Analysis of sea-watching data from Holme Bird Observatory, Norfolk

BTO Research Report 629

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CONTENTS

LIST OF FIGURES

SUMMARY

1. Sea-watching represents an under-used and potentially valuable resource for exploring patterns of seabird distribution around the UK coast and as a tool for monitoring species using the marine environment.

2. One of the most comprehensive UK sea-watching datasets has been collected from the Norfolk Ornithologists' Association's Holme Bird Observatory through standardised observations undertaken since May 2005. In this report, we provide the results of a collaborative project between NOA and BTO investigating this dataset.

3. The key aim of the project is to explore the potential of sea-watching data, using NOA's Holme Bird Observatory dataset as a case study. The project aims to both demonstrate the outputs that standardised sea-watching data at bird observatories can provide on a site-level in a format that is readily accessible to both amateur and professional ornithologists alike and, through statistical modelling analyses, understand the potential of sea-watching data as a wider monitoring tool. In this way, it is hoped that the work will provide support for the proposed development of a national sea-watching scheme (http://www.bto.org/news-events/news/national-sea-watching-workshop-report).

4. The seasonal and annual variation in numbers of key species recorded at Holme Bird Observatory has been summarised. Species recorded at Holme include those that winter in the area, those that breed in the area and passage migrants whose numbers peak in spring and autumn. The most commonly recorded species at Holme Bird Observatory were seabirds including Herring Gull, Gannet and Sandwich Tern. However, significant numbers of other species were also recorded including Wigeon, Common Scoter and Red-throated Diver.

5. An initial analysis sought to determine whether influxes of ducks on the Wash could be related to cold weather in continental Europe.

6. It was demonstrated that passage rates of Common Scoter, Common Eider and Red-breasted Merganser increased during cold winters in continental Europe. These results are cause for concern given the high concentration of offshore wind farms planned for the area, which may represent an additional energetic cost to the birds at a time when they are already under an increased metabolic stress.

6. Statistical modelling analyses then revealed how the numbers of six commonly recorded species – Gannet, Fulmar, Arctic Skua, Great Skua, Kittiwake and Sandwich Tern – varied in relation to environmental factors, as collected on the standardised recording forms by observers. These species were selected as they were felt to be representative of different ecological groups occurring around Holme Bird Observatory.

7. These models showed that species abundances were most strongly influenced by seasonality, but also by wind speed and direction.

8. Model results were used to develop preliminary annual indices of the numbers of these species at Holme Bird Observatory. These indices were compared to appropriate regional trends derived from the Seabird Monitoring Programme.

9. Indices derived from the models provided a good match to observed regional population trends. Models considering environmental factors typically matched observed population trends more accurately than those which did not, indicating the value of correcting for environmental conditions in the development of these indices.

10. These analyses have shown that modelling can be used to investigate the factors causing variability in the numbers of seabirds observed at Holme Bird Observatory and do suggest that sea-watching data can be used to produce annual indices that reflect observed population trends taken from national recording schemes.

1. INTRODUCTION

The UK and Irish coastal waters are home to *ca*. 8 million breeding seabirds (Mitchell *et al*. 2004), of which several species occur in internationally important concentrations. The productivity of seabirds is also monitored annually at many breeding colonies through Seabird Monitoring Programme (SMP: Mavor *et al.* 2006, JNCC 2010, http://www.jncc.gov.uk/page-1550). However, while changes in the sizes of the breeding populations of seabirds in the British Isles have been well-documented, less is known of the populations of seabirds that pass through or winter in UK territorial waters. Wintering UK gull populations have been monitored by the decadal Winter Gull Roost Surveys (Burton *et al.* 2003, Banks *et al.* 2007). Boat and aerial surveys have also revealed much about the distributions of seabirds using offshore areas throughout the year (http://www.jncc.gov.uk/page-1547). There is nevertheless much still to be learnt concerning the seasonal and annual variability in seabird numbers using UK territorial waters.

