating the appropriate regions. Larger regions will encompass more data, and hence greater certainty, but may increase variability in migratory routes and tendencies, rendering an overall score less meaningful. While it may be possible to group species with similar migration ecologies, it is likely that delineating regions separately for each species (though possibly from a menu of relatively standardised areas) may be the most satisfactory approach.

Such a score could either be combined with the overall risk factor developed elsewhere in the Report (see Section 5), perhaps with a divisor to scale it appropriately in relation to the other risk factors considered. Alternatively, the factor could be multiplied by $\log_{10}$ population size for the area to be considered, to generate an independent risk factor. Scaling this number by 1/25 would roughly normalise the range of the risk factor from 0 to 1 (since few populations of interest will exceed 1 million birds).

Additionally one would need to incorporate the risk posed by cross-infection of co-occurring species in the area. In principle, this could be scored similarly to the risk posed by the principal species, but down-weighted by an appropriate factor that reflects the likelihood of transmission between species. In many cases the frequency of such cross-species transmission may be poorly known, and it may also be regionally variable, which would further complicate the development of an appropriate risk score.

3.4.3 Future developments

This initial development of a method to summarise bird movements in a quick and timely manner can be further developed. The statistical analysis of ringing data is a relatively quick process but the presentational maps have to be manually produced in ArcView and can take 1-2 hours per species. This process could be made much quicker by the automating the map production process. This would enable large numbers of species to be run relatively quickly and easily interpretable results produced.

The analysis here has also only considered one scenario of data (birds in B&I in October to March only) and, in an outbreak, it may be necessary to run a variety of queries on the data. For example it may be desirable to restrict the analysis to birds in southern Europe in spring or those occurring in B&I during a smaller or larger subset of months. Where an outbreak in Europe has been identified, it would be desirable to run analyses for species also known to occur in close proximity with that species. This would give an indication of the relative risk of these species arriving in B&I at a certain time. This would only be possible if the automation process could be speeded up.

This would require a script to be written to automate the maps. The SAS statistical analysis program could be modified to produce the relevant script.

To provide an 'at glance' tool to determine if there was a risk of wildbirds carrying H5N1 to the UK, a spreadsheet of 'high risk' species could be produced showing the number of recoveries by month of each species in each country, where recoveries were available. This has been done for the species considered here (see Appendix 5.1) but this could be improved by (a) expanding the number of species and (b) automating the updating process as new recoveries became available. Accessibility could be improved by making this web-accessible so that the latest version was always available.

	Type (%)		Finding Circumstance		
	Alive	Dead	Deliberately Taken	Other Human	Natural Causes
Bewick's Swan	81	19	32	30	15
Whooper Swan	37	63	13	68	6
White-fronted Goose	4	96	99	1	1
Brent Goose	28	72	70	6	24
Eurasian Wigeon	1	99	98		
Eurasian Teal	1	99	97	1	2
Northern Pintail	2	98	97	1	1
Common Pochard	4	96	89	7	1
Tufted Duck	4	96	85	11	
Northern Lapwing	1	99	56	22	10
Black-headed Gull	23	77	27	27	21

Table 3.4.3.1 Recovery circumstances of birds included in this study.

For those found dead, an indication of the cause of death is given, where this was identified by the finder. 'Deliberately Taken' essentially means shot, though a few birds will have been taken using other methods, e.g. traps or poisoned. 'Other Human' includes birds that died for some other reason related to human activities, e.g. collision with power lines or road casualties. 'Natural Causes' includes those records where the cause of death was explicitly identified, e.g. the bird had apparently starved or been predated. This is often difficult to determine, and many birds noted as 'Other' may be included in this category.

4. DEVELOPMENT OF A TOOL TO IDENTIFY PRIORITY AREAS FOR SURVEILLANCE OF H5N1 AVIAN INFLUENZA IN WILD BIRDS IN GREAT BRITAIN

Stuart E. Newson[1], Lucy C. Snow[2], Andrew J. Musgrove[1] and Peter A. Cranswick[3]

[1] British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU, United Kingdom
[2] Centre for Epidemiology & Risk Analysis, Veterinary Laboratories Agency, New Haw, Addlestone, KT15 3NB, United Kingdom
[3] The Wildfowl & Wetlands Trust, Slimbridge, Gloucestershire, GL2 7BT, United Kingdom

SUMMARY

Recent outbreaks of highly pathogenic avian influenza H5N1 (AI) in Europe and elsewhere in the world have highlighted the need for enhanced surveillance and early detection of the disease in Great Britain (GB). One possible route by which H5N1 could be introduced into GB is through migratory wild birds carrying infection in from Europe or Asia. Using knowledge of the GB poultry industry and wild bird populations, we present a tool to identify priority areas for surveillance. These are areas in which the likelihood of H5N1 incursion into GB and subsequent spread to commercial poultry is considered to be highest.

We focus here on 24 wild bird species, which migrate to GB and are thought most likely to introduce and spread the disease to poultry. However, monitoring data have been collated for all wild bird species that regularly occur in GB to be in a position to provide information for any species at short notice. In parallel, an analysis of information contained in Defra's GB poultry register (GBPR) was carried out and used to rank domestic poultry holdings according to the estimated likelihood of an incursion of H5N1 directly from a wild bird source. Scores were assigned to holdings based on a number of premises-level variables including the number and species of poultry present and whether birds were housed indoor or outdoor.

By bringing together the ornithological and epidemiological analyses above, an incursion risk profile was produced for GB showing areas where AI incursion is thought more likely to occur. The outputs of this work show that surveillance would be best focused on areas of Norfolk, Suffolk, Lancashire, Lincolnshire, the Southwest of England and the Welsh Borders. These areas have significant poultry populations (including a high number of free range flocks) and high abundance of the 24 wild bird species of highest concern. Smaller priority areas were identified in Anglesey, south west Wales and the Firth of Forth area of Scotland, which have a high abundance of the wild birds and dense but localised poultry populations.

In conclusion, this work provides a tool to direct resources and enable the early detection of H5N1 in GB in areas where domestic poultry are at greatest risk. The tool can be updated to incorporate new wild bird or poultry data or additional species as the international situation changes. This work has important practical applications for contingency planning and for directing targeted surveillance.

4.1 INTRODUCTION

Traditionally, avian influenza viruses have been divided into two classes based on their ability to cause disease; high pathogenicity avian influenza (HPAI), which is restricted to the AI subtypes H5 and H7 (although not all viruses of these subtypes cause HPAI) and low pathogenicity AI (LPAI). Current theories, backed up by an increasing amount of evidence suggest that HPAI viruses emerge from an avirulent LPAI precursor virus (of H5 and H7 subtypes) that mutates to become HPAI after several passages in infected birds (Alexander 2000; Bragstad *et al.* 2005).

Free-living birds provide a reservoir for all avian influenza subtypes, where the virus multiplies in the gastrointestinal tract producing large amounts of virus, usually without showing clinical signs in the host (Tracey *et al.* 2004). The occurrence of influenza A virus among these birds, particularly migratory wildfowl, is of particular concern because their annual migrations put them in contact with a large number of domestic animal species that could become infected (Webster *et al*. 1995). In wild wildfowl hosts the H and N subunits appear to be stable and do not mutate as they do in domestic poultry (Sharp *et al.* 1997), so birds may carry the virus long distances. There is some evidence that AI is also maintained in some shorebirds and gulls but these subtypes tend to be different to those isolated from wildfowl (Kawoka *et al.* 1988). Whilst evidence that initial outbreaks in domestic poultry occur as a result of spread from wild birds is largely circumstantial, there appears to be a positive correlation between the location of AI outbreaks in poultry and wild bird migratory routes (Alexander 2000, Krauss *et al*. 2004), although outbreaks may also arise from the transport of poultry from sources areas.

In addition to being a primary source of infection, it is possible that wild birds may also act as a secondary source of infection of AI between commercial poultry flocks, although this has been little documented. HPAI viruses have rarely been isolated from free-living wild birds and where they have, it has usually been in the vicinity of outbreaks of HPAI in poultry or close to known outbreaks in poultry. It may be that poultry infected with HPAI will have little contact with wild birds due to the high speed at which HPAI causes death in poultry (Alexander 1995). However, wildfowl may be able to transmit LPAI between flocks, which could later mutate into HPAI (Van der Goot *et al.* 2003).

One of the aims of surveillance activities in Great Britain is the early detection of H5N1 following introduction. One proposed mechanism for this is passive surveillance, through public reporting via a helpline combined with carcass collection and laboratory analyses. However, with finite resources, it is important to focus on areas where the likelihood of incursion to domestic poultry is greatest. In Great Britain wild bird monitoring is extremely well established, with most species being well monitored on an annual or near-annual basis by one or more monitoring schemes. We take advantage of this data source here to identify priority areas for surveillance in Great Britain where the likelihood of H5N1 arriving in wild bird populations is most likely, and using data from Defra’s GB Poultry Register, where domestic poultry are most likely to come into contact with wild birds.

4.2 MATERIALS AND METHODS

4.2.1 Wild bird abundance

We currently focus on 24 wild bird species, which according to expert opinion have an increased probability of exposure to H5N1 outside the EU, and which migrate to Great Britain (Table 4.4.1). For information on movements for each of these species see Wernham *et al.* (2002). However, it is appreciated that a much wider group of species may be important in secondary spread, if there was an outbreak of H5N1 in Great Britain. To be in a position to provide information on the distribution and abundance for any species or combination of species at short notice for any month, monitoring data from ten schemes were collated for all wild bird species that are regularly recorded in Great Britain, comprising some 200 million records. Information on each source of data used in the current data set and survey-specific actions to summarise these data where necessary at the lowest recorded 10 km square resolution is provided in Appendix 1. It was necessary to use survey data from a number of schemes, because no one data source provides the best information for all species and months.

Abundance scores (0-5) were assigned to each 10 km square / species / month for each survey, where 0 is species absence, and abundance increases from 1-5. For multi-species surveys, abundance scores were determined by ordering the raw counts within a survey from smallest to largest and dividing the data into five bands, each containing an equal or approximately equal number of counts. This scaling within surveys, across species / months produces relative scores that are comparable within and to a large degree between surveys, such that a species occurring in low numbers in a particular month will only ever receive a low abundance score. Where there were multiple abundance scores for a 10 km square / species / month, it was necessary to use the most appropriate data source. To achieve this, we assigned scores by looking through the data according to a particular survey hierarchy. Table 4.4.2

shows the hierarchy used for the entire dataset covering all wild bird species regularly recorded in Great Britain. Using this hierarchy, an abundance score for a 10 km square / species / month is used if the abundance score is >0. If the abundance score is 0, the next survey in line is checked for a score greater than 0 and so forth. If all surveys record an abundance score of 0, then the resulting abundance score for that 10 km square / species / month is 0. At the lowest level in the hierarchy, the wintering and breeding Atlases achieve complete geographical coverage at the 10 km square resolution.

In the absence of H5N1 in Great Britain the probability of H5N1 incursion is likely to be greatest following the main arrival of migratory waterbirds in Great Britain from October to December. To consider this period, the maximum score recorded for each 10 km square / species / month over the three month period is taken to produce a single map for each of the 24 species (Figure 4.4.1), which was summed across species to produce a combined wild bird species map. All maps in this report were produced in ArcView 3.3 (Bragstad 1998).

4.2.2 Holding-level risk of incursion for domestic poultry

Identification of areas in which domestic poultry is at highest risk of becoming infected with H5N1 via contact with wild birds was carried out using information contained in the GB poultry register (GBPR, extract 12th May 2006). Domestic poultry holdings were ranked according to the estimated likelihood of an incursion from a wild bird source. Poultry considered here include chickens, turkeys, geese and ducks (CTDG) (including ducks reared for breeding or shooting).

Scores were assigned to poultry holdings based on a number of holding-level factors. These included the number and species present on the holding and housing type (indoor or outdoor). Outdoor ducks and geese were considered to be at highest risk followed by outdoor chickens or turkeys. Indoor birds were considered to be at the lowest risk, but have still been assigned a risk score based on size of holding. Larger premises (number of birds) receive a higher score and this effect was considered to be greater in outdoor birds. Temporal changes in poultry density were not considered and bird numbers represent the number of birds usually held on a premises.

Using the scores for the various risk components below, the risk for each species present on each premises was calculated separately as the product of the separate risk factors. The total premises risk was then estimated by summing the species risks. The different components of species and premises risk are scored as follows:

N_i, the number of birds (CTDG) of species *i* on the premises	Score
<50	1
50-999	2
1,000-4,999	3
5,000-9,999	4
10,000-24,999	5
25,000-49,999	6
50,000-99,999	7
100,000-499,999	8
500,000-999,999	9
1000000+	10

SH_i, combined species and housing score	
Outdoor ducks or geese	3
Outdoor chickens or turkeys	2
Indoor, any species	1

HB_j, whether the premises is a commercial hatchery or large breeder premises with high bio-security

Commercial hatchery	0
Commercial breeder (>1,000 breeding birds)	0
Not-commercial hatchery	1

Using these scores for each risk factor, Sp_{ij}, the score for species *i* on premises *j* was calculated as:

$$Sp_{ij} = (N_i * SH_i) \quad (1)$$

Where N_i is the score assigned based on the number of birds of that species present and SH_i was the combined species and housing score. The total risk for premises *j* was then calculated as:

Total risk for premises *j*: $R_j = (\Sigma\ Sp_{ij}) * HB_j$ (2)

Where HB_j is whether the premises is a commercial hatchery or breeder. Because HB_j is a premises level variable and constant for all species on the premises, if the premises is a commercial hatchery or breeder and hence assigned a score of 0, the whole premises is assigned a score of 0, indicating negligible risk.

Using 10 km grid squares, risk scores where then calculated for each square based on the sum of the risk score for premises within that square.

Combining wild bird abundance with poultry risk

A single priority area map for surveillance was calculated as the product of the score of wild bird abundance and the score for poultry risk in each 10 km square.

4.3 RESULTS

4.3.1 Wild bird abundance

A map based on the combined abundance scores for the 24 priority wild bird species is shown in Figure 4.4.2. The contribution that an individual species makes to the combined species map is dependent on the abundance and distribution of the species, with the most abundant and widespread species (e.g. Mallard, Northern Lapwing and Black-headed Gull) contributing most (about 9% of combined species total), and least abundant and localised species (e.g. Ruff, White-fronted Goose and Brent Goose) contributing least (<1% of combined species total) to the combined species map (Table 4.4.3). This map shows that H5N1 is most likely to enter GB via wild birds through East Anglia (Norfolk, Suffolk, Essex and Cambridgeshire), Staffordshire, Shropshire, Northamptonshire, Nottinghamshire, Bedfordshire, Leicestershire, Lincolnshire, East Sussex, Kent, Cheshire, Merseyside and Fife region. Surveillance of wild birds in these areas would maximise the chance of detecting a wild bird with H5N1, irrespective of the likelihood that the bird would come into contact with poultry.

4.3.2 Poultry Risk

The ranking of 10 km squares by risk of incursion to poultry is shown in Figure 4.4.3. Raw scores have been grouped into 6 quantiles, where 1 indicates squares considered at highest risk of incursion and squares with a rank of 6 having negligible risk as these squares contain no registered poultry. In all cases ranks are ordinal. Large areas of the Scottish highlands, North of England and inland Wales appear to contain no poultry, probably due to the fact that these are mountainous or hilly areas and unsuitable for poultry keeping. The lower lying areas of England, north and south coasts of Wales and the East coast of Scotland should be considered higher risk. In particular, looking at where the highest ranking squares occur, Norfolk, Suffolk, Devon, Lancashire and the Welsh Borders (Hereford, Shropshire, Cheshire) appear to be at greatest risk as these areas have large poultry populations, and particularly Devon, have a high proportion of outdoor holdings. North and West Yorkshire, Lincolnshire, Nottinghamshire and Derbyshire also contain a large number of high-ranking squares. Smaller areas of high risk to poultry occur in Anglesey, north east Scotland, the Fife region and some parts of Cumbria, East and West Sussex and Kent.

4.3.3 Combined wild bird and poultry analyses to identify high priority surveillance areas

Figure 4.4.4 shows a map of combined wild bird and poultry scores, with squares ranked from 1-6 indicating the order of priority for wild bird surveillance. Squares with a rank of 6 had scores of zero, indicating either an absence of wild birds or poultry and thus negligible probability of a direct incursion. All 10 km squares in the top rank (i.e. approximately top 20% of scored squares) are defined as priority squares for surveillance. As such, an area will only be flagged as high priority if there is a high combined abundance score for the 24 wild birds of concern and they are likely to come into contact with domestic poultry (i.e. high risk score for poultry).

The geographical distribution of priority squares shown in Figure 4.4.4 suggests that surveillance should ideally be focused on areas of Norfolk, Suffolk, Lancashire, Lincolnshire, the South west of England and the Welsh Borders. These areas have significant poultry populations (including a high number of free range flocks) and high abundance of the 24 wild bird species of highest concern. Smaller priority areas were identified in Anglesey and the Firth of Forth area of Scotland, which have significant numbers of the wild birds and dense but localised poultry populations. Surveillance in these areas would maximise the probability of detecting H5N1 in a wild bird that may potentially be introduced into a poultry flock.

Table 4.4.4 provides a summary of the above by county with areas ranked by the proportion of 10 km squares identified as high priority. This table uses county boundaries before unitary authorities were introduced in 1995 as it was felt that prioritising unitary authories and metropolitan districts was of less use from an incursion viewpoint as these areas tend to be urban and will thus have few poultry or wild birds. The table shows a similar geographical pattern to Figure 4.4.4 with top ranked counties (with over 40% of squares identified as high priority) including Somerset, West Yorkshire, Nottinghamshire, Norfolk, Suffolk and Cheshire. Whilst a summary by county is useful for visualising broad scale patterns, local areas of importance such as Anglesey are not highlighted at this scale, and may be missed unless finer resolution maps are also considered.

To help our understanding and interpretation of the patterns of priority areas for surveillance, we present a map showing those areas where there is a large difference between wild bird and poultry ranks (Figure 4.4.5). In general wild bird ranks were higher than poultry in coastal squares, and in Scotland, the London area and surrounds, the Cambridgeshire Fens and Anglesey and North Wales. Poultry ranks were higher than wild bird ranks in inland Suffolk, the southwest of England, especially Devon and Cornwall, and in Herefordshire and Shropshire.

4.4 DISCUSSION

This work provides a means to direct resources to enable the early detection of H5N1 in wild birds in GB in areas where domestic poultry are at greatest risk. This has important practical applications for contingency planning and for directing targeted surveillance. The outputs presented here have shown that with finite resources, surveillance would be best focused on areas of East Anglia, particularly Norfolk and Suffolk, Lancashire, Lincolnshire, the South and Southwest of England and the Welsh Borders, all areas with high densities of potentially at risk migratory wild birds and poultry. In addition, other areas in central England, Anglesey, the Firth of Forth and North East Scotland, have local areas of high priority and should not be ignored.

The maps identify areas where there are high densities of poultry holdings at greatest risk and also high densities of selected wild migratory birds. It is important when interpreting these maps to be clear as to what question is selected and what the maps are showing. For example, if the aim were to identify where surveillance should be targeted in order to maximise the chances of finding a wild bird with H5N1, it would be important to consider the wild bird map (Figure 4.4.2) in addition to the combined map (Figure 4.4.5). Figure 4.4.2 highlights areas where there may be a high abundance of wild birds and therefore a high probability that one or more may be infected with H5N1, but which contain fewer poultry and so are not identified on the combined map (e.g. areas of Scotland, Figure 4.4.5). Conversely, if the aim was to identify where the next outbreak in poultry may occur as a result of contact with wild birds, it is important to also consider the poultry map (Figure 4.4.3) as areas such as Devon, which have high densities of outdoor poultry, score relatively lower on the combined map due to the absence of high densities of wild birds. The combined wild bird / poultry map (Figure 4.4.5) presented here attempts to combine the information to produce a single overview, taking into account wild bird abundance and poultry populations to maximise the chances of detecting H5N1 in a wild bird from an area where there is a high chance of AI being introduced into poultry.