One source of data that is currently under-utilised is the considerable information that is gathered by birdwatchers who watch seabirds around the UK's coasts. Such studies have previously been used to examine the distribution of threatened species (Yesou 2003) and to consider the potential collision risk with offshore turbines (Huppop *et al.* 2006). These birdwatchers are highly skilled, and provide records to local bird observatories and for county reports. At many sites, sea-watching is undertaken through much of the year, and the data collected is potentially of considerable value not only in terms of monitoring the numbers of birds using particular sites or regions, but also in understanding the reasons for variability in numbers. Regular monitoring of seabird movements is extremely challenging given their high mobility and inaccessibility in the offshore environment. However, the recent development of sea-watching schemes such as SeaWatch Southwest (http://www.seawatch-sw.org/), that record numbers of species of birds over given time periods from observation points have proved highly successful in mobilising volunteer sea-watchers.

The UK already has in place monitoring schemes for many groups of birds, many of which are organised on behalf of the UK government by the British Trust for Ornithology (BTO), but no such national monitoring scheme exists for collating information on the movements of seabirds. Consequently, BTO recently held a workshop to collate national expertise on best practice in the design of a monitoring scheme for recording the movements of seabirds around the coast. This workshop, which was funded by The Crown Estate, sought to bring together expert observers and key users of bird data. Organisation of the workshop was helped by the Norfolk Ornithologists' Association (NOA: http://www.noa.org.uk/) and the Bird Observatories Council (http://www.birdobscouncil.org.uk/) who were supportive of the idea of a national scheme. The conclusions of the workshop and recommendations for taking the proposed national monitoring scheme forward are reported in Thaxter *et al.* (2011).

One of the most comprehensive UK sea-watching datasets has been collected from NOA's Holme Bird Observatory through standardised observations undertaken since 2006 (Cooke 2006, 2007, 2008, 2009, 2010). In this report, we provide the preliminary outputs of a collaborative project between NOA and BTO investigating this dataset.

The key aim of the project is to explore the potential of sea-watching data, using NOA's Holme Bird Observatory dataset as a case study. The project aims to both demonstrate the outputs that standardised sea-watching data at bird observatories can provide on a site-level in a format that is readily accessible to both amateur and professional ornithologists alike and, through statistical modelling analyses, understand the potential of sea-watching data as a wider monitoring tool. In this way, it is hoped that the work will provide support for the proposed development of the national sea-watching scheme.

Building on a national sea-watching workshop (Thaxter *et al.* 2011), an extensive analysis of sea-watching data was undertaken. This report details the main findings of these analyses and highlights the value of sea-watching as a monitoring tool.

This report is therefore split into three main sections:

i. **Initial exploration**
   An investigation of the patterns and trends within the data at an inter- and intra-specific level. This will be used to inform future analyses, both within this report and elsewhere.

ii. **Can you detect cold-weather movements of ducks from continental Europe to Eastern England through sea-watching?**
   Using passage rates for five of the most frequently recorded waterfowl species, we investigated their movements in relation to cold weather in continental Europe, using information of sea surface temperature on the Wadden Sea (a key area for many European waterbird species) to test the hypothesis that UK birds originate from the continent. After assessing this connectivity, we discuss these results in the applied context of offshore windfarms as a potential barrier to movements and potential impacts on these species.

iii. **Does sea-watching data reflect what is happening with seabird populations at a national level?**
   We model variation in the recorded passage rates for six commonly recorded seabird species in relation to underlying environmental conditions. We then use the outputs from these models to produce population indices and compare these indices to those produced using national monitoring schemes.

iv. **What do indices tell us about changes in local populations?**
   We construct population indices for additional species based on data from Holme Bird Observatory and relate changes in these indices to changes in the local environment, in particular the construction of the nearby Lynn and Inner Dowsing offshore wind farms.

2. INITIAL EXPLORATION

2.1 Methods

2.1.1 Data

Data used in this analyses were collected by NOA staff, members and others at the Holme Bird Observatory, Norfolk (OS Grid Reference: TF717450) over the period 2006-2010 (Cooke 2007, 2008, 2009, 2010). Data were originally collected on standardised recording forms and were subsequently inputted electronically by volunteers overseen by BTO.

One of the recommendations from the national sea-watching workshop (Thaxter *et al.* 2011) in developing a national sea-watching scheme was that it would be most efficient to use an existing system to enter and collate data and that BTO/RSPB/BWI/SOC *BirdTrack* scheme (http://www.bto.org/volunteer-surveys/birdtrack) provides a suitable online platform that could be developed for this purpose. The *BirdTrack* online system has recently been developed to allow the inputting of sea-watching data. However, further development of the *BirdTrack* online system would be required for a full national scheme, and this would only be possible once agreement was reached on the structure of the scheme and the exact data that need to be recorded and with full consultation and agreement with all partners in the scheme.

Given that *BirdTrack* does not currently include all the fields for which sea-watching data have been collected at Holme Bird Observatory, a system was thus devised to ensure that these data could still be input into *BirdTrack* – and thus incorporated into any future national sea-watching database – while ensuring that the important additional data collected on the recording forms were not omitted. This development and the management of the subsequent inputting of data were enabled through funding from NOA.

For the purposes of this review and the analyses undertaken, the count data collected were first standardised as numbers of birds recorded per hour. Such a standardisation is necessary so that meaningful comparisons can be made.

2.1.2 Data summary and initial data exploration

After a summary of the data, initial analyses aimed to summarise, in a readily accessible format, both seasonal and annual variation in the numbers of key species or species groups recorded at Holme Bird Observatory and species' direction of travel (either east or west, along the coast). Species groups considered were seaduck (scoters, Eider and Long-tailed Duck), other wildfowl, divers, waders, seabirds, passerines, raptors and 'others'. It should be noted that counts often omitted records of species groups other than those that are typically recorded offshore, and hence the frequency of occurrence of these groups is likely to be underestimated in this summary and subsequent analyses.

We also considered how the number of each species recorded varied in relation to wind direction using data obtained from the Met Office MIDAS dataset from the nearby weather station at Weybourne (Met Office 2012). If the wind is more likely to blow from a particular direction, it is likely that birds will be recorded most frequently when the wind is blowing from this direction. Therefore, to determine whether wind direction is influencing the number of birds recorded, we compare the distribution of wind directions across the study period as a whole, with the distribution of wind directions during periods when each species was recorded. If wind direction is influencing the number of birds recorded, we would expect to see an obvious difference between these distributions.

2.2 RESULTS

2.2.1 Data summary

Holme Bird Observatory is a site of intensive sea-watching effort. Sea-watches between 2006 and 2010 ran for between 15 minutes and 8 hours between the hours of 6 am and 7 pm, with a mean length of 1 hour 15 minutes. In total, on 1168 days between 2006 and 2010, 36,128 records were collected of 658,019 birds of 153 species and sub-species. Over the course of the study period, westerly winds prevailed (Figure 1)