Most previous outbreaks of H5N1 in GB (e.g. the 1963, 1979 and 1991 outbreaks in Turkeys) have been in Norfolk, with a few cases in Suffolk and Herefordshire (Alexander, 1982, 1993), all areas with over a quarter of the squares in the county classed as high priority in the present work. The Aberdeen area of Scotland, which experienced a single farm outbreak of H5N1 in 1959, has also been identified here as an area of the country where incursion is relatively high. The Whooper Swan found in Cellardyke, Scotland, from which H5N1 was isolated was not situated in a high priority square. However, from a wild bird perspective, the square was ranked as second priority, and was adjacent to a top ranking wild bird square. The recent LPAI (H7N3) outbreak in April 2006 occurred in three premises close to Dereham, Norfolk. Although the exact route of primary introduction remains unknown in these cases, all three affected premises are situated in a high priority 10 km square.

A necessary assumption of this work is that the GBPR and wild bird data are reliable. The GBPR currently provides the best source of poultry population data for GB, although there is the possibility of low level site duplication, double counting of birds and non-registration of premises, which may influence the 10 km squares identified as high priority. For the wild bird data, the use of several survey data sources should reduce the influence of known geographical and habitat biases associated with particular surveys, although remaining level of bias is uncertain.

By using 10 km squares, we have provided a rapid and standardised means of identifying priority areas. However, it is accepted that wild birds and poultry and not distributed homogenously within 10 km squares, and that particular sections of 10 km squares may be more important. In addition, we appreciate that whilst poultry are essentially static, wild birds of some species may move some large distances between sites. Gulls for example may feed at one or more site during the day and roost at another site some distance away. Counts from survey data should reflect the use of sites by these species, so we have not considered including neighbouring squares or a wider buffer zone around priority squares here. If information from 10 km squares are then summarised at a larger resolution for example at a county level, it is important to appreciate the influence of summarising information at this scale.

The tool should be regarded as adaptive, in that the cut-point at which squares are flagged as high priority be reviewed over time depending on the number of number of birds collected and resources available for bird collection and laboratory analysis. The tool will also be updated to incorporate new wild bird or poultry data or additional species if the international situation changes.

Common name	Scientific name
Mute Swan	*Cygnus olor*
Whooper Swan	*Cygnus cygnus*
Bewick's Swan	*Cygnus columbianus*
Greater White-fronted Goose (European sub-species)	*Anser albifrons albifrons*
Brent Goose (dark-bellied sub-species)	*Branta bernicla bernicla*
Shelduck	*Tadorna tadorna*
Mallard	*Anas platyrhychos*
Gadwall	*Anas strepera*
Northern Pintail	*Anas acuta*
Northern Shoveler	*Anas clypeata*
Eurasian Wigeon	*Anas penelope*
Common Teal	*Anas crecca*
Common Pochard	*Aythya ferina*
Tufted Duck	*Aythya fuligula*
Moorhen	*Gallinula chloropos*
Coot	*Fulica atra*
Northern Lapwing	*Vanellus vanellus*
Eurasian Golden Plover	*Pluvialis apricaria*
Snipe	*Gallinago gallinago*
Ruff	*Philomachus pugnax*
Black-headed Gull	*Larus ridibundus*
Common Gull	*Larus canus*
Herring Gull (Baltic sub-species[1])	*Larus argentatus argentatus*
Lesser Black-backed Gull (SW Scandinavian sub-species[1])	*Larus fuscus intermedius*

Table 4.4.1 Species (and specific races where relevant) which according to expert opinion have increased probability of exposure to H5N1 outside the EU, which migrate to Great Britain.

[1] Monitoring schemes do not record Herring and Lesser Black-backed Gull to sub-species level. Whilst the Baltic sub-species of Herring Gull (*argentatus*) and SW Scandinavian sub-species of Lesser Black-backed Gull (*intermedius*) which are of interest here are common in Great Britain between October to December an unknown proportion of counts will relate to the British breeding sub-species of Herring Gull (*argenteus*) and Lesser Black-blacked Gull (*graellsii*).

Hierarchy[1]	April - August	September - March
1	Rook, Heron and Seabird 2000 breeding gull surveys	Winter Gull Roost Survey & Wetland Bird Survey Goose and Swan roost counts
2	Wetland Bird Survey core count	Wetland Bird Survey core counts
3	Waterways Breeding Bird Survey	Winter Farmland Bird Survey
4	Breeding Bird Survey	Winter Atlas
5	Breeding Atlas	

[1] where 1=top level

Table 4.4.2 Survey hierarchy.

Species	**No. of occupied 10 km squares (% of total)**	**Mean abundance score on occupied squares**	**Contribution to combined species map**
Mute Swan	1,677 (57%)	2.53	3.7%
Whooper Swan	941 (32%)	2.54	2.1%
Bewick's Swan	448 (15%)	2.54	1.0%
Greater White-fronted Goose (*albifrons*)	256 (9%)	2.53	0.6%
Brent Goose (*bernicla*)	256 (9%)	3.02	0.7%
Shelduck	1,008 (34%)	2.52	2.2%
Mallard	2,508 (86%)	4.00	8.7%
Gadwall	800 (27%)	2.67	1.8%
Northern Pintail	712 (24%)	2.31	1.4%
Northern Shoveler	886 (30%)	2.64	2.0%
Eurasian Wigeon	1,556 (53%)	3.65	4.9%
Common Teal	1,916 (66%)	3.58	5.9%
Common Pochard	1,469 (50%)	3.09	3.9%
Tufted Duck	1,614 (55%)	3.26	4.7%
Moorhen	1,960 (67%)	2.74	4.6%
Coot	1,652 (56%)	3.25	4.6%
Northern Lapwing	2,247 (77%)	4.51	8.8%
Eurasian Golden Plover	1,550 (53%)	4.11	5.5%
Snipe	2,122 (73%)	2.63	4.8%
Ruff	305 (10%)	1.91	0.5%
Black-headed Gull	2,272 (78%)	4.49	8.8%
Common Gull	2,237 (77%)	3.92	7.6%
Herring Gull	2,298 (79%)	3.80	7.5%
Lesser Black-backed Gull	1,541 (53%)	2.69	3.6%

Table 4.4.3 Number of 10 km squares occupied by each species, mean abundance scores on occupied squares and the relative contribution that each species makes to a combined wild bird species map.

County*	% of squares high priority (number)	% squares high priority from wild bird perspective (number)	% squares high priority from poultry perspective (number)
Somerset	46% (24)	17% (9)	62% (32)
West Yorkshire	45% (15)	27% (9)	36% (12)
Nottinghamshire	42% (15)	47% (17)	28% (10)
Norfolk	42% (32)	45% (35)	39% (30)
Suffolk	41% (24)	38% (22)	43% (25)
Cheshire	41% (16)	54% (21)	28% (11)
Lancashire	41% (20)	29% (14)	31% (15)
East Sussex	38% (13)	47% (16)	38% (13)
Worcestershire	38% (13)	24% (8)	56% (19)
Staffordshire	37% (17)	43% (20)	26% (12)
Dorset	36% (18)	28% (14)	38% (19)
Derbyshire	34% (15)	23% (10)	30% (13)
Shropshire	33% (18)	13% (7)	46% (25)
Avon	32% (9)	36% (10)	32% (9)
Essex	31% (18)	48% (28)	22% (13)
West Sussex	31% (11)	28% (10)	31% (11)
Warwickshire	29% (11)	34% (13)	37% (14)
Leicestershire	29% (12)	45% (19)	21% (9)
South Yorkshire	28% (8)	38% (11)	21% (6)
Gloucestershire	27% (12)	20% (9)	36% (16)
Herefordshire	26% (9)	6% (2)	63% (22)
Hampshire	25% (15)	41% (24)	15% (9)
Lincolnshire	25% (21)	39% (32)	22% (18)
Merseyside	25% (5)	70% (14)	10% (2)
Devon	25% (24)	8% (8)	45% (44)
Kent	24% (15)	47% (29)	19% (12)
Bedfordshire	22% (5)	43% (10)	9% (2)
West Midlands	21% (4)	37% (7)	21% (4)
Humberside	21% (13)	37% (23)	16% (10)
Greater Manchester	21% (5)	13% (3)	21% (5)
Buckinghamshire	20% (7)	34% (12)	20% (7)
Oxfordshire	20% (8)	32% (13)	15% (6)
Northamptonshire	19% (8)	62% (26)	12% (5)
North Yorkshire	17% (20)	15% (18)	22% (26)
Cambridgeshire	17% (9)	41% (22)	7% (4)
Cleveland	16% (3)	16% (3)	21% (4)
Tyne & Wear	15% (2)	38% (5)	8% (1)
Wiltshire	15% (8)	2% (1)	15% (8)
Clwyd	15% (7)	23% (11)	10% (5)
Berkshire	14% (4)	29% (8)	7% (2)
Surrey	13% (4)	30% (9)	17% (5)
Durham	10% (4)	3% (1)	8% (3)
Fife region	10% (3)	40% (12)	7% (2)
Hertfordshire	10% (3)	27% (8)	7% (2)
Cumbria	9% (9)	14% (14)	7% (7)
Isle of Wight	9% (1)	55% (6)	9% (1)

Table 4.4.4 The percentage (number) of each county identified as high priority based on combined, wild bird and poultry ranks.

County*	**% of squares high priority (number)**	**% squares high priority from wild bird perspective (number)**	**% squares high priority from poultry perspective (number)**
Cornwall & Isles of Scilly	7% (5)	11% (8)	14% (10)
Greater London	7% (2)	37% (11)	0% (0)
Tayside region	5% (5)	12% (13)	3% (3)
Gwynedd	5% (5)	25% (16)	2% (1)
Central region	4% (5)	14% (7)	2% (1)
Powys	4% (2)	4% (3)	5% (4)
South Wales	3% (2)	25% (16)	8% (5)
Lothian	3% (1)	17% (6)	0% (0)
Orkney	2% (1)	18% (8)	0% (0)
Dyfed	2% (2)	15% (17)	0% (0)
Grampian region	1% (1)	6% (7)	1% (1)
Strathclyde region	0% (0)	7% (18)	0% (0)
Dumfries & Galloway	0% (0)	12% (11)	0% (0)
Western Isles islands area	0% (0)	5% (5)	0% (0)
Highland	0% (0)	2% (8)	0% (0)
Northumberland	0% (0)	23% (17)	0% (0)
Scottish Borders	0% (0)	6% (4)	0% (0)
Shetland	0% (0)	2% (1)	0% (0)

***** boundaries prior to the introduction in 1995 of unitary authorities and metropolitan districts.

Table 4.4.4 (continued)

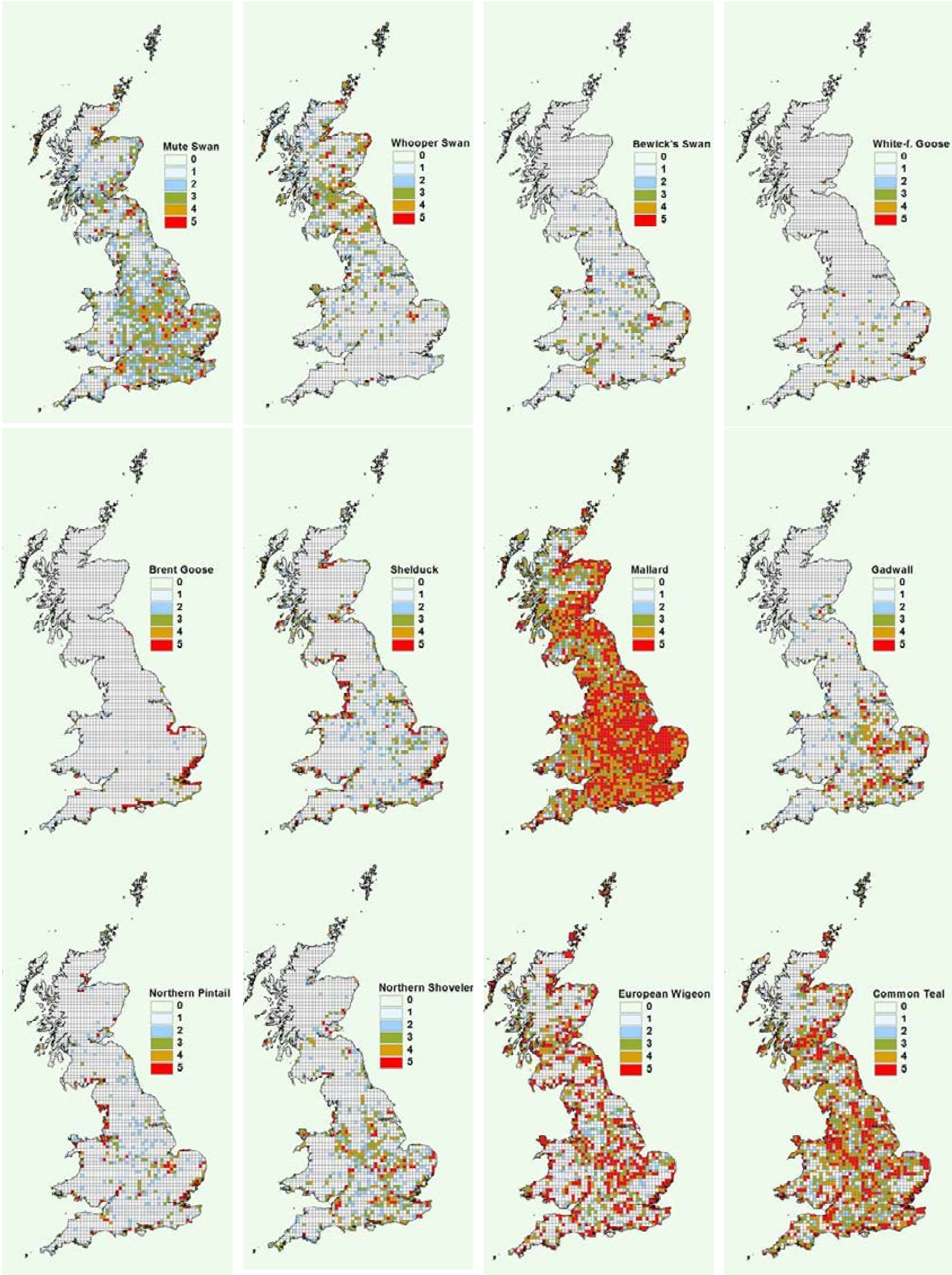


Figure 4.4.1 Abundance score maps for each of the 24 high priority wild bird species.

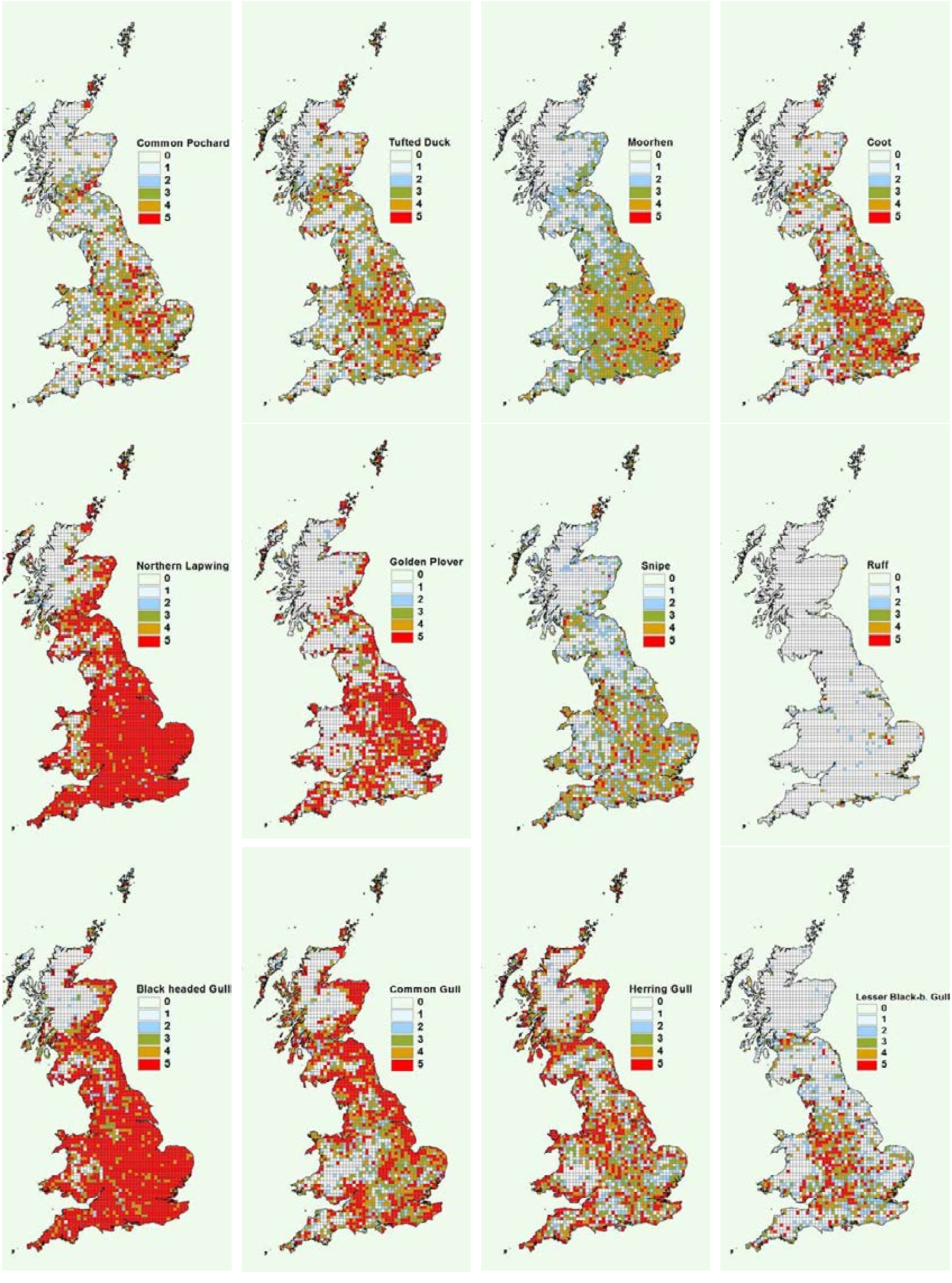


Figure 4.4.1 (continued)

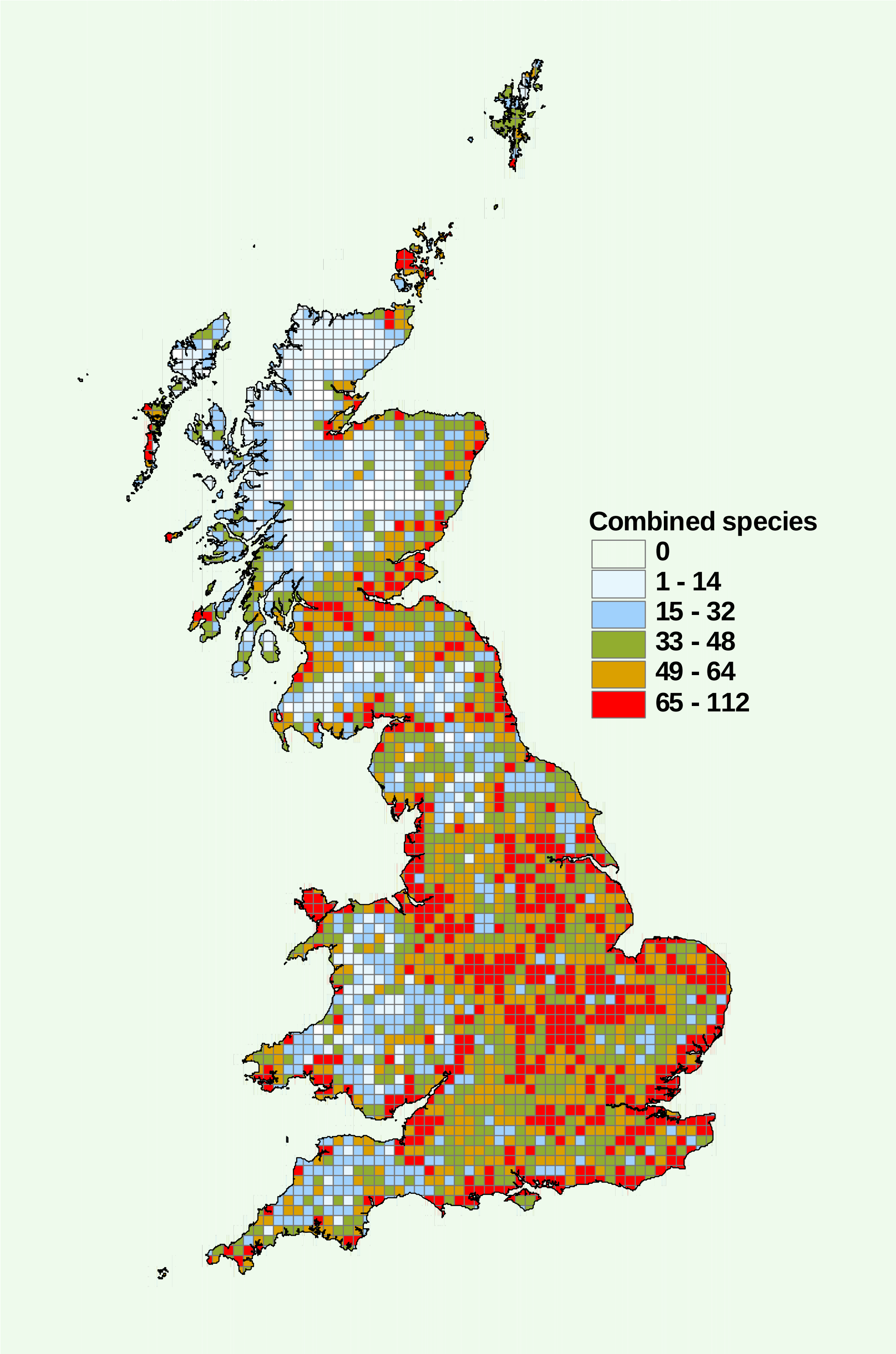


Figure 4.4.2 Wild bird abundance scores based on the combined scores for the 24 high-priority wild bird species.