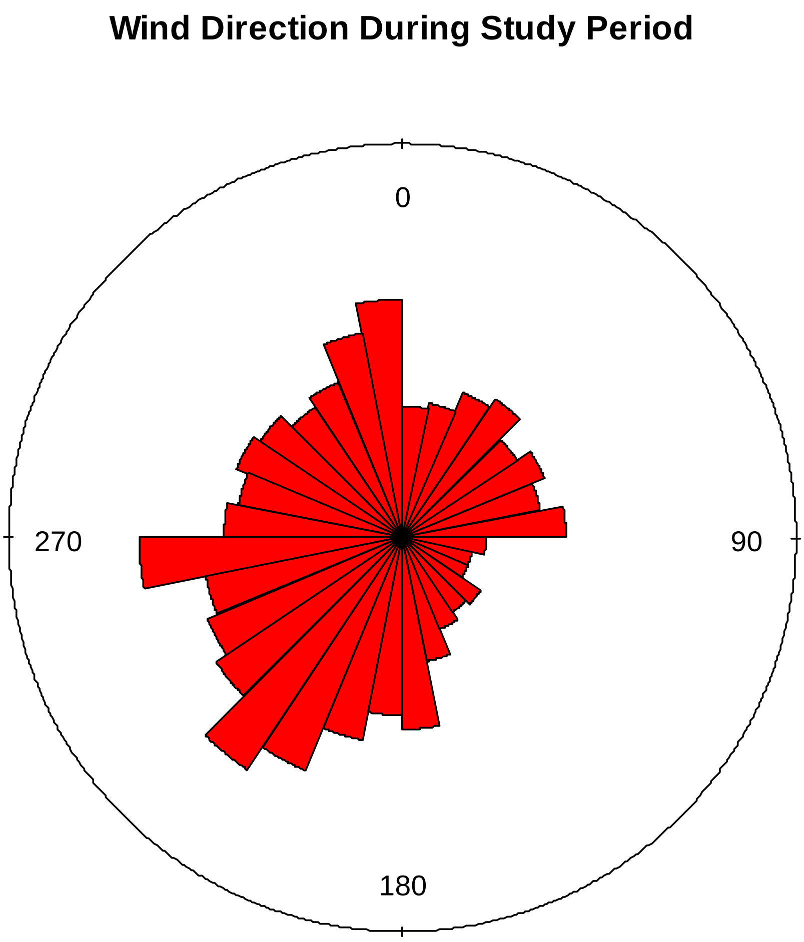


Figure 1 Prevailing wind directions during study period

Seabirds made up the bulk of the data with 11,071 records of 234,920 birds (Figure 2). Other groups were also well represented with 3372 records of wildfowl (excluding seaduck), 2348 records of waders, 2206 records of seaduck (Scoter, Eider and Long-tailed Ducks) and 1023 records of divers.

In terms of the total number of birds recorded, the most common species within the area was the Common Scoter *Melanitta nigra* with 168,268 birds counted and up to 5000 recorded at any one time. Of the seabirds, the species with the highest numbers recorded were the Herring Gull *Larus argentatus* with 74,003 birds, the Common Gull *Larus canus* with 28,469 birds, the Gannet with 28,016 birds and the Sandwich Tern with 21,250 birds. Other species with notable numbers included the Wigeon *Anas penelope* with 18,872 birds, the Bar-tailed Godwit *Limosa lapponica* with 14,883 birds, the Dark-bellied Brent Goose with 11,892 birds and the Oystercatcher *Haematopus ostralegus* with 10,720 birds recorded.

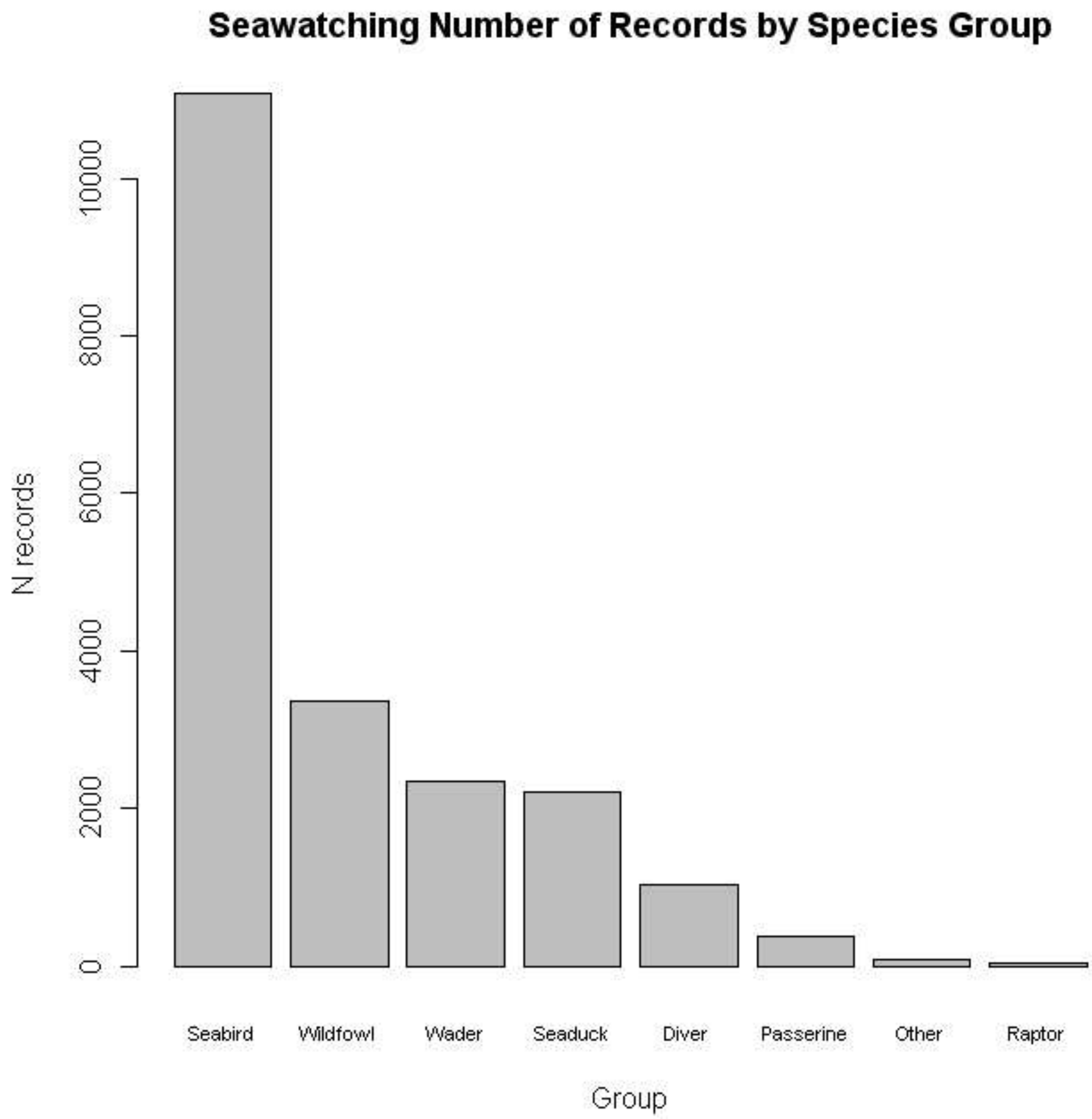


Figure 2 Number of records of each species group collected during sea-watches at Holme Bird Observatory between 2006 and 2010

2.2.2 Initial data exploration

For each of the 31 seabird and waterbird species commonly recorded during sea-watching at Holme Bird Observatory graphs are presented below showing the mean hourly passage rate for each 10 day period across the year for 2006 to 2010, the number of observations in response to prevailing wind conditions, which should be interpreted with reference to Figure 3.1.1., and the direction of travel during the spring and autumn migration periods.