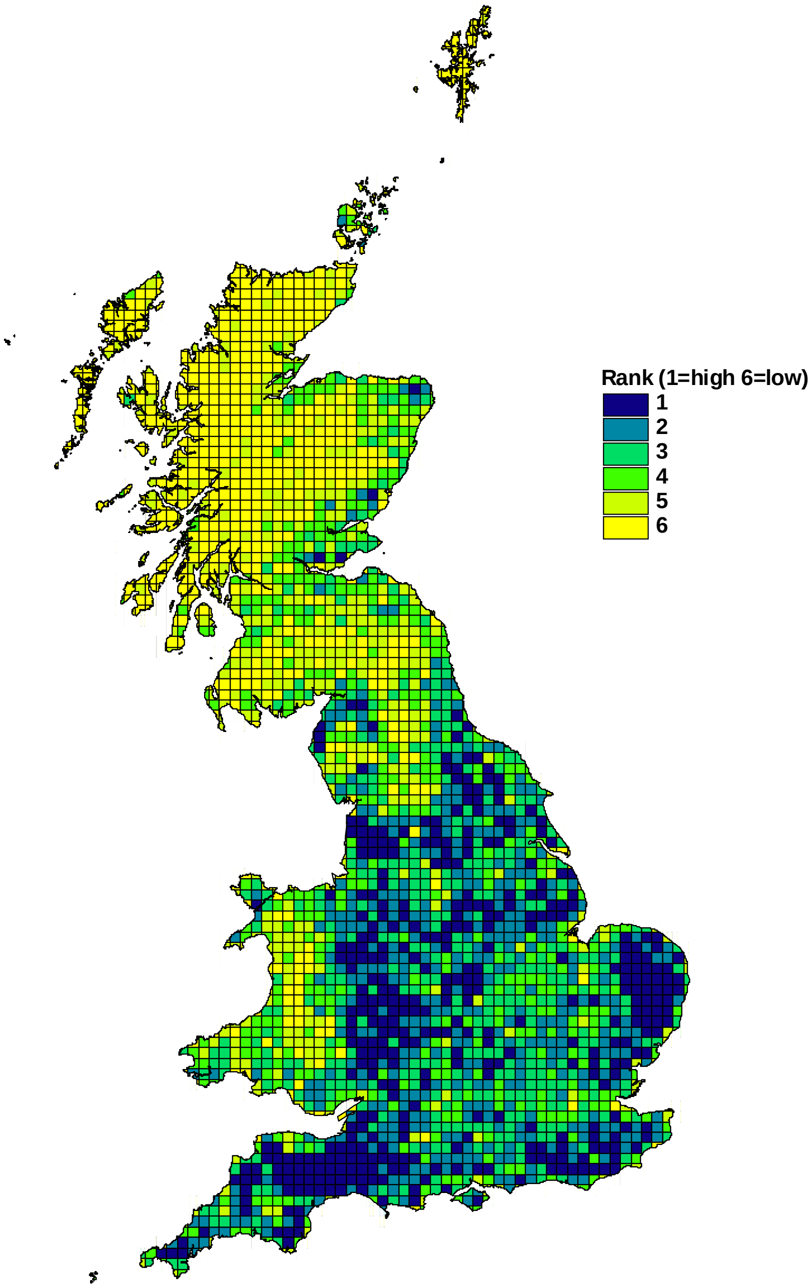


Figure 4.4.3 Domestic poultry scores (ranked 1-6 in order of high to low concern).

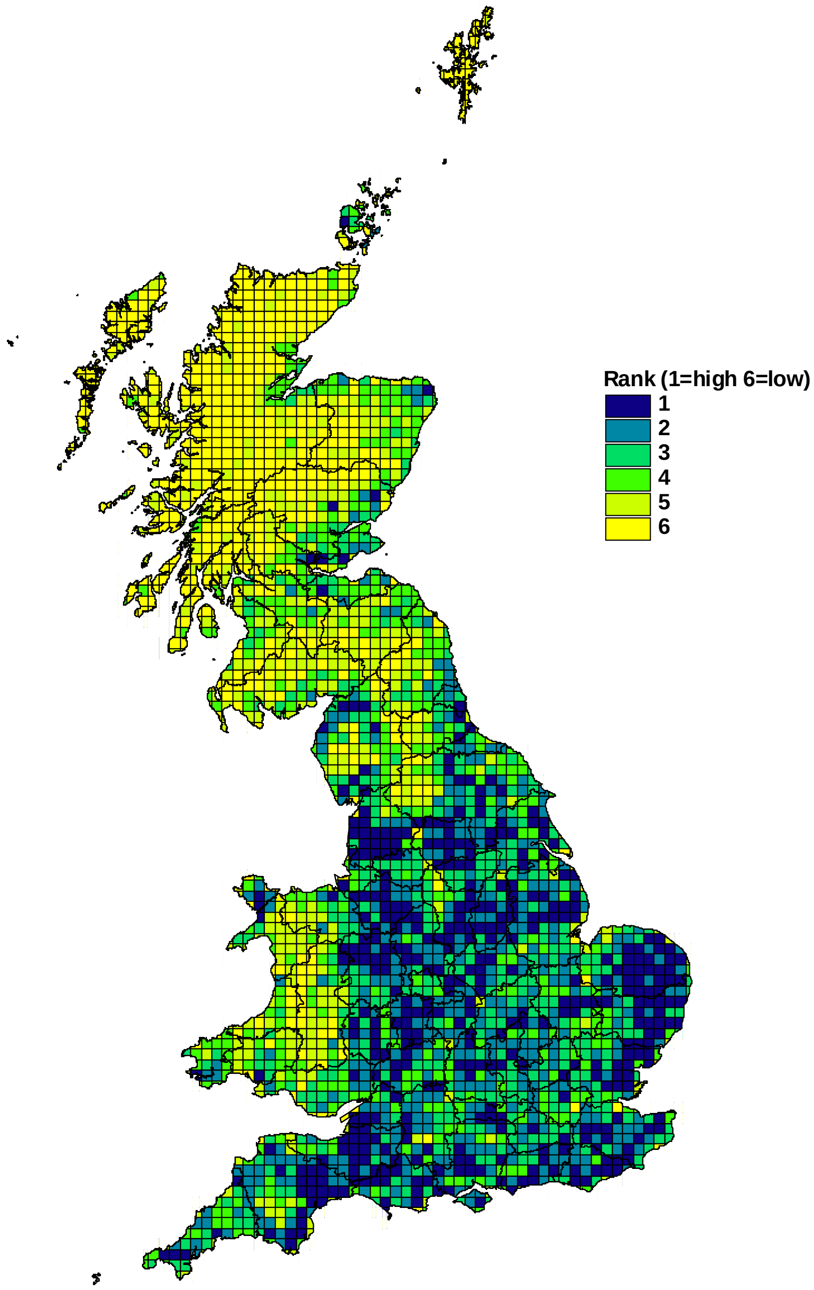


Figure 4.4.4 Combined poultry and wild bird scores to show areas of GB where the probability of incursion of H5N1 is likely to be highest given our understanding of bird and poultry populations in those areas (ranked 1-6 in order of high to low priority/concern).

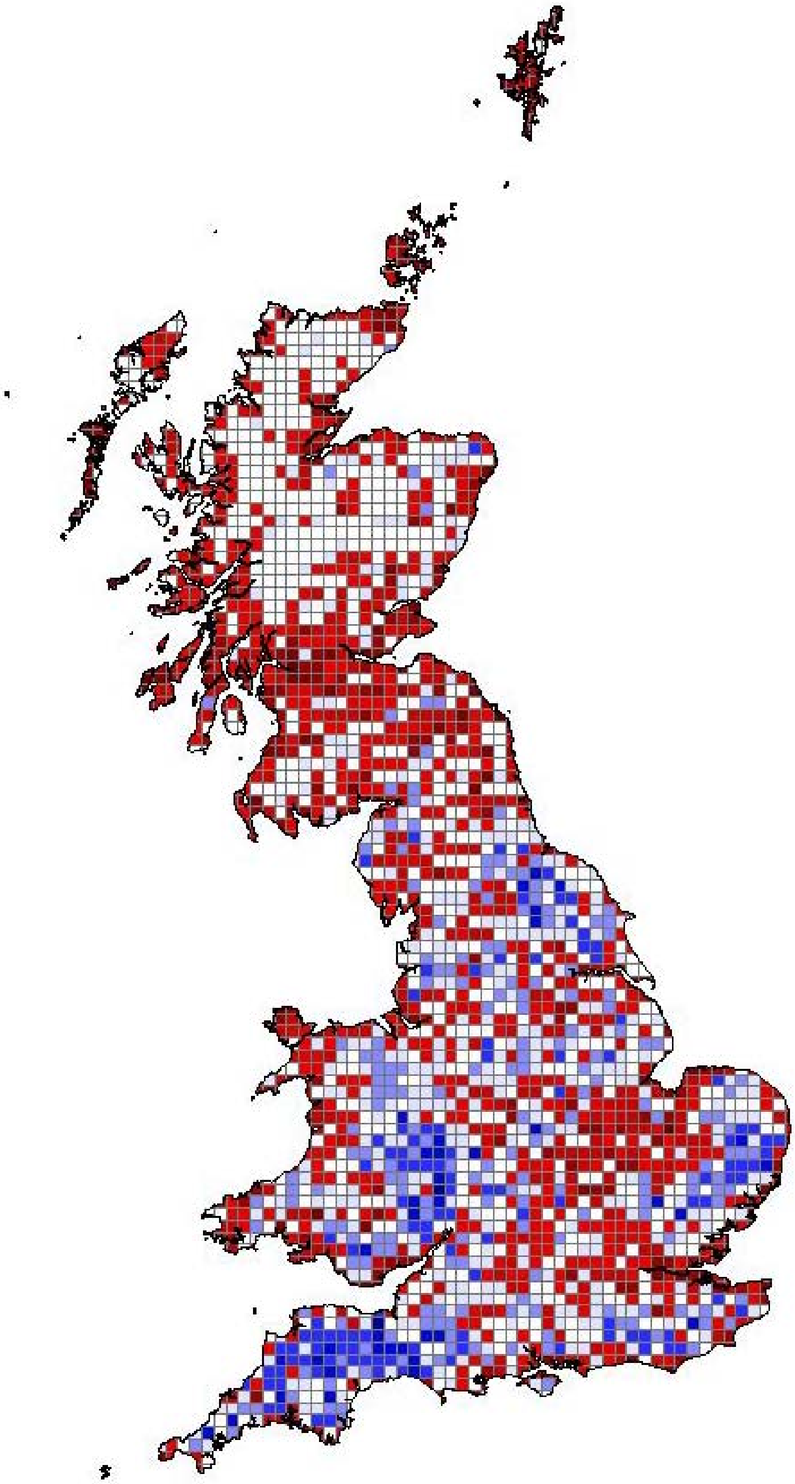


Figure 4.4.5 Difference between wild bird and poultry ranks, where dark red indicates squares where wild bird rank > poultry rank and dark blue indicates squares where poultry rank > wild bird rank.

5. SURVEILLANCE IN GREAT BRITAIN FOR HIGHLY PATHOGENIC AVIAN INFLUENZA (H5N1): CONSIDERING A WIDER GROUP OF CARRIER SPECIES

Stuart E. Newson[1], Andrew J Musgrove[1], Dan E Chamberlain[1] and Peter Cranswick[2]

[1] British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU, United Kingdom
[2] The Wildfowl & Wetlands Trust, Slimbridge, Gloucestershire, GL2 7BT, United Kingdom

5.1 INTRODUCTION

If H5N1 were to become established in wild birds in Great Britain, a wider group of species than considered in the previous chapter could act as carriers and be involved in the spread of the disease. The following is an attempt to introduce a weighting, such that wild birds most likely to transmit H5N1 to domestic poultry would contribute most to a priority area map.

It is appreciated that there is much to learn about factors that influence the likelihood of wild bird infection, its spread within and between wild bird populations and its transmission from wild birds to domestic poultry. With this uncertainty, the following should be treated as a provisional framework, which can be adapted and developed in relation to changes in our understanding of these issues. The contribution that we want particular wild bird species to make to a priority area map may also change in response to outbreaks.

We have developed a formulaic approach here, to allow the framework of the tool to be tested.

5.2 METHODS

5.2.1 General formula for determining the proportional risk of poultry infection

The tool aims to describe the proportional risk P of domestic poultry becoming infected with H5N1 by wild birds, considering a wider group of carrier species for each 10 km square and month of the year.

$$P = N \times R \quad (1)$$

where N relates to the premises with domestic poultry and likelihood that these sites could be infected (the calculation of which is discussed elsewhere), and R relates to wild birds and likelihood that particular species could be infected and come into contact with domestic poultry, irrespective of N.

$$R = \Sigma\ (Ri) \quad (2)$$

where Ri is the risk of domestic poultry being infected through contact with a wild bird of given species i.

Ri depends upon two things, the likelihood that wild bird species i (Ci) will come into contact with domestic poultry and the likelihood that species i is infected with H5N1 (Di)

$$Ri = Ci \times Di \quad (3)$$

Ci depends upon two things, the number of individuals of species i present in the area (Xi) and the proximity and hence likely contact of species i with domestic poultry (Bi).

$$Ci = Xi \times Bi \quad (4)$$

Di, the chance of the individual wild bird being infected, depends upon what we know about the disease, so brings into play the known propensity of different species to harbour the virus, their flocking tendency, use of water-bodies and information on recent outbreaks (see section 2.2 for details of its calculation).

Xi, is the relative abundance (scored 0-5) of species *i* in any particular 10 km square and month (see previous chapter for details)

For *Bi*, (scored 0-3) our assessment is currently based on the probability of a wild bird species coming into contact with poultry as defined by EFSA for Europe (2006), see Table 5.2.2.1. However in a British context we feel this list could be improved upon. For example the list does not include Lesser Black-backed Gull and Stock Dove both species, which we feel would be likely to interact with free-range poultry.

To summarise:

$$P = N \times \Sigma (Xi \times Bi \times Di)$$

5.2.2 Calculating *Di*, the chance of the wild bird being infected with H5N1

Di is the sum of scores relating to the propensity of the wild bird species to harbour the virus, its gregariousness, use of freshwater habitat, and the status of recorded infections of H5N1 in this species.

In terms of the propensity of the species to harbour the virus, many species are likely to be potential carriers that have not been screened for HPAI (H5N1). Where testing for disease presence has been carried out, there is a bias in the species of wildfowl in particular being over-represented. For this reason we classify species according to the relative occurrence of AI recorded within the species group (e.g. wildfowl, gamebirds etc) for which we use the figure published in http://www.nwhc.usgs.gov/publications/field_manual/_chapter_22.pdf as a guide, in combination with information from workstream 1.

Whilst there is discussion as to whether *Di* should take the movements and timing of wild bird movements into account, at present the components of *Di* will be scored as follows:

Propensity to harbour the virus	Score
Wild bird species of highest concern (24 species)	10
Wildfowl (excluding priority species)	7
Gulls and waders (excluding priority species)	5
Gamebirds, corvids and raptors	3
Other species	1
Flocking behaviour	
Regularly flocks	1
Does not flock	0
Use of freshwater habitat	
Uses freshwater habitat/s	1
Does not use freshwater habitat/s	0
H5N1 infection status in Europe	
Outbreak within 3 months	4
Outbreak within 3-12 months	3
Outbreak >12 months	2
No previous or existing outbreak	0

Di can be updated given new information on outbreaks

A demonstration of the calculation of *Ri*, the risk of domestic poultry being infected through contact with three example wild bird species, Mallard, Corn Bunting and Blue Tit is shown in Appendix 5.1.

Common name	Scientific name	Contact with poultry	Score
Egrets	*Egretta spp.*	Low	1
Herons	*Ardea spp.*	Medium	2
Great Cormorant	*Phalacrocorax carbo*	Medium	2
Storks	*Ciconia spp.*	Low	1
Mute Swan	*Cygnus olor*	Medium	2
Greylag Goose	*Anser anser*	Medium	2
Canada Goose	*Branta canadensis*	Low	1
Ducks	*Anas & Aythya spp.*	Low	1
Mallard	*Anas platyrhynchos*	High	3
Coot	*Fulica atra*	Medium	2
Moorhen	*Gallinula chloropus*	Medium	2
Golden Plover	*Pluvialis apricaria*	Low	1
Northern Lapwing	*Vanellus vanellus*	Medium	2
Black-headed Gull	*Larus ridibundus*	High	3
Common Gull	*Larus canus*	High	3
Herring Gull	*Larus argentatus*	Low	1
Wood Pigeon	*Columba palumbus*	High	3
Collared Dove	*Streptopelia decaocto*	High	3
Pheasant	*Phasianus colchicus*	High	3
Larks	*Alauda & Galerida spp*	Low	1
Pipits	*Anthus spp*	Low	1
Wagtails	*Motacilla spp*	Medium	2
Fieldfare	*Turdus pilaris*	Medium	2
Redwing	*Turdus iliacus*	Medium	2
Magpie	*Pica pica*	High	3
Jackdaw	*Corvus monedula*	High	3
Rook	*Corvus frugilegus*	Medium	2
Carrion Crow	*Corvus corone*	Medium	2
Raven	*Corvus corax*	Low	1
Starling	*Sturnus vulgaris*	High	3
House Sparrow	*Passer domesticus*	High	3
Tree Sparrow	*Passer montanus*	High	3
Finches	*Fringilla & Carduelis spp*	Medium	2
Buntings	*Miliaria, Emberiza spp.*	Medium	2

Table 5.2.2.1. The probability of a wild bird species coming into contact with poultry as defined by EFSA 2006. “Migratory birds and their possible role in the spread of highly pathogenic Avian Influenza”. *EFSA Journal* **357**, 1-46.

EFSA define the probability of contact with poultry as being ‘High’, ‘Medium’ or ‘Low’. For species not included on this list, we create an additional category ‘Very low’. Categories are scored from 0 (Very Low) to 3 (High).

6. COLD WEATHER MOVEMENTS REVIEW

Jacquie A. Clark and Robert A. Robinson

British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU, United Kingdom

6.1 INTRODUCTION

In temperate regions, severe winter weather may cause birds to move in order to avoid the cold (eg Baillie *et al.* 1986, Ridgill & Fox 1990), or lead to increased mortality (eg Dobinson & Richards 1964, Davidson & Evans 1982) and may drive changes in distribution, numbers and composition of populations. The extent of cold weather movements varies (eg Baillie *et al.* 1986, Ridgill & Fox 1990) both geographically and temporally, as does the distribution of cold weather mortality (Dobinson & Richards 1964, Clark 1982a, b). Severe weather mortality of waders is more common in the colder east, although in future, with global warming, winter weather severe enough to cause both movement and increased mortality amongst waders is likely to become rarer as temperatures increase (Hulme & Jenkins 1998). Indeed, recent shifts to the north and east in the distribution of waders both within Britain & Ireland (Austin & Rehfisch 2005) and on a European scale (Maclean *et al.* in prep) and in Tufted Duck on the Continent (Hofer *et al.* 2005) have already been detected, and appear to be related to changes in winter temperature (Rehfisch & Crick 2003).

Severe weather has both direct and indirect effects on birds and may cause them either to change their behaviour to ameliorate the effects or to move to a different area in an attempt to avoid the harsh weather. A reduction in temperature increases the energy requirements of birds and may also make it more difficult for individuals to obtain prey. Similarly, increased wind speed increases energy requirements as the temperature experienced is reduced by higher wind speed (‘wind chill’ Steadman 1971). Increased wind also has indirect effects on birds, again by making foraging more difficult.

Many species move in response to cold weather with some studies showing substantial shifts in bird populations, most notably in waterbirds (eg Allsopp & Madge 1979, Baillie *et al.* 1986, Beer & Boyd 1964, Chandler 1981, Doude van Troostwijk 1965, Harrison & Ogilvie 1967, Monval & Pirot 1989, Owen *et al.* 1986, Pilcher 1964, Ridgill & Fox 1990, Saint-Gerand 1982). In northwest Europe, most movements are to the south and west of the wintering range that a species occupies in milder years, so that they move to an area where warmer temperatures are likely to mean that food supplies are more available (Ridgill & Fox 1990). Birds forced out of Scandinavia and the Baltic tend to move towards Poland and Denmark and further west into the Waddensea (eg Monval & Pirot 1989). In extreme cold, birds from the far north may reach Britain or the Atlantic coast of France and Iberia. Birds also move to Britain from the near Continent (eg Ridgill & Fox 1990). Monval & Pirot (1982) suggest that the Netherlands, France, the British Isles and Spain are the most important refuge areas for birds seeking to avoid severe weather. In common with birds elsewhere, movements of British birds tend to be to the south and west, even though for waders east coast estuaries hold a higher density of prey and are likely to be a better habitat (Holloway *et al.* 1995). It is worth noting that such movements are not without costs: if birds move they can experience increased mortality through exposure or starvation (Whyte & Bolen 1984) or by increased success of human hunters (Raffin & Lefeuvre 1982).

Different species of birds have varying movement strategies in response to severe weather, which may be related to their feeding ecology (Baillie 1984). Amongst ducks, the most susceptible species are those that feed in freshwater habitats that become frozen. Waders that feed on inland fields, such as Lapwing and Golden Plover, tend to be most vulnerable to cold weather as their habitat will usually freeze before coastal habitats; they make cold weather movements most readily (Baillie *et al.* 1986). Species feeding exclusively on intertidal flats (eg Grey Plover, Knot) tend not to move in periods of cold weather as their habitat is least likely to freeze, although coastal waders in the Waddensea, where conditions are more severe, do make cold weather movements. Some cold weather movements have been recorded in species such as Oystercatcher which largely feed on intertidal flats, but such movements are less common (Baillie *et al.* 1986) and have been demonstrated in some situations (Pilcher 1964, van Eerden 1977, Hulscher 1989, Camphuysen *et al.* 1996) but not others (Swennen & Duiven 1983, Camphuysen *et al.*1996). The 'decision' of individuals to move may relate to the severity of the weather and the availability of food. For example, Oystercatchers in the Netherlands appear to follow a strategy of remaining on their normal wintering grounds as long as possible but of moving south (generally not to Britain) once their reserves are only just sufficient for a move (Hulscher 1989).

The extent of movements may also be affected by the time of year. Suter & van Eerden (1992) found that diving ducks died on an important wintering site for wildfowl in Switzerland and in the western part of the Dutch Waddensea in March 1986 after a month-long cold spell in February. They speculated that wildfowl migration strategy does not account for extremely long cold spells in late winter as the probability of such events is low. They thought that birds therefore risked staying and starving instead of moving and possibly surviving.

6.2 METHODS

Here, we review instances of severe weather movements reported in the literature. Information about species which have been recorded making regular movements, or moving in large numbers, is organised by species, the remaining species are summarised separately. To put the main species accounts into context, the flyway population, European breeding population, UK summer abundance, UK winter abundance, summer range of the B&I population and winter range of the B&I population are given. This information is taken from the spreadsheet (chapter 2). Definitions of the information provided can be found in the notes to the spreadsheet and are reproduced in this chapter as appendix 6.1. A short section on species were cold-weather movements have been looked for but not found is included. Appendix 6.2 gives a summary of severe weather periods in Britain & Ireland in the last 50 years.

Where appropriate, maps showing movements or positions of birds in cold weather have been reproduced. For several species, maps of the winter recoveries of birds either ringed or found in Britain & Ireland have been drawn, but excluding:

- Either the ringing or finding date was outside the winter period defined as November to February.
- The finding condition of the bird was coded as long dead.
- The finding condition of the bird was coded as unknown.
- The accuracy of the finding coordinates was greater than 50 minutes.
- The accuracy of the finding date was greater than 15 days.
- The accuracy of the finding date was long dead.
- The accuracy of the finding date was unknown.

Recoveries were included where the finding date used was the report date, as this is generally within a few days of finding.

For Teal, for which there is much data, only those recoveries within a single winter were selected, with the finding location marked with an open circle. These records were further filtered to include only those over 150 km in distance.

For all other species, all with fewer data, the open circles denote the later of the two records in the winter period, regardless of the actual calendar years involved (for example 01/11/1985 is considered earlier than 01/12/1984).

It should be noted that much of the information on severe weather movements has been collected incidentally as part of other studies. Much of the information is anecdotal, not quantitative, and often cannot determine where birds went when fewer were present in area, or where they came from when numbers increased. Cold weather movements can be detected by counts and by changes in the pattern of recoveries of ringed birds. There have been some quantitative studies using counts (eg Monval & Pirot 1989), recoveries of ringed birds (eg Baillie *et al.* 1986) or both (eg Ridgill & Fox 1990). However, even these studies have some limitations. Monval & Pirot (1989) used International Waterfowl Research Bureau (IWRB) counts from across Europe, but these counts are only available for mid-January and therefore will often miss severe weather movements. Also, counts alone can provide correlations, but do not confirm particular movements. In addition, Monval & Pirot (1989) noted that the count data did not really cover open sea specialists (Red-breasted Merganser, Smew, Goldeneye and sea ducks) and that Coot and Tufted Duck moving offshore may have been missed. Baillie *et al.* (1986) used ringing recoveries and were thus able to show connectivity, but this study was restricted to birds ringed in Britain & Ireland and did not relate the ringing recoveries to counts. Ridgill & Fox (1990) brought together ringing recoveries and counts on a European scale. They used IWRB mid-January counts, but had some additional data from November and March for some years and only had recovery data from a limited number of ringing schemes (Britain, the Netherlands, and France, with limited data from Belgium and Finland).

6.3 SPECIES ACCOUNTS

6.3.1 Species thought to make regular and/or substantial cold-weather movements

Mute Swan *Cygnus olor*

Flyway Population	250,000
European Breeding Population	71,000 – 100,000
UK Summer Abundance	12,400 (11,950 – 12,800)
UK Winter Abundance	43,500
Summer Range of UK Population	UK
Winter Range of UK Population	UK

A review of immigration of Mute Swans to Britain & Ireland (Harrison & Ogilvie 1967), suggested that birds from the Continent arrive in the southeast in cold weather, albeit in small numbers. Evidence from ringing recoveries suggests that these birds originate from Sweden, Germany and the Netherlands, with birds from south and southeast England moving to France (Fig 6.3.1.1). Mute Swans in Sweden move to the south coast with the onset of freezing conditions (Berglund *et al.* 1963) and, in particularly severe weather, may then move on to the Baltic and Denmark, with some arriving in southeast England (Harrison & Ogilvie 1967). Mute Swans ringed in Denmark and the Netherlands have been found as far south as France in cold winters (Harrison & Ogilvie 1967). Mute Swans in Britain & Ireland are sedentary and do not move in response to severe weather (Baillie *et al.* 1986).

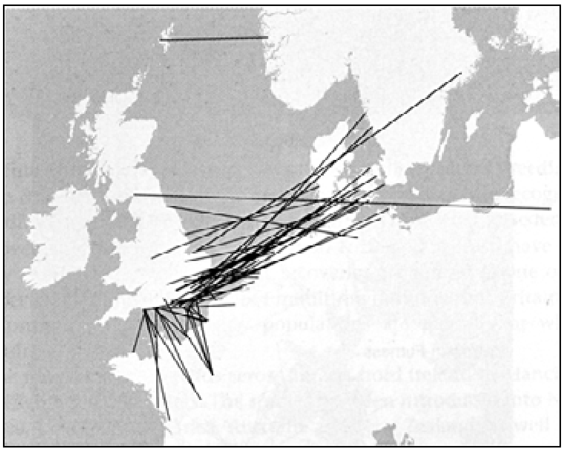


Figure 6.3.1.1 Movements of Mute Swans between Britain & Ireland and abroad. Reproduced from Wernham *et al.* 2002.

Pink-footed Goose *Anser brachyrhynchus*

Flyway Population	240,000
European Breeding Population	50,000 – 69,000
UK Summer Abundance	Rare
UK Winter Abundance	240,000
Summer Range of UK Population	Eastern Greenland, Svalbard, Iceland
Winter Range of UK Population	UK; rare in Ireland

Extensive movements of Pink-footed Geese from Germany were observed in cold weather in February 1956 with increased numbers being recorded in the Netherlands, Belgium and northern France (Holgersen 1958). Holgersen (1958) does not mention any evidence of movement to Britain in this cold spell.

Pink-footed Geese in the Netherlands move southwest, especially to Belgium (Lok *et al.* 1992). While those in Belgium also disperse to the west in cold weather, with some birds moving from their normal wintering areas of the Oostkustpolders (Oostende and Brugge to the Dutch/Belgian border) to the River Yzer valley, although the destination of displaced birds is not always clear (eg 75% of the population was unaccounted for in January 1985) (Meire *et al.*1988).

Pink-footed Geese appear to make cold-weather movements within Britain, with birds moving from Scotland to northwest England in 1961/62, 1962/63, 1978/79 and 1981/82 (Baillie *et al.* 1986). However, it is now the normal pattern for birds to move from Scotland to Lancashire and Norfolk over the course of the winter, probably in response to food availability in Norfolk, so the effect of cold weather is now harder to discern (Collier *et al.* 1986). Moreover, the numbers of Pink-footed Geese in Norfolk are well in excess of those on the near Continent (Burfield & van Bommel 2004) and so it would be difficult to notice a cold weather arrival form the east, except through observations of individually marked birds.

Although there does not appear to be any evidence of Pink-footed Geese from the Continent coming to Britain in cold weather, this possibility cannot be discounted.

White-fronted Goose *Anser albifrons*

Flyway Population	1,000,000
European Breeding Population	1,700 – 2,000
UK Summer Abundance	Rare
UK Winter Abundance	26,790
Summer Range of UK Population	Greenland and Arctic Tundra
Winter Range of UK Population	UK

In January 1963 exceptional numbers of White-fronted Geese were reported in Britain & Ireland, both in normal wintering sites and at places where they did not normally occur. Ringing recoveries showed that at least some of these geese came from the Netherlands (Beer & Boyd 1964), and there was large-scale emigration from there after blizzards on 30 December and 3-4 January (Doude van Troostwijk 1965).

The number of White-fronted Geese wintering in the Netherlands does not appear to be affected by the weather, although cold weather does appear to lead to increased numbers in Belgium (eg 32,000-55,000 in 1985/87, but 16,000-20,0000 in two subsequent mild winters) (Lok *et al.* 1992). Also the distribution of White-fronted Geese in Belgium changes in cold winters, with birds moving from traditional wintering areas to use new wintering areas in northeast Flanders and along the River Yzer valley (Meire *et al.* 1988).

In a cold winter in 1998/99 the amount of grazing on the foreshore by White-fronted Geese in the northwestern part of the Lower Rhine area was lower than in a warmer winter in 1997/98 suggesting birds had moved out (Bellasus 2001). Goose frequency was also reduced in the severe winter of 1996/97. In both these periods, birds moved to the nearby polders, but there does not appear to be any evidence of more distant movements.

It is likely that in severe weather, White-fronted Geese will move to Britain from the near Continent.

Canada Goose *Branta canadensis*

Flyway Population	Not available
European Breeding Population	2,500 – 10,000 (non-introduced)
UK Summer Abundance	41,275
UK Winter Abundance	82,550
Summer Range of UK Population	UK
Winter Range of UK Population	UK

In the severe winter of 1978/79 600 Canada Geese, thought to be from the Swedish breeding population (a few birds carried Swedish rings), moved to the Netherlands (Dirksen 1980, Lok *et al.* 1992). Influxes have also been seen in more recent cold winters (Lok *et al.* 1992).

The population of Canada Geese in Britain is largely sedentary, although there is evidence that small numbers of birds from central Britain move to southern Britain and France in severe weather (Baillie *et al.* 1986).

Barnacle Goose *Branta leucopsis*

Flyway Population	54,100 (E Greenland), 23,000 (Svalbard)
European Breeding Population	18,000 – 21,000
UK Summer Abundance	1,000 (naturalised birds)
UK Winter Abundance	67,000
Summer Range of UK Population	Svalbard, eastern Greenland, Novaya Zemlya
Winter Range of UK Population	UK; chiefly Scotland and Ireland

Barnacle Geese wintering in the Netherlands show a varied response to cold weather, depending on where they are able to find snow-free feeding areas (Lok *et al.* 1992). In some years birds move to the Delta area in the Netherlands or into Belgium and France, but in other years they may only move short distances. No evidence of Barnacle Geese moving to Britain & Ireland in cold weather has been reported.

Brent Goose *Branta bernicla*

Flyway Population	215,000 (Dark-bellied, W Siberia), 5,000 (Light-bellied, Svalbard, N Greenland)
European Breeding Population	600 – 1,700
UK Summer Abundance	Rare
UK Winter Abundance	98,100 (Dark-bellied), 22,900 (Light-bellied)
Summer Range of UK Population	Western Siberia, Greenland, Svalbard
Winter Range of UK Population	UK; mainly coastal

Madsen (1984) used count data to look at distribution of Light-bellied Brent Geese around the North Sea and found that the distribution was related to weather conditions. When the weather was severe on Continental coasts the population size in Britain increased, with the whole population moving to Lindisfarne in northeast England in 1978/79 and 1981/82.

Numbers of Dark-bellied Brent Geese wintering in the Netherlands decline markedly in severe winters when they may move to Britain and France (Lok *et al.* 1992). Several colour-ringed birds that were seen in the Netherlands in March 1987 were also seen later that month in East Anglia (Lok *et al.* 1992).

Few winter recoveries involving Britain & Ireland show the movements listed above (Fig 6.3.1.2), but they do demonstrate some movement into Britain in winter.

Figure 6.3.1.2 Winter (November to February) movements of Brent Goose. The lines join the positions of the bird and the circles show the position of each individual later in winter. Recoveries between winters as well as those within one winter are included.

Shelduck *Tadorna tadorna*

Flyway Population	300,000
European Breeding Population	35,000 – 56,000
UK Summer Abundance	10,900
UK Winter Abundance	81,300
Summer Range of UK Population	UK
Winter Range of UK Population	UK; autumn moult migration to Waddensea.

Shelduck regularly move from the north and east of their breeding range to Britain in winter, with more pronounced movements taking place in severe winters (Ridgill & Fox 1990). There is also evidence for a move out of northern Britain (Baillie *et al.* 1986). In the severe winter of 1978/79 the proportion of the western European Shelduck found on the Dutch, German and Danish coasts fell from the average of 48% to just 31%. Similar decreases were recorded in 1981/82 (29%) and 1984/85 (35%). The displaced birds appear to move to the west with increases in the population of 40-60% being found in British and French wintering sites in severe winters. The birds seem to move into Britain and then continue west to Ireland, with smaller numbers moving to France (Ridgill & Fox 1990).

Wigeon Anas penelope

Flyway Population	1,500,000
European Breeding Population	≥ 1,700,000
UK Summer Abundance	300 – 500
UK Winter Abundance	426,000
Summer Range of UK Population	UK, many from northern and eastern Europe
Winter Range of UK Population	UK, some southern Europe

Wigeon is a mobile species which is one of the first to move in cold weather, with the distance moved being proportional to the severity of the weather (Ridgill & Fox 1990). In mild winters, Wigeon are concentrated on the Continental coast (60%), but when it is cold, they move to Britain & Ireland, and north and west France, reaching Iberia in particularly severe spells (Baillie *et al.* 1986, Ridgill & Fox 1990). Ridgill & Fox (1990) showed inverse correlations between the numbers in Denmark and Germany and those in east Britain and west Britain & Ireland and Iberia. They also found inverse correlations between the numbers in the Netherlands and those in east Britain and west France. Similarly, Ruger *et al.* (1986) showed negative correlations between numbers in Belgium, the Netherlands, Germany and Denmark when compared to numbers in Britain, Ireland, north France and north Spain.

In January 1979, less than 25% of the flyway population of Wigeon remained on the Continental coast (normally 60%) with 50% being found in Britain and the rest being in Ireland, France and Spain (Fig 6.3.1.3). A substantial increase in numbers was recorded at Marismas del Guadalquivir, Spain where there were over 72,000 more Wigeon there than had been seen in the previous year when only about 39,000 were present (Ridgill & Fox 1990). Also, in the severe weather in 1981/82 the number of Wigeon in the Netherlands fell from 300,000 to 126,000 with increases being seen in Britain and France (the number of Wigeon in Mont Saint Michel Bay, France (a refuge area in cold weather) increased by 25,000 in January 1982 (Schricke 1984)). A movement of Wigeon from the Netherlands in 1985 was mirrored by an increase in Britain and Spain, but not in France, where the weather was unusually severe, forcing birds to continue to move south to Spain (Ridgill & Fox 1990). These patterns of movement have been confirmed by examining recoveries of ringed birds where the median position of recoveries in severe winters is more southerly than that in mild winters (Fig 6.3.1.4).