2.2.2.1 Great Northern Diver **Gavia immer**

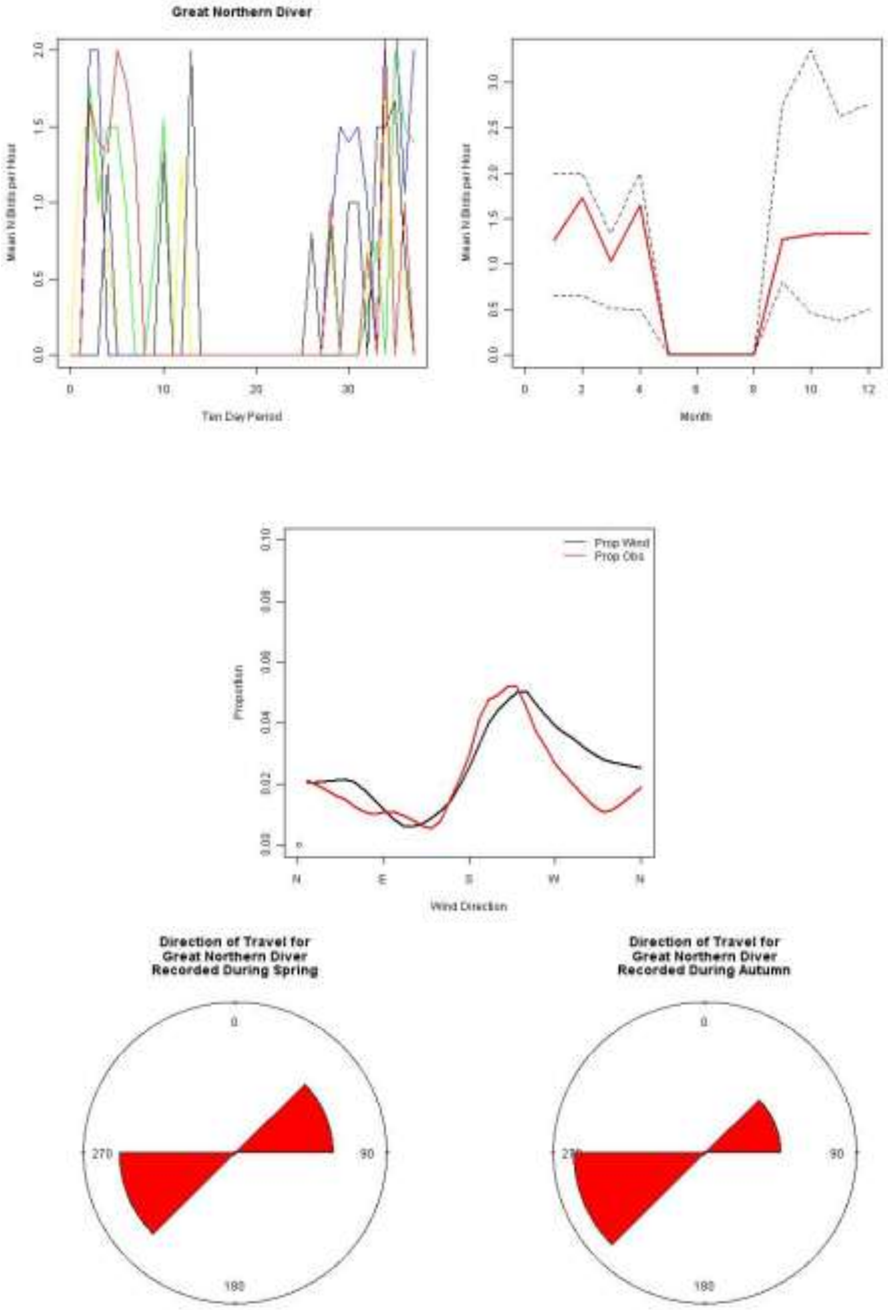


Figure 3 (Clockwise From Top Left) Seasonal variation in the numbers of Great Northern Divers per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Great Northern Divers recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Great Northern Divers recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Great Northern Divers were recorded most commonly during the winter, when in most years they are recorded at a rate of 1-2 per hour. Great Northern Divers were absent from the area during the summer.

The number of Great Northern Divers recorded in response to the different wind conditions was roughly proportional to the occurrence of these conditions at Holme Bird Observatory. Consequently, it appears that the prevailing wind conditions had little impact on the numbers of Great Northern Divers that were recorded during sea-watching.

During the spring, Great Northern Divers were recorded in equal numbers flying East and West. Over the autumn there was a tendency for more birds to be flying in a westerly direction.