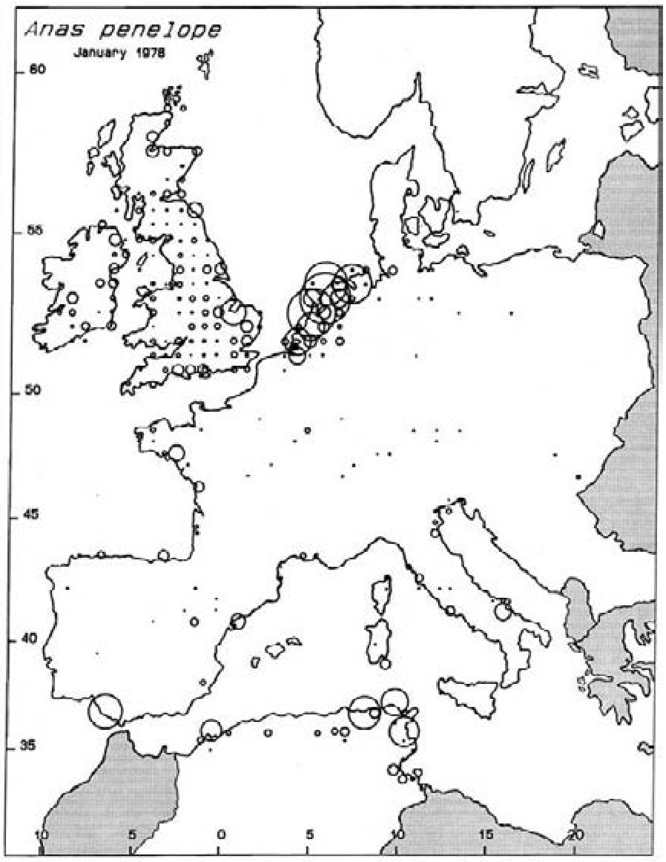


Figure 6.3.1.3 Distribution of Wigeon in the Western Palaearctic in January 1978. Circles are proportional to the number counted. Shaded areas indicate states that did not contribute count data. Reproduced, with permission, from Ridgill & Fox (1990).

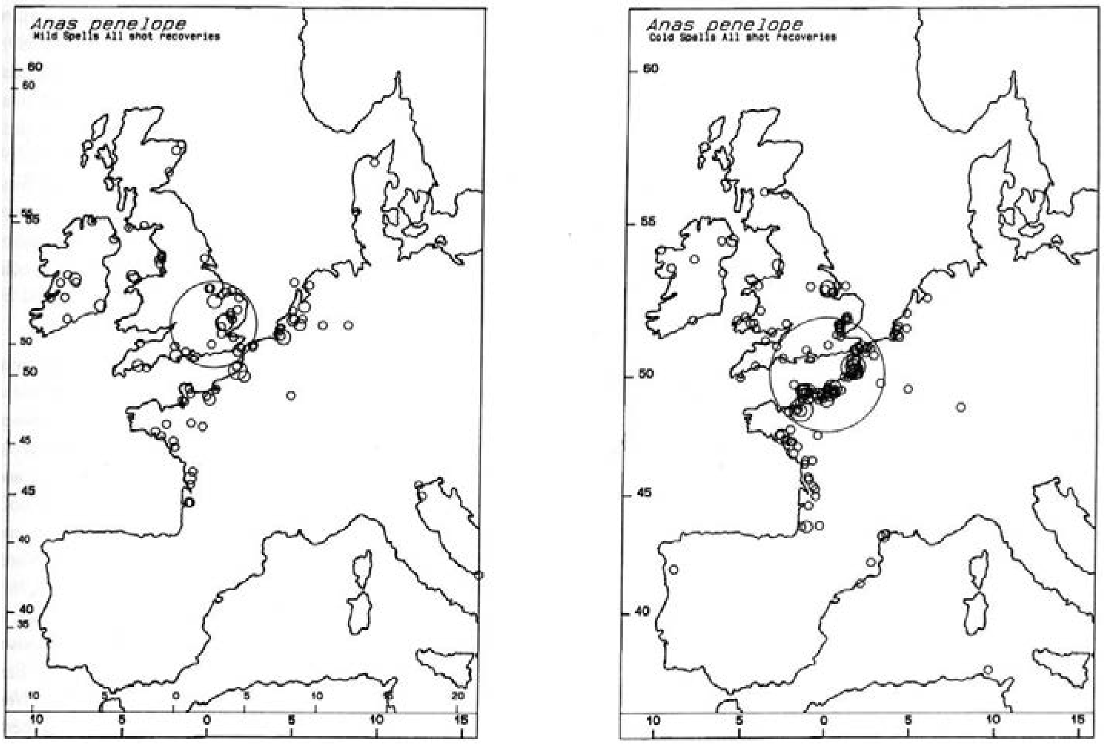


Figure 6.3.1.4 Recovery distribution of Wigeon shot during the winter of ringing. Those shot in mild spells (left) are contrasted with those shot in cold spells (right). The large circle is the median recovery position, showing how this has changed in severe weather (the circumference is proportional to the sample size). Reproduced, with permission, from Ridgill & Fox (1990).

Wigeon have also been recorded moving within Britain in cold weather. For example, in January 1979 there were 11,200 Wigeon on the Ouse Washes, but this number fell to 600 in February when the weather grew cold (von Kanel 1981). Although there is no information on where these birds went, the numbers on the Ouse Washes increased again to 4,000 in March, suggesting that the movement may have been relatively local (von Kanel 1981).

Mapping all winter (November to February) recoveries of Wigeon demonstrates the westerly movements into and within Britain as well as onward southerly movements into France and Iberia (Fig 6.3.1.5).

Figure 6.3.1.5 Winter (November to February) movements of Wigeon. The lines join the positions of the bird and the circles show the position of each individual later in winter. Recoveries between winters as well as those within one winter are included.

Gadwall *Anas strepera*

Flyway Population	60,000
European Breeding Population	28,000 – 35,000
UK Summer Abundance	790
UK Winter Abundance	17,500
Summer Range of UK Population	UK, Iceland, Scandinavia to northwest Siberia
Winter Range of UK Population	UK, France, Low Countries, Mediterranean

Results from ringing at Abberton, Essex and Slimbridge, Gloucestershire suggest that Gadwall ringed on the continent move into Britain in severe weather (Wernham *et al.* 2002). The proportion of foreign-ringed birds found at these two major ringing stations almost doubled between the studies of Owen *et al.* (1986) (data up to 1982) and Fox & Mitchell (1988) (data to January 1988), suggesting influxes in the cold weather spells that occurred in the meantime. Baillie *et al.* (1986) suggested that there is increased movement of Gadwall from Britain to France in severe weather.

Teal Anas crecca

Flyway Population	400,000
European Breeding Population	255,000 – 540,000
UK Summer Abundance	2,200 (1,600 – 2,800)
UK Winter Abundance	197,000
Summer Range of UK Population	UK, Iceland, Scandinavia to northwest Siberia
Winter Range of UK Population	UK, possibly southern Europe in harsh winters

Teal are a highly mobile species that move in response to even short cold spells (Ogilvie 1982, 1983, Baillie *et al.* 1986, Ridgill 1989, Ridgill & Fox 1990). They move south and west when weather conditions affect their shallow water habitat, which is vulnerable to freezing. In cold winters the Continental coasts north and east of Belgium hold 45-65% fewer birds than in mild winters and numbers increase in Britain, Ireland and northern France (Ridgill & Fox 1990). There is also a change in the pattern of ringing recoveries with more birds being found to the south and west (Fig 6.3.1.6.) In 1978/79 between 40,000 and 50,000 Teal left the Waddensea and moved to Britain & Ireland and France, with even larger numbers moving in 1981/82 (Ridgill & Fox 1990). However, in 1984/85 the numbers in Britain and France fell as these countries also experienced particularly hard weather (Salmon & Moser 1985). Some sites in Spain and France are only important for this species in severe winters, with few birds using them in mild winters (Ridgill & Fox 1990).

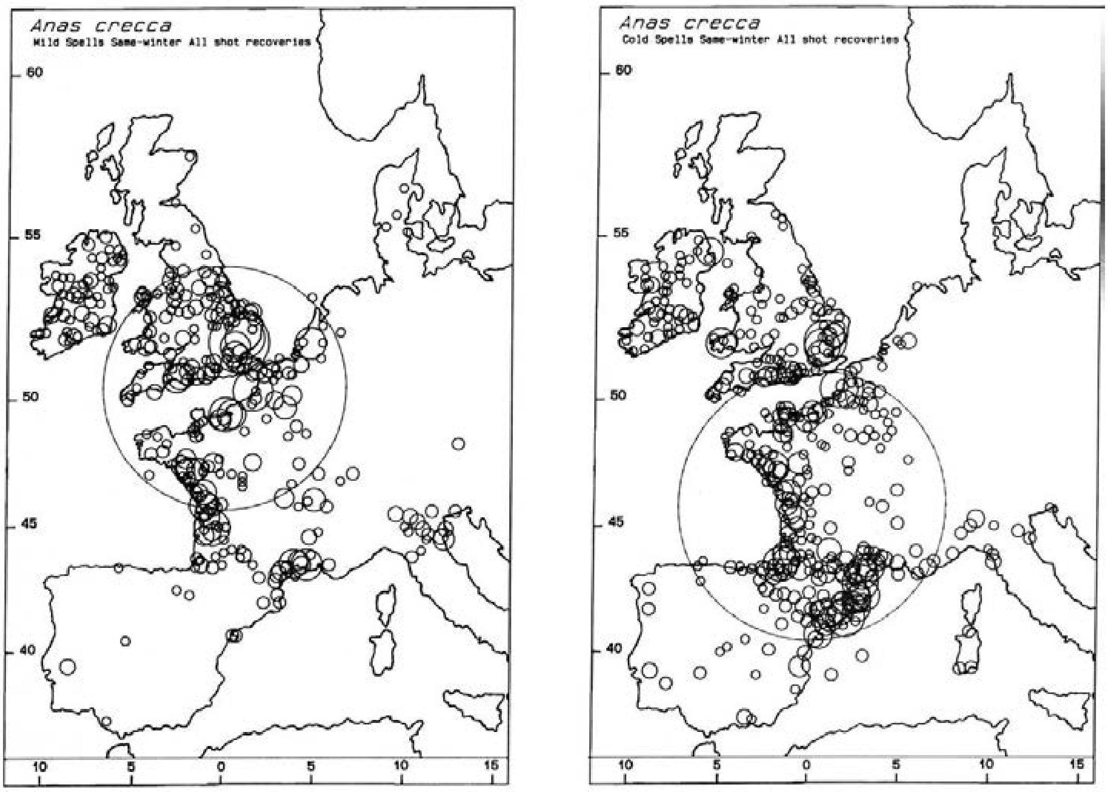


Figure 6.3.1.6 Recovery distribution of Teal shot during the winter of ringing. Those shot in mild spells (left) are contrasted with those shot in cold spells (right). The large circle is the median recovery position, showing how this has changed in severe weather (the circumference is proportional to the sample size). Reproduced, with permission , from Ridgill & Fox (1990).

Teal ringed in Denmark and Netherlands mainly move south in Continental Europe in severe weather, as do those ringed in Britain & Ireland, but some Dutch-ringed Teal also move westwards to Britain & Ireland in some conditions (Wernham *et al.* 2002). There is evidence that Teal make a rapid return to their normal wintering area, although in three very severe winters (1954, 1956 and 1963) few returned north and presumably left for breeding grounds from the cold-weather refuge (Ogilive 1983).

There appears to be some differences between the reaction of the sexes to severe weather. Ogilivie (1983) found that females moved earlier in some years, but if the hard weather continued, males also moved. However, in other years males moved at same time and occasionally before the females, so this may not be relevant.

In severe weather in Britain & Ireland, the most common movement is south or southwest into France and, especially in colder spells, Iberia (Fig 6.3.1.7). The figure also shows movements into Britain from the north and westwards movements to Ireland.

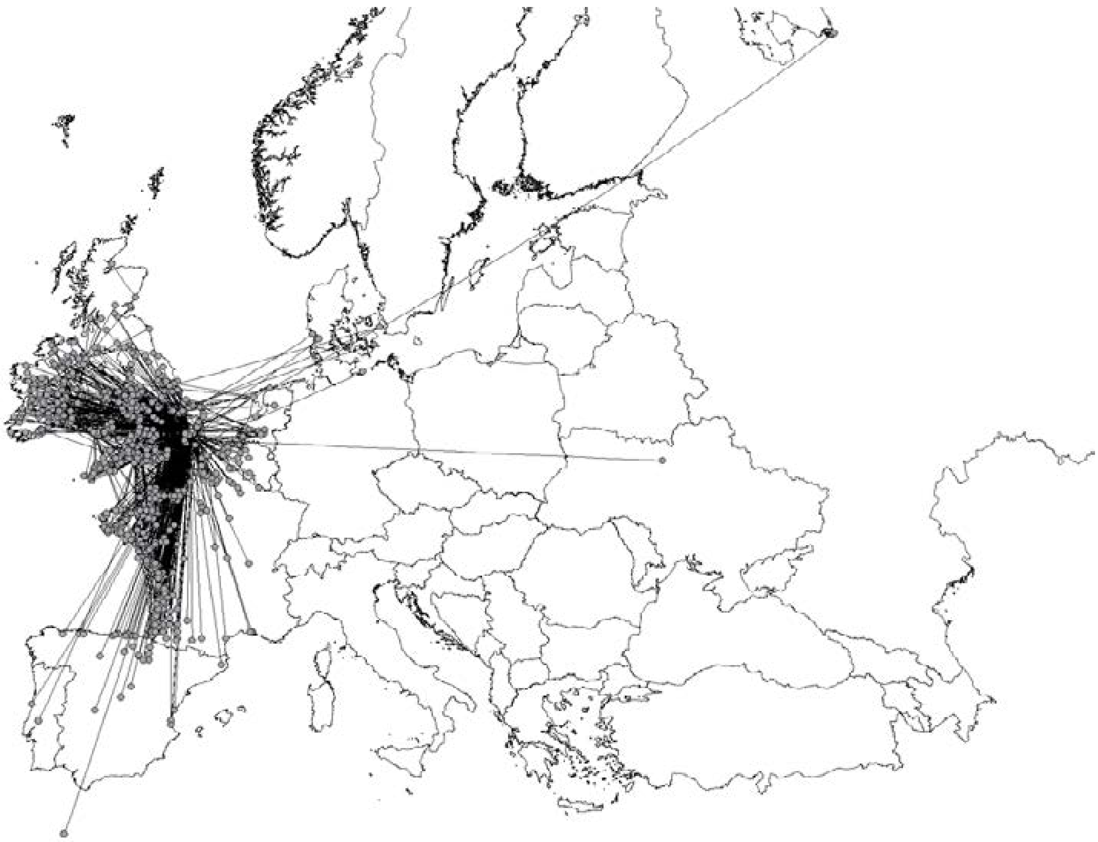


Figure 6.3.1.7 Winter (November to February) movements of Teal . The lines join the positions of the bird and the circles show the position of each individual later in winter. Only recoveries of at least 150 km that took place within a winter are included.

Mallard Anas platyrhynchos

Flyway Population	4,500,000
European Breeding Population	2,000,000 – 3,400,000
UK Summer Abundance	110,950 (63,000 – 158,900)
UK Winter Abundance	371,000
Summer Range of UK Population	UK and northern Europe
Winter Range of UK Population	UK and France

In periods of extreme cold in North America, Mallard may migrate to areas that are warmer or where more food is available (Diefenbach *et al.* 1988). In Europe, however, Mallard do not tend to move very far in cold winters, although some movements have been detected in extreme winters (Ridgill &

Fox 1990). For example, there was an influx to Britain in 1978/79 (possibly involving birds from Denmark, the Netherlands and Belgium, Baillie 1984), but little change was detected in 1981/82 or 1984/85 (Ridgill & Fox 1990). Movements detected in 1962/63 were thought to be birds redistributing within Britain (Baillie 1984). There is some evidence of Mallard from the Waddensea, and possibly Britain, moving to France (Baillie *et al.* 1986) and Schricke (1984) notes that Mont Saint Michel Bay in France forms a cold weather refuge for this species.

It is possible that Mallard from the near Continent will move to Britain in extremely severe weather.

Pintail *Anas acuta*

Flyway Population	60,000
European Breeding Population	20,000 – 35,000
UK Summer Abundance	26 (12 – 40)
UK Winter Abundance	28,180
Summer Range of UK Population	UK and northern Europe, Iceland
Winter Range of UK Population	UK

Cold weather movements of Pintail from the Danish, German and Dutch coast to Britain & Ireland, northern France and Iberia have been detected from ringing recoveries (BWP, Ridgill & Fox 1990). Baillie *et al.* (1986) noted a movement into west Britain. However, Ridgill & Fox were unable to confirm the more widespread movements from count data due to the clumped distribution of Pintail and the large variation in the numbers counted each year. A more recent analysis of count data in B&I (Cranswick *et al.* 1999) has shown a double peak in indexes in some years, notably in late 1980s and early 1990s. It is thought that these two peaks may represent Icelandic birds arriving early and dispersing, followed by Continental birds that have been pushed west by cold weather.

Movements of Pintail to Britain may therefore be expected in severe weather.

Shoveler *Anas clypeata*

Flyway Population	40,000
European Breeding Population	30,000 – 50,000
UK Summer Abundance	1,250 (1,000 – 1,500)
UK Winter Abundance	15,200
Summer Range of UK Population	UK, northern Europe
Winter Range of UK Population	UK, Low Countries, southern Europe

Shoveler live in shallow waters which are the first to freeze in cold weather, therefore their wintering distribution tends to be more southerly than for other duck species in Europe, presumably to avoid the effects of cold weather on their vulnerable environment (Wernham *et al.* 2002). There are therefore no cold weather movements from the far north. They do, however, move out of the Waddensea in cold weather in many winters, appearing in western France and Britain & Ireland (Ridgill & Fox 1990). In the most severe winters they also move to Iberia, although some birds winter there regularly (Ridgill & Fox 1990). There is evidence that Shoveler leave Britain in severe weather (Baillie *et al.* 1986) and substantial movements out of Britain have been recorded in some years, such as in early 1987 (Salmon *et al.* 1987). Some Shoveler from the near Continent may be expected to move to Britain in cold weather.

Pochard *Aythya ferina*

Flyway Population	350,000
European Breeding Population	100,000 – 180,000
UK Summer Abundance	472
UK Winter Abundance	85,500
Summer Range of UK Population	UK, eastern Europe, northern Europe, northwest Russia
Winter Range of UK Population	UK, Low Countries, southern Europe

Pochard show major movements out of the Baltic and the Waddensea in severe weather, moving to the south and west of their normal wintering area (Ridgill & Fox 1990) (Fig 6.3.1.8). For example, in January 1979 the number of Pochard counted in the Netherlands was only 31,000, compared to a total of over 80,000 in January of the previous year. At the same time increases in numbers were recorded in Britain and France and an analysis of ringing recoveries showed a highly significant increase in the number of recoveries in France (Ridgill & Fox 1990). Both count data and ringing recoveries have also shown that Pochard from eastern Britain move to north and west France in cold weather (Baillie *et al.* 1986, Ridgill & Fox 1990). Pochard wintering further east in Europe make cold weather movements to the lakes of Switzerland, which remain unfrozen even in harsh weather.

It is likely that Britain will receive Pochard from the Continent in spells of severe winter weather.

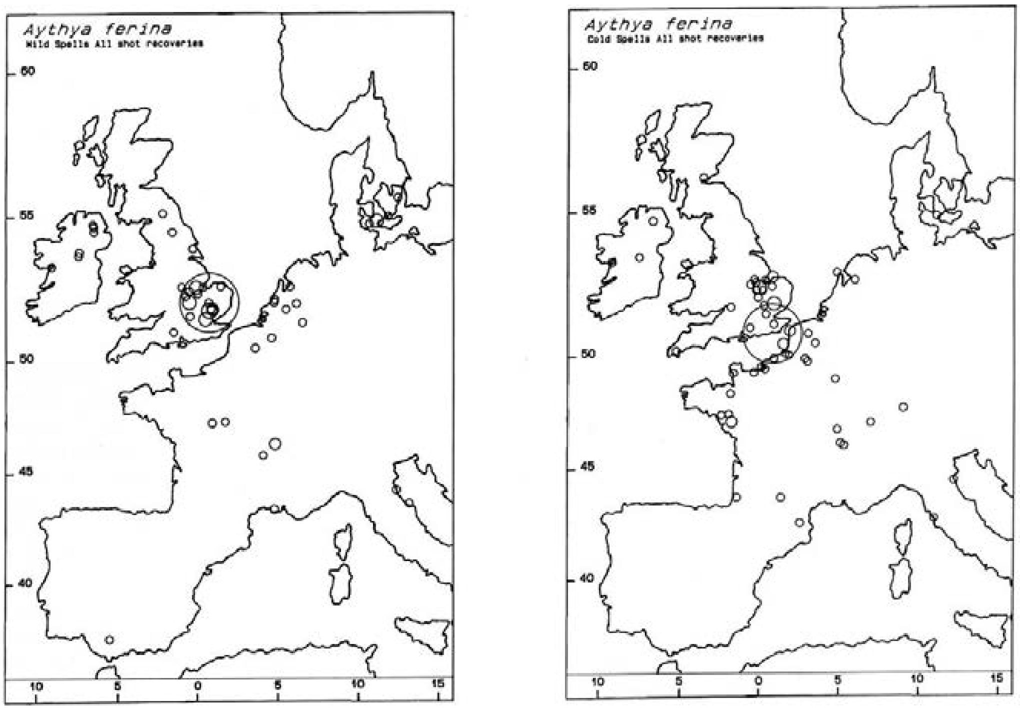


Figure 6.3.1.8 Recovery distribution of Pochard shot during the winter of ringing. Those shot in mild spells (left) are contrasted with those shot in cold spells (right). The large circle is the median recovery position, showing how this has changed in severe weather (the circumference is proportional to the sample size). Reproduced, with permission, from Ridgill & Fox (1990).

Tufted Duck *Aythya fuligula*

Flyway Population	1,200,000
European Breeding Population	200,000 – 320,000
UK Summer Abundance	10,850 (10,200 – 11,500)
UK Winter Abundance	120,000
Summer Range of UK Population	UK, northern Europe
Winter Range of UK Population	UK, The Netherlands

Tufted Duck make cold weather movements, but these may be hard to detect as they may move to small waters that have remained ice-free or to uncounted areas of the sea (Ridgill & Fox 1990). In addition, in Sweden, Tufted Ducks have been found dead and emaciated and have suffered a decrease in survival following cold weather (Nilsson 1984b), suggesting these birds have not moved. However, count data shows a fall in numbers in Denmark in cold versus mild winters (40-50% lower in cold winters), with concurrent increases in Germany (increase of 30-40%), although numbers in the

Netherlands also fall in cold weather. Increases are seen in France and Spain, but the numbers do not account for all the birds displaced from northern Europe. Counts do not show evidence of Britain & Ireland receiving Tufted Ducks in cold weather (Ridgill & Fox 1990), but there was a significant increase in the number of recoveries in cold weather in north, east and west Britain & Ireland, suggesting that movements may take place.

Recent work on the movements of Tufted Ducks ringed or found in Switzerland has shown that birds are moving north earlier than previously (Hofer *et al.* 2005). These Tufted Ducks are now north of 50^{o}N about 50 days earlier than formerly, suggesting a shift in wintering grounds with less harsh weather – a pattern that may be being repeated for other species.

Baillie *et al.* (1986) showed that the majority of cold weather movements of Tufted Ducks ringed in Britain & Ireland are from Scotland, eastern England and western Britain. Clear departures were detected in 1978/79 and 1981/82. The birds move to southern England and Europe south of the Wadden sea, primarily France and Spain (Baillie *et al.* 1986, Ogilvie 1982). In addition, Ogilvie (1987) showed that breeding females and their young ringed in southern Scotland migrate southwest to Ireland in winter, but Tufted Duck ringed further south in Britain are mainly sedentary except in hard weather when they (and particularly young males) move south to France and Iberia.

Figure 6.3.1.9 shows winter movements of Tufted Duck into Britain, across to Ireland and to the south. It is likely that such movements are a response to severe weather.

Figure 6.3.1.9 Winter (November to February) movements of Tufted Duck . The lines join the positions of the bird and the circles show the position of each individual later in winter. Recoveries between winters as well as those within one winter are included.

Red-breasted Merganser ***Mergus serrator***

Flyway Population	170,000
European Breeding Population	64,000 – 108,000
UK Summer Abundance	2,370
UK Winter Abundance	10,500
Summer Range of UK Population	UK, Iceland, Scandinavia, northern Russia
Winter Range of UK Population	UK, Scandinavia, Low Countries

There were a number of reports of small numbers of Red-breasted Merganser inland in February 1979, possibly as a result of birds moving in from the Baltic (Allsop & Madge 1979).

Oystercatcher ***Haematopus ostralegus***

Flyway Population	1,020,000
European Breeding Population	293,000 – 425,000
UK Summer Abundance	112,750 (98,500 – 127,000)
UK Winter Abundance	338,700
Summer Range of UK Population	UK, Iceland, Faroes, Scandinavia, Low Countries
Winter Range of UK Population	UK, France, Spain, Low Countries

Oystercatchers in the British Isles do not appear to move in response to severe weather (Clark 1982a, b, Baillie *et al.* 1986), although some local movements between estuaries have been recorded (Pilcher 1964, Dare 1970). Moser & Summers (1987) found no evidence of cold weather movements in Britain & Ireland. Instead, Oystercatchers remain on their normal wintering grounds and are subject to increased mortality (Clark 2002, 2004). By contrast, those wintering in the Netherlands are known regularly to make cold weather movements (called cold rushes), although these tend to be to the south and therefore may not involve B&I (but see below). Such movements have been detected in 10 of 92 years in the Waddensea (Goss-Custard 1996). Camphuysen *et al.* (1996) analysed these movements between 1972 and 1996 based on sea-watches at sites along the Dutch coast. A cold rush was defined as a southward movement of at least several hundred Oystercatchers over a period of a few hours at a time of, or following, severe weather. There were 19 days with cold rushes in periods of severe weather. There was no clear set of circumstances in which the movements occurred, although they were generally on days on which the temperature was below the average for the time of year. Four of the movements occurred at the beginning of a cold period, seven half way through and eight at the end. The authors commented that there was a remarkable lack of southward movement in a 30 day period of severe weather in 1985/86.

In a comparison of the number of recoveries of Dutch-ringed Oystercatchers between mild and severe winters (1977-1996) by Zwarts *et al.* (1996) only 4% of the recoveries were abroad in mild winters in contrast to 23% in severe winters, suggesting cold weather movements are taking place. Also, local recoveries (in the Wadden Sea) reduced from 88% to 54%. Recoveries also suggested that the proportion of birds leaving the Netherlands varied between 0 and 60%. More males leave the area at the onset of cold weather possibly as females start winter with more fat than males or because females are subordinate and would find it harder to establish themselves in a new area. Most birds are thought to go to France (and are shot there so the recovery rate is likely to be higher), with a few to Britain (Zwarts *et al.* 1996). Figure 6.3.1.10 demonstrates how few winter movements of Oystercatchers from the Continent to Britain have been recorded, although there are nearly 10,000 recoveries on the BTO database. Increased counts of Oystercatchers have been reported from France in severe winters (Triplet 1999), as have changes in the pattern of recoveries. In 1987 the origin of ringed Oystercatchers shot in France differed from that in the previous eight years (1978/79 – 1985/86), with very high proportions of German rings being reported (27% compared to 4%) suggesting that many of the birds came from the north and east of the Waddensea (Goss-Custard 1996).

There are also some reports of Oystercatchers moving from the German and Danish Waddensea into the Dutch Waddensea. For example, van Eerden (1977) reported a movement of 40,000 Oystercatchers on 30 December 1976. The weather then improved and the birds are not thought to have moved any further south. Similar movements were recorded in December 1981 (Maas & den Ouden 1982) and January and February 1982 and high numbers of Oystercatchers were present in the Dutch Waddensea in January 1986 (Camphuysen *et al.* 1996, Meltofte *et al.* 1994).

Figure 6.3.1.10 Winter (November to February) movements of Oystercatcher. The lines join the positions of the bird and the circles show the position of each individual later in winter. Recoveries between winters as well as those within one winter are included.

Golden Plover *Pluvialis apricaria*

Flyway Population	930,000
European Breeding Population	436,000 – 645,000
UK Summer Abundance	22,600
UK Winter Abundance	310,000
Summer Range of UK Population	UK, Iceland, Scandinavia (The Netherlands on passage)
Winter Range of UK Population	UK, southern Europe, north Africa

Ringing recoveries have shown large-scale movements of Golden Plover in response to cold weather, but little is known about the extent, frequency, or duration of these movements (Wernham *et al.* 2002). More than 500,000 Golden Plovers winter from Denmark to the Netherlands, but numbers vary depending on the weather (Byrkjedal & Thompson 1998). If there is cold weather between November and January, Golden Plover leave this area moving to Belgium, France, Iberia and the British Isles (Jukema & Hulscher 1988). Golden Plover ringed in the Netherlands have been found as far south as north Africa in cold spells and the pattern of recoveries is directly related to the date and severity of winter weather. The percentage of recoveries of Golden Plover ringed in the Netherlands and found from France to north Africa increases from 1.2-1.4 in mild winters (1980, 1982, 1983) to 2-2.5 in severe winters (1981, 1984) (Jukema & Hulscher 1988). There were increased numbers of Golden Plover on non-estuarine shores in cold weather in 1985 suggesting influxes, possibly from the Continent (Moser & Summers 1987).

Golden Plover from Britain may move to Ireland and France in severe weather (Kirby & Lack 1993) and birds from Britain & Ireland are found in Portugal in severe weather, although less than 5% of the birds are thought to originate from here (Leitao & Peris 2004). In France, numbers of Golden Plover have been reported to be associated with changes in weather. Numbers may vary by up to 20 times around Vienne (Yeatman-Berthelot & Jarry 1991) and in Seine-et-Marne they vary irregularly through the winter, with all birds leaving the area in cold periods (Balanca 1984).

Grey Plover *Pluvialis squatarola*.

Flyway Population	247,000
European Breeding Population	*c.* zero
UK Summer Abundance	Rare
UK Winter Abundance	53,300
Summer Range of UK Population	Arctic Tundra
Winter Range of UK Population	UK, Southern Europe, North Africa

There have been few reports of cold weather movements by Grey Plover, although Townshend (1982) found that certain individuals only appeared on his study site on the Tees Estuary in cold winters, suggesting a different pattern of movements in such winters. In addition, high populations of Grey Plover on some estuaries (eg Orwell Bay) in January and February 1985, the return of particular individuals to the Tees (Davidson & Clark 1985a, 1985b) and increased numbers of Grey Plover on non-estuarine shores (Moser & Summers 1987) suggested that some birds had moved in from the Continent. It appears however, that many Grey Plover remain on their normal wintering site in cold weather and are subject to increased mortality (Clark 2002, 2004).

Lapwing *Vanellus vanellus*

Flyway Population	2,800,000 – 4,000,000
European Breeding Population	1,100,000 – 1,700,000
UK Summer Abundance	156,000 (137,000 – 174,000)
UK Winter Abundance	1,750,000
Summer Range of UK Population	UK, Low Countries, northern Europe
Winter Range of UK Population	UK, southern Europe, north Africa

The number of Lapwings in Britain & Ireland increases in autumn and there are further arrivals as frosts occur in Europe (Wernham *et al.* 2002). Lapwing are largely found inland feeding on fields and when the fields are frozen Lapwings move west and south and use more estuarine habitats. Sometimes these are local movements with birds returning after a few weeks, but they can be substantial. Examples of such cold weather movements include: 4,500 recorded passing southwest over Tring, Hertfordshire in 50 minutes on 9 December 1967 (Gladwin & Sage 1996), 8,900 west over Kenfig Dunes, Glamorgan in three hours on 27 December 1965 (Hurford & Lansdown 1995) and 10,200 in 2.5 hours over Portsmouth, Hampshire on 30 January 1972 (Clark & Eyre 1993).

Large scale emigration of Lapwings to France, Iberia and Ireland was observed during the severe winter of 1962/63 (Ash 1964, Dobinson & Richards 1964, Spencer 1964). Indeed, in the cold winters of 1961/62 and 1962/63 there were 23 and 56 recoveries respectively in Iberia compared to average of 5.6 per winter for the other 38 winters 1958-1997, showing movement to that area (Wernham *et al.* 2002). In 1978/79 and 1981/82 it was possible to provide quantitative information on movements of Lapwing out of estuaries from BTO Bird of Estuaries Enquiry (BoEE) (now Wetland Bird Survey (WeBS)) counts (Marchant 1982). In 1981/82 most Lapwing left the British mainland in cold weather from second week of December to mid January, although numbers built up again in eastern England in February (Kirby & Lack 1993). The reduction in numbers of Lapwings on estuaries of 55-77% is likely to have underestimated the overall extent of movement out of the country, as inland feeding areas are very vulnerable to freezing (Baillie *et al.* 1986) so unmonitored birds in these areas will also have emigrated. By contrast, in the mild winters of 1982/83 and 1983/84 the distribution of Lapwings in Britain and Ireland remained fairly constant between November and March. However, in 1984/85 there were increased densities of Lapwings in southeast and eastern England, suggesting that birds may have moved in from the Continent (Moser & Summers 1987).

Significantly more BTO-ringed Lapwings from north and central Britain have been recovered in Continental Europe in cold than in mild winters (Baillie *et al.* 1986). The mean distances between the ringing and recovery place of Lapwings ringed in Britain were also significantly greater in severe than in adjacent mild winters (Baillie *et al.* 1986).

Lapwing numbers in France show seasonal fluctuations associated with the severity of the weather (Balanca 1984). Numbers of Lapwing increase in Portugal when there is cold weather in northern Europe with around 25% of these birds coming from Britain & Ireland (the remainder are from the Netherlands southern Scandinavia and Germany) (Leitao & Peris 2004).

Figure 6.3.1.11 shows the movement of Lapwings into Britain from the Continent in winter as well as the movements from Britain into France and Iberia.

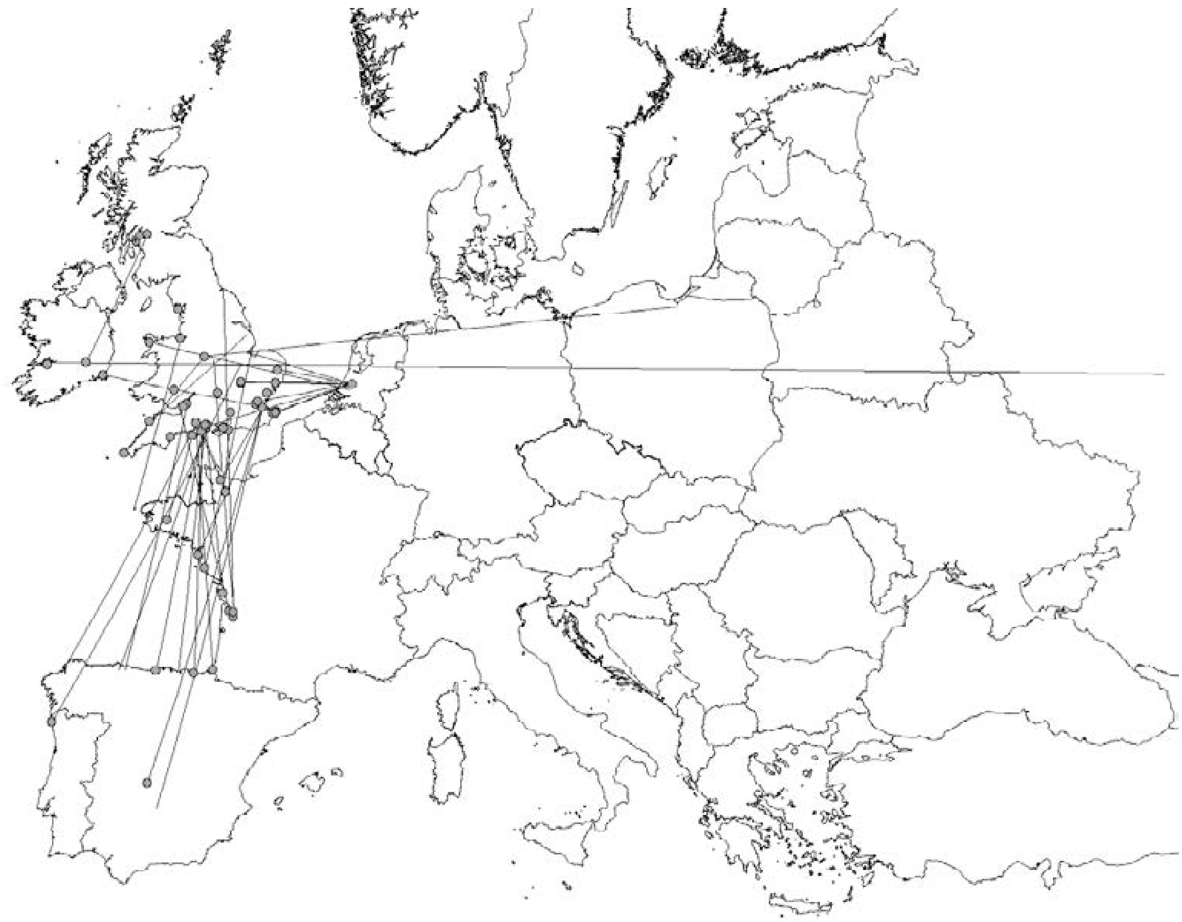


Figure 6.3.1.11 Winter (November to February) movements of Lapwing. The lines join the positions of the bird and the circles show the position of each individual later in winter. Recoveries between winters as well as those within one winter are included.

Dulin *Calidris alpina*

Flyway Population	1,330,000
European Breeding Population	285,000 – 440,000
UK Summer Abundance	9,150 – 9,900
UK Winter Abundance	577,100
Summer Range of UK Population	UK, Iceland, Greenland, northern Fennoscandia, western Siberia
Winter Range of UK Population	West Africa, UK, Mediterranean Basin

There is some evidence for cold weather influxes of Dunlin into Britain. In 1984/85 Dunlin were thought to have left the Waddensea and there were some local movements between adjacent estuaries in Suffolk and Essex (Davidson & Clark 1985a, 1985b). There were increased numbers on non-estuarine shores in the cold weather in 1985 suggesting influxes, possibly from the Continent (Moser & Summers 1987). In February 1991 an unusually low percentage of ringed Dunlin were found amongst those picked up dead on the Wash estuary, suggesting that birds from the Continent, where fewer are ringed, had moved into the area (Clark *et al.* 1993). There have also been major influxes of Dunlin to the Orwell Estuary in periods of severe weather on the Continent, again suggesting a movement across the North Sea (Davidson & Evans 1985). However, Baillie *et al.* (1986) found no evidence of cold weather movements in this species and there is evidence of increased mortality in severe weather (Clark 2002, 2004)..