2.2.2.2 Red-throated Diver **Gavia stellata**

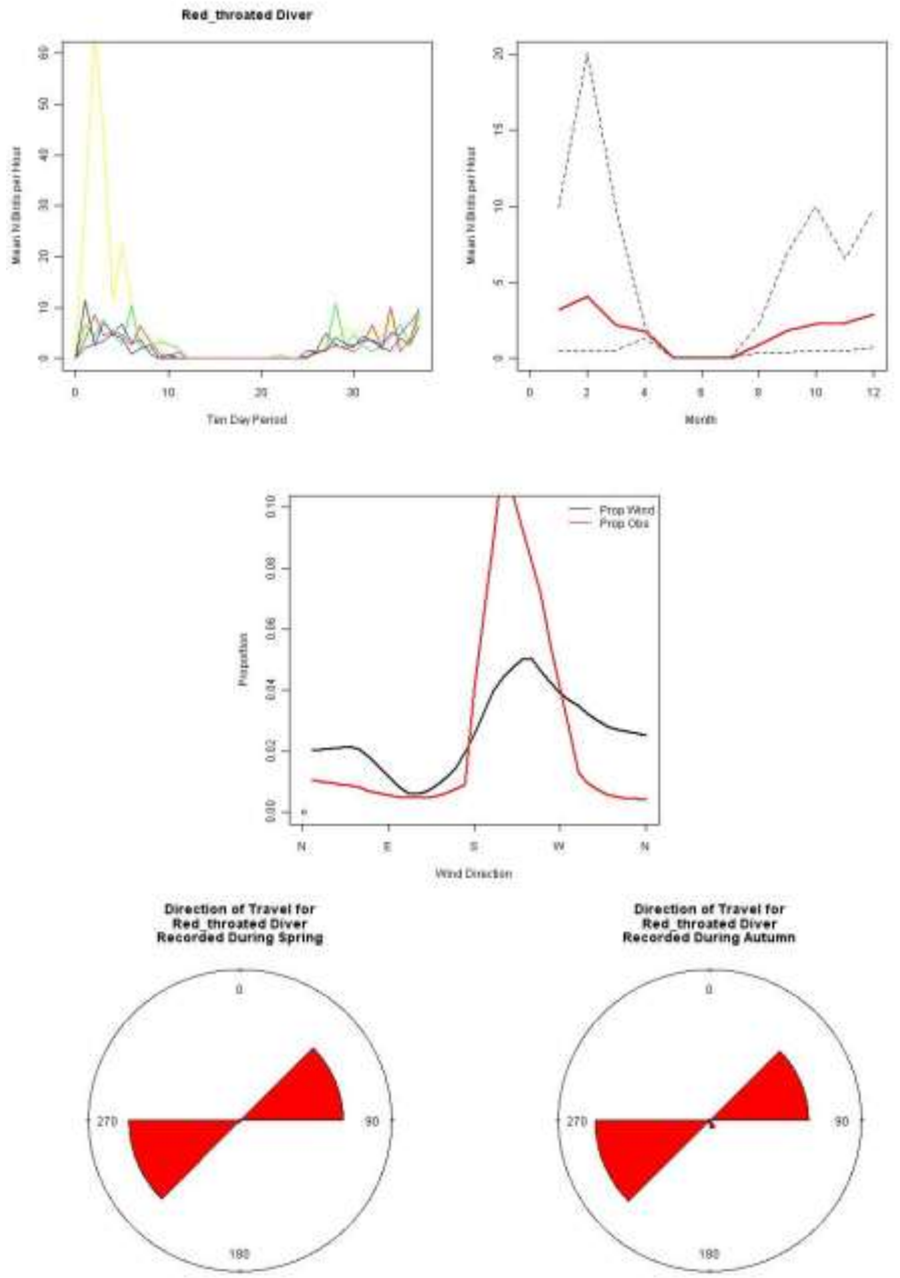


Figure 4 (Clockwise From Top Left) Seasonal variation in the numbers of Red-throated Divers per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Red-throated Divers recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Red-throated Divers recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Red-throated Divers were recorded most commonly during the winter, at a rate of 5-10 per hour. A large influx of Red-throated Divers was recorded during 2007 when the mean hourly rate peaked at 60 birds per hour due to an unusual influx of prey items (Cooke *et al.* 2007). Red-throated Divers were absent from the area over summer.