Bar-tailed Godwit *Limosa lapponica*

Flyway Population	120,000
European Breeding Population	1,100 – 4,400
UK Summer Abundance	Rare
UK Winter Abundance	65,430
Summer Range of UK Population	Arctic Tundra (passage in UK)
Winter Range of UK Population	UK, West Africa

A very high count of Bar-tailed Godwit at Foulness, Essex of 16,000 birds (a record concentration of this species in Britain) in January 1985 coincided with severe weather both in Britain and on the Continent and was thought to indicate immigration to the country (Salmon & Moser 1985). Bar-tailed Godwits on non-estuarine shores in eastern England and eastern Scotland also increased at this time, again suggesting immigration from the Continent (Moser & Summers 1987).

Curlew *Numenius arquata*

Flyway Population	420,000
European Breeding Population	170,000 – 240,000
UK Summer Abundance	112,250 (99,500 – 125,000)
UK Winter Abundance	164,700
Summer Range of UK Population	UK, Low Countries, Scandinavia
Winter Range of UK Population	UK, western and southern Europe

Recoveries show that Curlew are very site faithful in winter, although some individuals from Britain & Ireland move south to France and Iberia in cold winters (Baillie *et al.* 1986). Dobinson & Richards (1964) recorded movements of Curlew from Britain to Ireland and there may also have been some movement to the west in 1981/82 where increased numbers were recorded in north Wales (Clark 1982a, b). Individual Curlew may feed exclusively on fields in the winter, although they may have to move to the coast in severe weather (Elphick 1979, Townshend 1981). These individuals may be more likely to move out of an area in severe weather than those that normally feed on the intertidal area (Baillie *et al.* 1986). However, birds in the southwest of Britain and in Ireland, where winters are milder, appear to be very faithful to their wintering sites (Baillie *et al.* 1986). Moser & Summers (1987) found no evidence of cold weather movements of Curlew in Britain & Ireland and there is evidence of increased mortality among this species in severe weather (Clark 2002, 2004). The evidence suggests that few, if any, Curlew from the Continent will move to Britain in severe weather.

6.3.2 Other species

Gaviidae (Divers)
Black-throated Divers were seen inland with increased frequency in February 1979 (although in small numbers) and were thought to have been displaced from the Baltic (Allsop & Madge 1979). There were also increases in the numbers of Red-throated Divers seen both moving along the coast and inland in early 1979, although the numbers involved were small. In addition, more Great Northern Divers moved south than was normal (Chandler 1981).

Podicipedidae (Grebes)
There were increased numbers of Great Crested Grebes (*Podiceps cristatus*) in Devon and Cornwall in early 1979 and also more Slavonian Grebes (*Podiceps auritus*) (Chandler 1981). There are occasional influxes of Red-necked Grebes (*Podiceps grisegena*) as birds are forced west by bad weather in the east which can greatly increase numbers (Chandler 1981). Such an influx was seen in February 1979 when birds were found inland in Britain (Allsop & Madge 1979). These birds were thought to have originated from the Baltic, but there was no evidence to support this. Black-necked Grebes (*Podiceps nigricollis*) in Britain & Ireland are present by mid-November and remain on site until spring departures (March), except in cold weather when birds not already on the coast move there (Clark & Eyre 1993).

Cormorant *Phalacrocorax carbo*
Counts of night roosts of Cormorants in the Netherlands in January 2003 and 2004 found fewer birds in January 2003 (16,400 compared to 25,745) (van Rhijn & Nienhuis 2004). This was thought to be a result of birds moving south following severe weather in December 2002 and January 2003 (it not clear where the birds moved to). In 2004 Cormorants started to breed early in the Netherland as they had remained in area to winter.

Bittern *Botaurus stellaris*
Bitterns move to the southwest of Europe in winter (Zink 1958). There is an influx of birds to Britain in December, with recoveries suggesting they come from the Netherlands, Belgium, Sweden and Germany following hard weather on the continent (Wernham *et al.* 2002). Differences in the timing of peak numbers correlate with severity of weather (Underhill-Day & Wilson 1978, Bibby 1981, Underhill-Day 1981).

Anatidae
Between 20,000 and 35,000 of the 40,000 Bean Geese (*Anser fabalis*) in Sweden depart when the first frost occurs (Nilsson 1984a). Of the remaining birds, most stay until hard weather arrives before moving southwest, with most being thought to move to eastern Germany. The number of Bean Geese of both races (*rossicus* and *fabalis*) in the Netherlands increases markedly in hard winters compared to mild winters (Lok *et al.* 1992) as birds move into the country. No evidence of these birds moving to Britain & Ireland has been reported.

There is a pronounced passage of Smew (*Mergus albellus)* through Sweden and the Baltic in mid-October to early November with arrivals around the North Sea peaking in December or sometimes January in response to cold weather further east (Wernham *et al.* 2002). In southeast England the numbers peak in January and the birds concerned are thought to be from the Dutch wintering population. A large influx was seen in 1978/79 (Chandler 1981).

In cold weather in January and February 1979 Ruddy Ducks (*Oxyura jamaicensis*) in Britain dispersed from their main areas in Avon and Staffordshire mainly to southern England and south Wales (Vinicombe & Chandler 1982). With warmer weather in March they returned to their normal areas to moult and then to the breeding waters. Similar movements were recorded in 1982 (Salmon 1982). Note that Ruddy Ducks in Britain are introduced and that the species is rare on the Continent.

More Velvet Scoter (*Melanitta fusca*) and Goosander (*Mergus merganser*) than normal were recorded in Britain in early 1979 (Chandler 1981).

Rallidae (Rails)
Water Rails (*Rallus aquaticus*) breeding in north and central Europe move south and southwest and winter mainly to Britain and France (Flegg & Glue 1973, de Kroon 1980). The majority of migrants to Britain are thought to come from Germany, but the proportion of the central European population moving to Britain is not known. Some birds from Iceland also come to Britain & Ireland (Taylor & van Perlo 1998). Movements are thought to be made in response to cold weather but little is known about this (Wernham *et al.* 2002).

Coot (*Fulica atra*) show little evidence of long movements in cold weather either from counts or recoveries (Baillie *et al.* 1986), although it seems likely that they do make small scale movements (Ridgill & Fox 1990). There is, however, an increase in the number of recoveries in cold weather, suggesting that cold weather leads to increased mortality for this species (Baillie *et al.* 1986, Ridgill & Fox 1990).

Great Bustard *Otis tarda*
Great Bustards in central Europe move in severe winters (mainly in response to snow cover) and suffer high mortality (Streich *et al.* 2006). There does not appear to be any information on where they move to, although it is clearly not Britain.

Snipe *Gallinago gallinago*
Baillie *et al.* (1986) found no evidence of cold-weather movements in Snipe from changes in recovery distance or distribution, but thought that this was because movements were balanced by increased mortality rates. They suggested that Snipe from Britain & Ireland move to France and Iberia in cold weather.

Laridae (Gulls)
Iceland Gull (*Larus glaucoides*) is a regular winter visitor to Britain & Ireland, arriving in small numbers (100-200) on the north and west coasts (Wernham *et al.* 2002). Higher than normal numbers appeared in 1983 and 1984 both in Britain & Ireland and rest of Europe and this was thought to linked to unfavourable weather conditions further north (Burneleau 1986).

The main influx of Glaucous Gulls (*Larus hyperboreus*) to Britain occurs in November and December, with birds arriving in Scotland. The timing of this influx is variable depending on conditions further north (timing of cold weather). Exceptional numbers occur in years when also there are higher than normal numbers of Iceland Gulls (James 1996). There was a large influx into Scotland in 1969 with 300 on Fair Isle and 100 on Fetlar but few further south (Wernham *et al.* 2002).

Passerines
A study of wintering passerines on coastal farmland in Spain found that their abundance was affected by severe weather, although it is not entirely clear if this is due to movements (which could be local) or mortality (Galarza 2000).

Work on Skylarks (*Alauda arvensis*) in southeast Scotland found that in one cold winter there were significantly more females than males caught and there were significantly more retraps in later winters of birds caught outside the cold spell than during it (Dougall 1997). In addition, the only three long distance movements (all further north in Scotland) detected in this study related to the spell of severe weather. This suggests that birds had moved into the area in cold weather. It is suggested that there are nomadic flocks of Skylarks in winter, particularly in severe weather, that are largely comprised of females, which are probably immature.
Waxwings (*Bombycilla garrulus*) are an irruptive species, making long-distance movements in some winters but not others, but these movements are probably related to food supplies rather than directly to cold weather (Wernham *et al.* 2002).

The main departure of Fieldfares (*Turdus pilaris*) from the breeding grounds is in October, but birds may stay in Fennoscandia through November and December and the variation in their migratory behaviour is thought to be related to food supply and weather (Huttunen 2004, Wernham *et al.* 2002). Few long-distance within-winter movements have been recorded after December, but failure to move can lead to high mortality (von Lubcke 1980, Swann 1980, Milwright 1994).

The autumn migration of Redwings (*Turdus iliacus*) peaks in October when birds move into southern Norway, and the North Sea coasts of Britain, the Netherlands and Belgium (Wernham *et al.* 2002). There is an onward movement from November with birds moving into western Britain, Ireland and particularly southwest France and Iberia. As with Fieldfare, irregular migratory behaviour is seen which may be a result of hard weather movements (Huttunen 2004).

Bramblings (*Fringilla montifringilla*) from Fennoscandia begin to move south and southwest in early September arriving in Britain in mid-September to early November (Wernham *et al.* 2002). The timing of migration is affected by both heavy snow cover and a poor beechmast crop and these conditions can lead to huge influxes into southern Germany and Switzerland. In some years weather conditions also bring new arrivals to Britain in midwinter (Taylor *et al.* 1999).

6.3.3 No evidence found despite being looked for

Species	References	Area
Little Egret *Egretta garzetta*	Voisin *et al.* (2005)	western France
Grey Heron *Ardea cinerea*	Baillie *et al.* (1986)	Britain & Ireland
Greylag Goose *Anser anser*	Lok *et al.* (1992)	Netherlands
Moorhen *Gallinula chloropus*	Baillie *et al.* (1986)	Britain & Ireland
Ringed Plover *Charadrius hiaticula*	Moser & Summers (1987)	Britain & Ireland
Knot *Calidris canutus* (weak evidence of movement from Britain to France, based on only 14 recoveries – Baillie *et al.* 1986) Evidence of increased mortality in severe winters (Clark 2002, 2004)	Baillie *et al.* (1986) Moser & Summers (1987)	Britain & Ireland
Sanderling *Calidris alba* (but few recoveries available)	Baillie *et al.* (1986)	Britain & Ireland
Purple Sandpiper *Calidris maritima*	Moser & Summers (1987)	Britain & Ireland
Woodcock *Scolopax rusticola* (but few recoveries available)	Baillie *et al.* (1986)	Britain & Ireland
Redshank *Tringa totanus* (weak evidence that birds ringed as chicks in northern Britain may move south in severe winters, but most very site faithful and show increased mortality in cold weather (Clark 2002, 2004))	Baillie *et al.* (1986)	Britain & Ireland

- Turnstone — Baillie *et al.* (1986) — Britain & Ireland
  Arenaria interpres — Moser & Summers (1987)
  (but only 23 recoveries available in severe winters – Baillie *et al.* 1986)

- Kingfisher — Baillie *et al.* (1986) — Britain & Ireland
  Alcedo atthis
  (but only 26 recoveries in severe winters and only 12 of them in cold spells)

6.4 DISCUSSION

Table 6.4.1 summarises the known cold weather movements of birds that are found in Britain & Ireland in winter. It clearly shows that the species most likely to move to the British Isles in substantial numbers in severe weather are geese, ducks and waders. This review suggests that the species most likely to move here in severe weather are: White-fronted Goose, Brent Goose, Shelduck, Wigeon, Teal, Pochard, Tufted Duck, Golden Plover, Lapwing and Dunlin. A similar pattern is seen amongst those species likely to move within Britain or out of Britain. However, it should be noted that these species are easy to detect as they are relatively large, they form flocks, are present at known sites and are well-ringed. Movements of smaller species that show different behaviour and are less easy to observe may be missed.

Although much information has been found as part of this review, it has highlighted the need for more quantitative studies using more data on a European or flyway scale. Much of the information in the literature has been gathered incidentally and is anecdotal in nature and the quantitative studies have not brought all the available information together. There is a need to bring together information on both counts and movements (from ringing recoveries) of birds to properly assess the extent, distance and direction of severe weather movements on a European scale and to relate them to particular weather conditions. This would allow us to predict when severe weather movements are likely to occur and to assess the possible movements that would be expected.

Species	**Into Britain**	**Within Britain**	**Out of Britain**
Red-throated Diver	1	U	U
Black-throated Diver	1	U	U
Great Northern Diver	1	U	U
Great Crested Grebe	1	U	U
Red-necked Grebe	1	U	U
Slavonian Grebe	1	U	U
Cormorant	U	U	U
Bittern	1	U	U
Little Egret	**0**	**U**	**U**
Grey Heron	*U*	*0*	*0*

Table 6.4.1 A summary of the known cold weather movements of birds that use Britain & Ireland in the winter.

Species thought to make regular and/or substantial cold-weather movements are shown in bold, those found not to make cold-weather movements are in italics. The level of movement is assessed on a three point scale: 0 – little or no movement reported, 1 – some movement, 2 – much movement. If there is no information for a particular category, it is marked U (for unknown). Where there is doubt, a ? is shown. Data summarised from text above.

Species	Into Britain	Within Britain	Out of Britain
Mute Swan	**1**	**1**	**1**
Pink-footed Goose	**U**	**1**	**0**
White-fronted Goose	**2**	**U**	**U**
Greylag Goose	**U**	**U**	**U**
Canada Goose	**U**	**1**	**1**
Barnacle Goose	**U**	**U**	**U**
Brent Goose	**2**	**1**	**1**
Shelduck	**2**	**2**	**1**
Wigeon	**2**	**2**	**2**
Gadwall	**2**	**2**	**2**
Teal	**2**	**2**	**2**
Mallard	**1**	**1**	**1**
Pintail	1	1	U
Shoveler	2	2	2
Pochard	**2**	**2**	**2**
Tufted Duck	**2**	**2**	**2**
Velvet Scoter	1	U	U
Smew	1	U	U
Red-breasted Merganser	**1**	**U**	**U**
Goosander	1	U	U
Ruddy Duck	0	1	0
Water Rail	?	?	?
Moorhen	**0**	**0**	**0**
Coot	?	?	?
Great Bustard	0	0	0
Oystercatcher	**1**	**1**	**1**
Ringed Plover	**0**	**U**	**U**
Golden Plover	**2**	**2**	**2**
Grey Plover	**1**	**1**	**0**
Lapwing	**2**	**2**	**2**
Knot	**0**	**0**	**1**
Sanderling	*0*	*0*	*0*
Purple Sandpiper	*U*	*0*	*U*
Dunlin	**2**	**1**	**0**
Snipe	U	U	?
Woodcock	**0**	**0**	**0**
Bar-tailed Godwit	**1**	**U**	**U**
Curlew	**U**	**1**	**1**
Redshank	**0**	**1**	**0**
Turnstone	**0**	**0**	**0**
Iceland Gull	1	U	U
Glaucous Gull	1	U	U
Kingfisher	**0**	**0**	**0**
Skylark	U	1	U
Waxwing	?	U	U
Fieldfare	1	U	U
Redwing	1	U	U
Brambling	1	U	U

Table 6.4.1 (continued)

6.5 BIRDTRACK AND COLD WEATHER MOVEMENTS

BirdTrack is an online bird recording scheme developed through a partnership between BTO, RSPB and BirdWatch Ireland. It operates year–round and uses data from birdwatchers' records to support species and site conservation at local, national and international scales. BirdTrack contributes to our knowledge of bird movements in two ways: by tracking movements of birds, and providing a means of monitoring many species that are not well covered by other surveys, many of which are scarce or difficult to census. Currently there are nearly 10,000 recorders registered with BirdTrack, of whom 60% regularly submit records. The success of BirdTrack relies on bird watchers completing lists – these are lists of all the birds recorded during a single visit at a particular location. By looking at the proportion of all lists recording a particular species an indication of its frequency of occurrence can be obtained. Such methods have proven very successful for looking at the patterns of arrival and departure of summer migrant passerines (Baillie *et al.* 2006), and have the potential to be extended to investigating other movement patterns.

All records entered into BirdTrack are submitted online, this allows efficient processing of large numbers of records. All records submitted to the database are validated automatically at a local level, allowing for region-specific triggers in validating records, for example 100 Pink-footed Geese in Norfolk would not be unusual, but would be in Essex where a count of 10 would be more likely). Daily checks of the data at a national level are also carried out; any unusual records (either of species or numbers) are queried with the original observer to confirm the details. This ensures a rigorous standard of data integrity is maintained across the database, which is an ORACLE/SQL relational database. Batch programs update the database on a daily database and currently provide updated feedback to the recorders, as tables, graphs and maps, also on a daily basis.

Currently the primary aim of BirdTrack is to record the presence of birds, though the ability to record number of birds present is also available, and many participants use this. Additional information is currently collected through a Comments box, but there are plans to formalise this data collection in the near future by explicitly recording other variables, such as breeding status. BirdTrack also has a history of highlighting special surveys designed to attract information to address particular questions, eg the recent wintering warbler survey (Conway 2005), designed to assess the abundance of warblers in different parts of the country during the winter months.

During periods of severe weather, many species of birds will undertake large-scale movements, either in terms of distance or number of birds making the movement, particularly when the weather conditions restrict access to food sources (see above). Such movements are often obvious locally, either through the presence of birds all moving in a consistent direction, or through the absence of birds where they had previously been regularly present. Currently, BirdTrack can be used to quantify the timing, and extent, of arrival into Britain of major influxes of birds, eg regular migrants at the beginning of the winter (Figure 6.5.1), but could help identify cold weather movements by recording information on both indicators of cold weather movements.

Information on seasonal changes in bird distribution can be plotted and examined through the current BirdTrack system. However, to form a meaningful analysis at a regional scale to detect large-scale shifts in bird numbers would require a greater number of observers submitting data, preferably on a regular basis from a network of sites. From this it would be straightforward to produce weekly summaries of records which could help identify regional distribution shifts in response to cold weather, or other environmental factors. Sufficient data to provide robust results is likely to be available only at a regional scale, though the database may be interrogated at a local scale to provide supporting information at a finer scale.

Currently, although observers record the presence of large flocks, there is no facility to indicate whether these are flock using the site, or those migrating overhead. It would be possible to develop a facility to record information on the number and direction of flight for flocks of birds. A number of observers already record such visible migration, eg observatories and coastal watch points, but this network could be extended and could be particularly useful for recording regional patterns of movement in waterbirds. During any cold weather period, this information could be imported into a GIS system to gain a clearer idea of the scale and spatial extent of movements. Considered at a regional level, such information would provide an indication of large-scale movements which could be related to local temperature or other environmental information and plotting direction of flight of recorded flocks on a map would yield synoptic maps (similar to wind speed indicators on weather charts) showing the scale and extent of movements. Such maps would require appropriate expert interpretation to account for observer coverage, but could provide weekly summaries of bird movements within the UK.

In summary, BirdTrack could be developed to provide a useful tool to provide additional information on the scale and extent of movements of birds in response to cold weather both into Britain and at a regional scale. It would also be valuable to assess the amount of information, at a regional level, that is available for pertinent species, both to investigate the feasibility of implementing a cold weather reporting system, and to provide baseline information on the movements and distribution of winter populations.

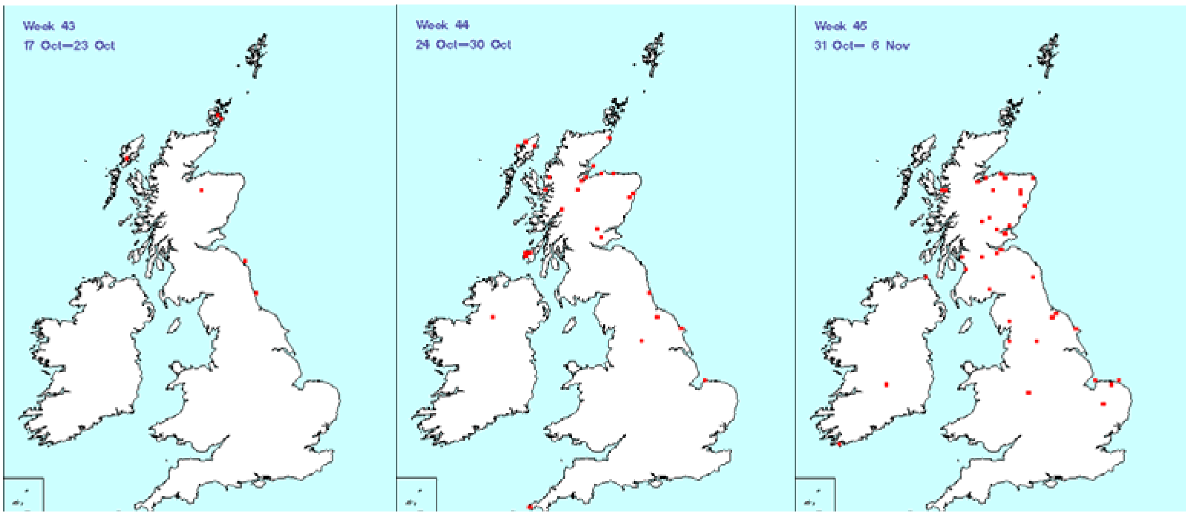


Figure 6.5.1 Maps showing spread of Waxwings *Bombycilla garrulous* into Britain over a three week period in 2004. Red dots indicate records of sightings, from 1 in Week 42 (10-16 Oct, not shown), 6 in Week 43 (left), 28 in Week 44 and over 50 in Week 45 (31 Oct-6 Nov, right) and subsequently.

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Chapter 6

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APPENDICES

Appendix 4.1 Sources of wild bird monitoring data used in the current data set and survey-specific actions to summarise these data where necessary at a 10 km square resolution.

Wetland Bird Survey (WeBS)

The Wetland Bird Survey (WeBS) is a joint scheme of the British Trust for Ornithology (BTO), Wildfowl & Wetlands Trust (WWT), Royal Society for the Protection of Birds (RSPB) and Joint Nature Conservation Committee (JNCC) to monitor non-breeding waterbirds in the UK. WeBS Core Counts are made annually at around 2,000 wetland sites of all habitats; estuaries and large still waters predominate. Monthly coordinated counts are made, principally from September to March, with fewer observations during the summer months. Additional winter roost counts for Geese and Swans are used in preference to core counts where available.

For the purposes of this work we first determined the maximum count for each species / month for each site surveyed over the last five years for which data are currently available (July 2000 to June 2005). For each site, we determined the central grid point and by overlaying a 10 km square grid, we assigned a 10 km square grid reference to each site / species / month. Because coverage of major water-bodies in Great Britain is close to complete, where more than one site records a species within a 10 km square and month, we calculate and use the sum of these site counts.

Winter Farmland Bird Survey (WFBS)

The BTO/JNCC Winter Farmland Bird Survey (WFBS) was carried out over three winters 1999/2000, 2000/2001 and 2002/2003 and aimed to document winter abundance, distribution and habitat selection by farmland birds. Over this period 1,090 1 km squares were surveyed by the WFBS where square selection was random but constrained to lowland farmland areas and avoided largely urbanised or wooded areas. WFBS involved three timed visits each winter, in which birds were surveyed from field perimeters. For each site / month we determined the maximum count across visits and by overlaying a 10 km square grid, we assigned a 10 km square grid reference to each site / species / month. Where more than one site is surveyed within a particular 10 km square / month, we use the maximum count recorded. We assume that sites surveyed within a 10 km square are representative of the 10 km square in which they were recorded.

Winter Gull Survey (WinGS)

Undertaken during the winter of 2003/04, the first phase of the BTO/JNCC Winter Gull Survey targeted 482 known gull roosts in Great Britain and Northern Ireland. This included both inland waterbodies and coastal sites. For each site, we determined the central grid point and by overlaying a 10 km square grid, we assigned a 10 km square grid reference to each site / species. Assuming that coverage of important roost sites is complete, we calculated and used the sum of site counts within each 10 km^2. Whilst data was not available for the entire winter period, we assume here that counts are representative of the months September to March.

Winter Atlas of 1981/82 - 1983/84

Full details of the survey methodology can be found in the Atlas of Winter birds in Britain and Ireland (Lack 1986). In summary multiple visits were made to 10 km squares, during each of which observers spent a minimum of one hour counting all birds seen or heard. To ensure that the species lists for each 10 km square were as complete as possible, additionally supplementary non-timed observations were also requested. A standardised measure of abundance was calculated as the number of birds of a species seen in a day (defined as six hours in the field), from which the maximum count over across visits was determined for each 10 km square. We assume that counts are representative of the months September to March. Coverage of 10 km squares in Great Britain was complete.

Waterways Breeding Bird Survey (WBBS)

Initiated in 1998 as a pilot project, the WBBS surveys linear waterways, providing monitoring data for a number of species, which are poorly monitored by other schemes. Two bird-recording visits are made annually between April and July to over 300, mostly randomly allocated sites, during which all birds seen or heard are recorded. Because the length of WBBS transects varies between sites, we divided here the maximum count across visits / years for each species by the length surveyed to standardise counts for each site. For this work we used all computerised data from 1998 (1998-2004). Where more than one site was surveyed within a 10 km square, we determined the maximum count. We assume that counts are representative of the period April to August.

Breeding Bird Survey (BBS)

Initiated in 1994 the BTO/JNCC/RSPB Breeding Bird Survey is the principal national monitoring scheme for widespread and abundant breeding birds in the wider countryside. Annually over 2,500 stratified random 1 km squares are surveyed in the UK, where squares are stratified regionally and by human population density to afford representative coverage of regions and habitats whilst making the most of available volunteer resources. Two bird-recording visits are made each season during which all birds seen or heard are recorded. For the purposes of this work we obtain the maximum count for each species / month for each 1 km square over the last 5 years (2000-05). We assign all counts to the appropriate 10 km square. Where more than one site is surveyed within a 10 km square, we use the mean count. We assume that sites surveyed within a 10 km square are representative of that 10 km square, and that these counts are representative of the period April to August.

The latest Breeding Atlas 1988 -1991

Full details of the methodology can be found in The New Atlas of Breeding Birds in Britain and Ireland 1988-91 (Gibbons *et al*. 1993). Fieldwork was conducted between April and July in each of four years 1988-91, across which coverage at a 10 km square level was complete. Observers visited as minimum of eight tetrads within each 10 km square, for which two hours were spent surveyed each tetrad. From these timed visits an index of abundance of each species for each 10 km square was calculated. We assume that the measures of abundance for each 10 km square are representative of the months April to August.

JNCC Seabird 2000 data (for breeding gulls)

The Seabird 2000 survey carried out in 2000-02 provides the most recent and reliable colony count data for breeding gulls. We use here data for six species of gulls: Black-headed, Lesser Black-backed, Great Black-backed, Herring and Common Gulls and Kittiwake. Assuming that colony coverage is complete, where there was more than one colony within a 10 km square, the sum of counts was calculated and used. Counts were assumed to be representative of the months April-August.

National Heronries Census.

The BTO Heronries Census provides close to a complete count Grey Heronries in Great Britain. For the purposes of this work we use the most recent computerised data for 2003. Because colony coverage is effectively complete, where there was more than one heronry within a 10 km square, we calculated and used the sum of site counts. We assume that colony counts are representative of the number of Grey Herons for the months April to August.

National Rook Survey

A national survey of rookeries was carried out by the BTO in 1996. Breeding Rooks are poorly monitored by other schemes, so this survey is believed to provide the most reliable data. Whilst all 10 km squares were surveyed, the proportion of tetrads covered within these varied. To standardise counts, counts within each 10 km square were summed (where there was more than one rookery within a 10 km square) and divided by the number of tetrads surveyed. We assume that colony counts are representative of the number of rooks for the months April-August.

Appendix 5.1 Demonstrating the calculation of *Ri*, the risk of domestic poultry being infected through contact with 3 example species, Mallard, Corn Bunting and Blue Tit.

Example 1: Mallard

Step 1. Calculating *Ci*, the likelihood that domestic poultry will come into contact with Mallard.

$Ci = Xi \times Bi$

Bi, the probability of a wild bird species coming into contact with poultry score = 3
Xi, the abundance score (may range between 0 and 5)

Ci = 0 (where abundance = 0)
Ci = 3 (where abundance = 1)
Ci = 6 (where abundance = 2)
Ci = 9 (where abundance = 3)
Ci = 12 (where abundance = 4)
Ci = 15 (where abundance = 5)

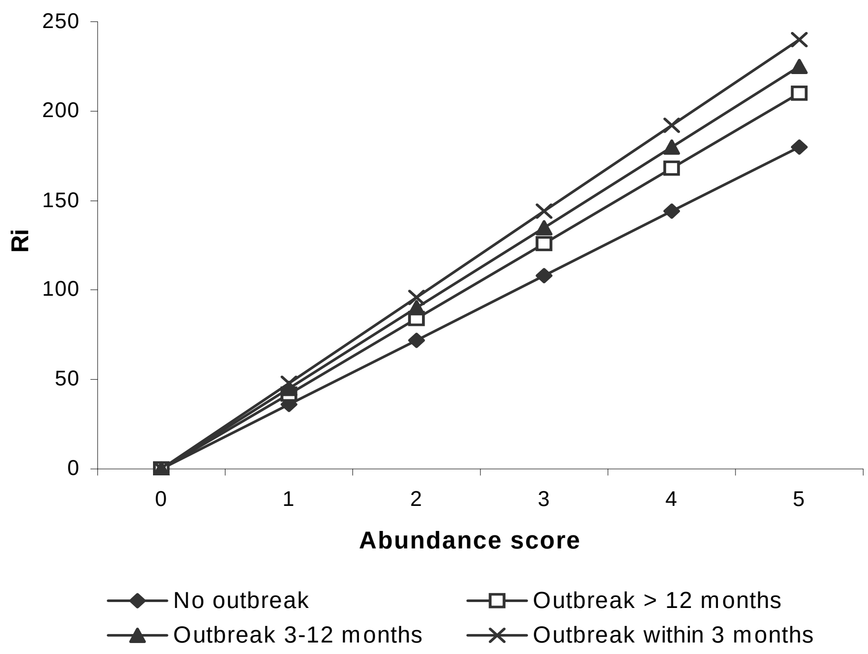
Step 2. Calculating *Di*, the chance of the individual wild bird being infected.

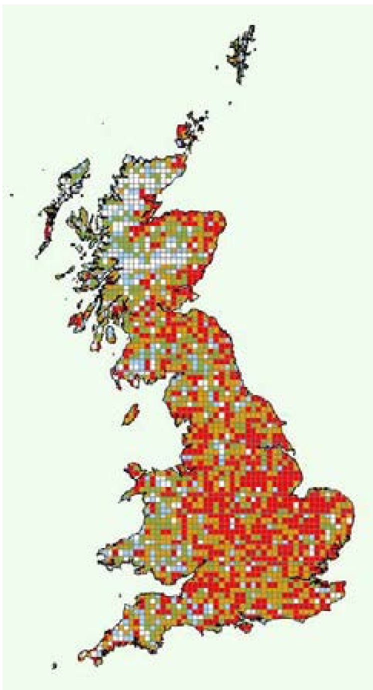
Di is the sum of the following scores:

Propensity of Mallards to harbour the virus = 10
Flocking behaviour = 1
Use of freshwater habitat = 1
Infection status = 0, 2, 3 or 4 (depending on whether and when infection occurred)

Step 3. Calculating *Ri*, where $Ri = Ci \times Di$

Example: January





Considering no outbreak in Europe

Example 2: Corn Bunting

Step 1. Calculating *Ci*, the likelihood that domestic poultry will come into contact with Corn Bunting.

$Ci = Xi \times Bi$

Bi, the probability of a wild bird species coming into contact with poultry score = 2
Xi, the abundance score (may range between 0 and 5)

Ci = 0 (where abundance = 0)
Ci = 2 (where abundance = 1)
Ci = 4 (where abundance = 2)
Ci = 6 (where abundance = 3)
Ci = 8 (where abundance = 4)
Ci = 10 (where abundance = 5)

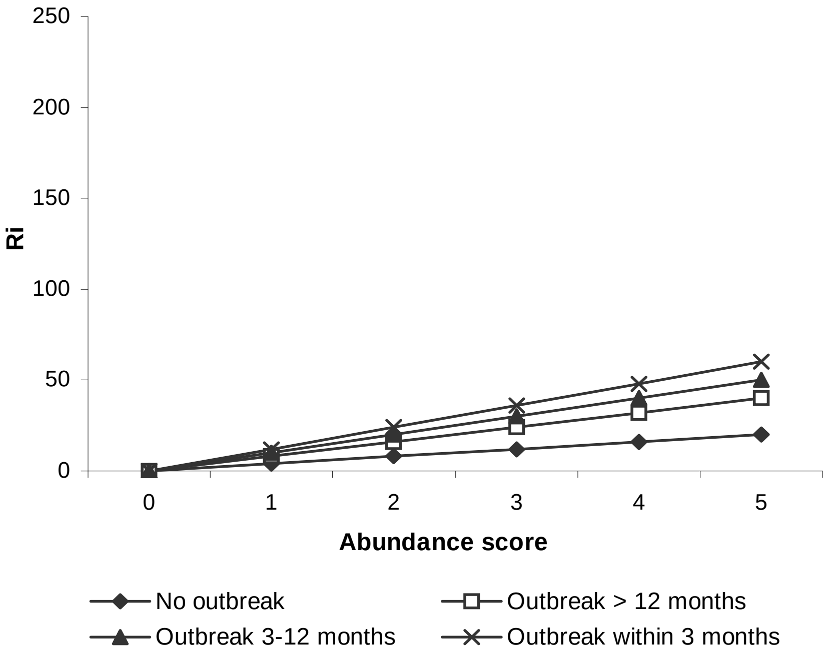
Step 2. Calculating *Di*, the chance of the individual wild bird being infected.

Di is the sum of the following scores:

Propensity of Corn Bunting to harbour the virus = 1
Flocking behaviour = 1
Use of freshwater habitat = 0
Infection status = 0, 2, 3 or 4 (depending on whether and when infection occurred)

Step 3. Calculating *Ri*, where $Ri = Ci \times Di$

Example: January



Considering no outbreak in Europe

Example 3: Blue Tit

Step 1. Calculating *Ci*, the likelihood that domestic poultry will come into contact with Blue Tit.

$Ci = Xi \times Bi$

Bi, the probability of a wild bird species coming into contact with poultry score = 0
Xi, the abundance score (may range between 0 and 5)

Ci = 0 (where abundance = 0)
Ci = 0 (where abundance = 1)
Ci = 0 (where abundance = 2)
Ci = 0 (where abundance = 3)
Ci = 0 (where abundance = 4)
Ci = 0 (where abundance = 5)

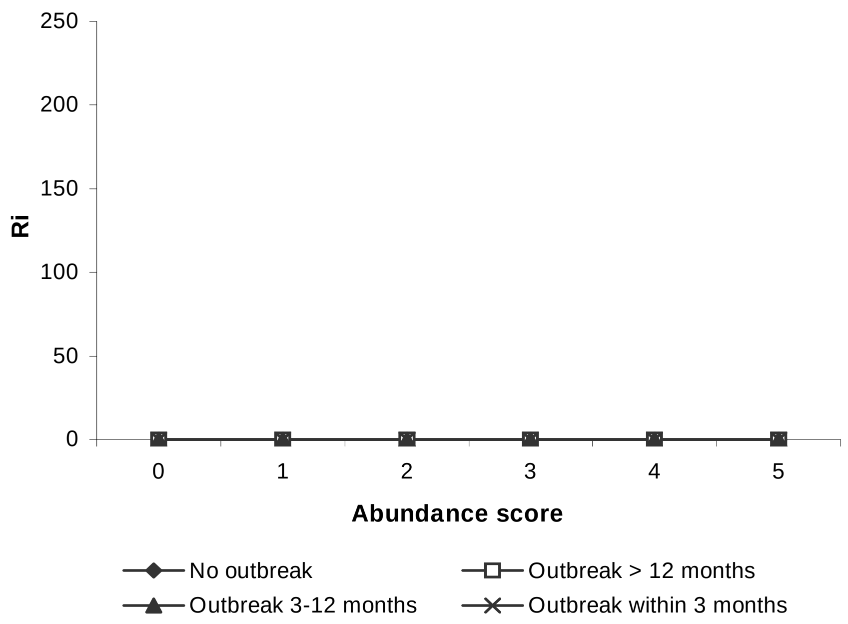
Step 2. Calculating *Di*, the chance of the individual wild bird being infected.

Di is the sum of the following scores:

Propensity of Blue Tit to harbour the virus = 1
Flocking behaviour = 0
Use of freshwater habitat = 0
Infection status = 0, 2, 3 or 4 (depending on whether and when infection occurred)

Step 3. Calculating *Ri*, where $Ri = Ci \times Di$

Example: January



Considering no outbreak in Europe

The probability of Blue Tits coming into contact with poultry scores 0, so the risk of domestic poultry being infected through contact with this species is zero.

Appendix 6.1 Figures given in the species accounts

Flyway Population
Source: Delany & Scott (2002).
Most waterbirds (e.g. ducks, geese, swans, waders) migrate along more or less coherent flyways, which span continents (e.g. Dunlin that breed in western Greenland, migrate through Europe, and winter in Africa). Consequently, for these species, Flyway Population is a more relevant unit than a population in a particular geographical area, which may only account for part of the population.

European Breeding Population
Source: Burfield & van Bommel (2004).
Estimated breeding population size of the species in Europe (excluding Russia, which hosts large, but poorly known, numbers of most species). In most cases, population size is given as a range reflecting likely lower and upper estimates of population size.

UK Summer Abundance
Sources: Baker *et al.* (2006), Burfield & van Bommel (2004), Fraser & Rogers (2001).
The best estimate of the breeding population in the UK. Where there is some uncertainty, lower and upper limits are indicated in parentheses. Where a range (only) is given, numbers breeding are variable between years. Where a bird is an occasional breeder, but common on passage, the average number of passage birds (in Britain) each year is given.

UK Winter Abundance
Source: Baker *et al.* (2006).
The best estimate of the wintering population in the UK. Only estimates for species that are surveyed in winter are given.

Range of species visiting Britain
Distributional origins of populations in Britain during the breeding and wintering seasons
Sources: Snow & Perrins (1998), Wernham *et al.* (2002).
Two fields give the origins of British summer and winter populations. Information is also given for birds that occur regularly on passage in either the spring (in the summer field) or the autumn (in the winter field).

Appendix 6.2 Winters reported in the literature to be severe and to have had an effect on bird mortality in Britain & Ireland, with sources.

Winter	Sources
1961/62	Harris 1962, Hope Jones 1962, Dobinson & Richards 1964
1962/63	Ash 1964, Booth 1964, Dobinson & Richards 1964
1978/79	Baillie 1980, Davidson 1981, 1982b
1981/82	Clark 1982, Evans 1982
1984/85	Davidson & Clark 1985
1985/86	Clark & Davidson 1986, Beecroft & Clark 1986
1986/87	Stroud 1992
1990/91	Clark *et al* 1993