The number of Red-throated Divers recorded appeared to peak in response to winds coming from a south to south westerly direction. A large number of Red-throated Divers winter in the Outer Thames Estuary (O'Brien *et al.* 2008), to the south of Holme Bird Observatory and this relationship may reflect wind influencing the dispersal of birds from this area.

In both spring and autumn, Red-throated Divers were recorded in roughly equal numbers flying both east and west.

2.2.2.3 Black-throated Diver **Gavia arctica**

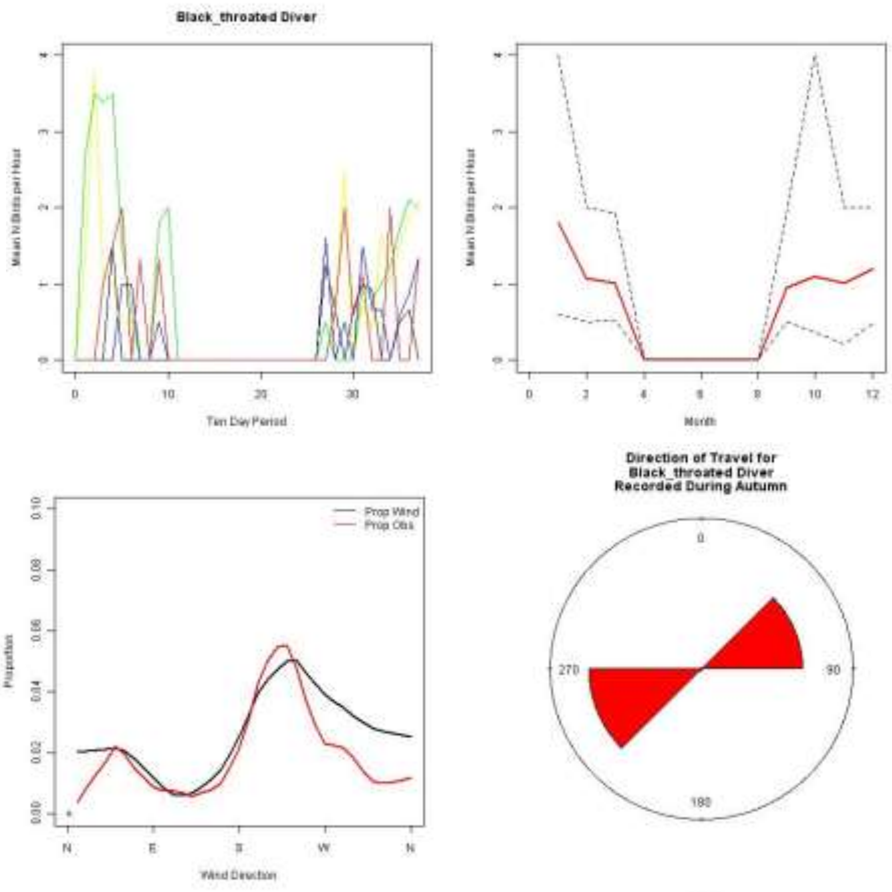


Figure 5 (Clockwise From Top Left) Seasonal variation in the numbers of Black-throated Divers per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Black-throated Divers recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Black-throated Divers recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Black-throated Divers were recorded most commonly during the winter, at a rate of 1-2 per hour. An influx of black-throated divers was recorded during 2006 and 2007 when the mean hourly rate peaked at 5 birds per hour.

The number Black-throated Divers recorded in response to the different wind conditions was proportional to the occurrence of these conditions at Holme Bird Observatory. Consequently, it appears that the prevailing wind conditions had little impact on the numbers of Black-throated Divers that were recorded during sea-watching.

In autumn, Black-throated Divers showed no strong preference for flying in an easterly or westerly direction.

2.2.2.4 *Great Crested Grebe* Podiceps cristatus

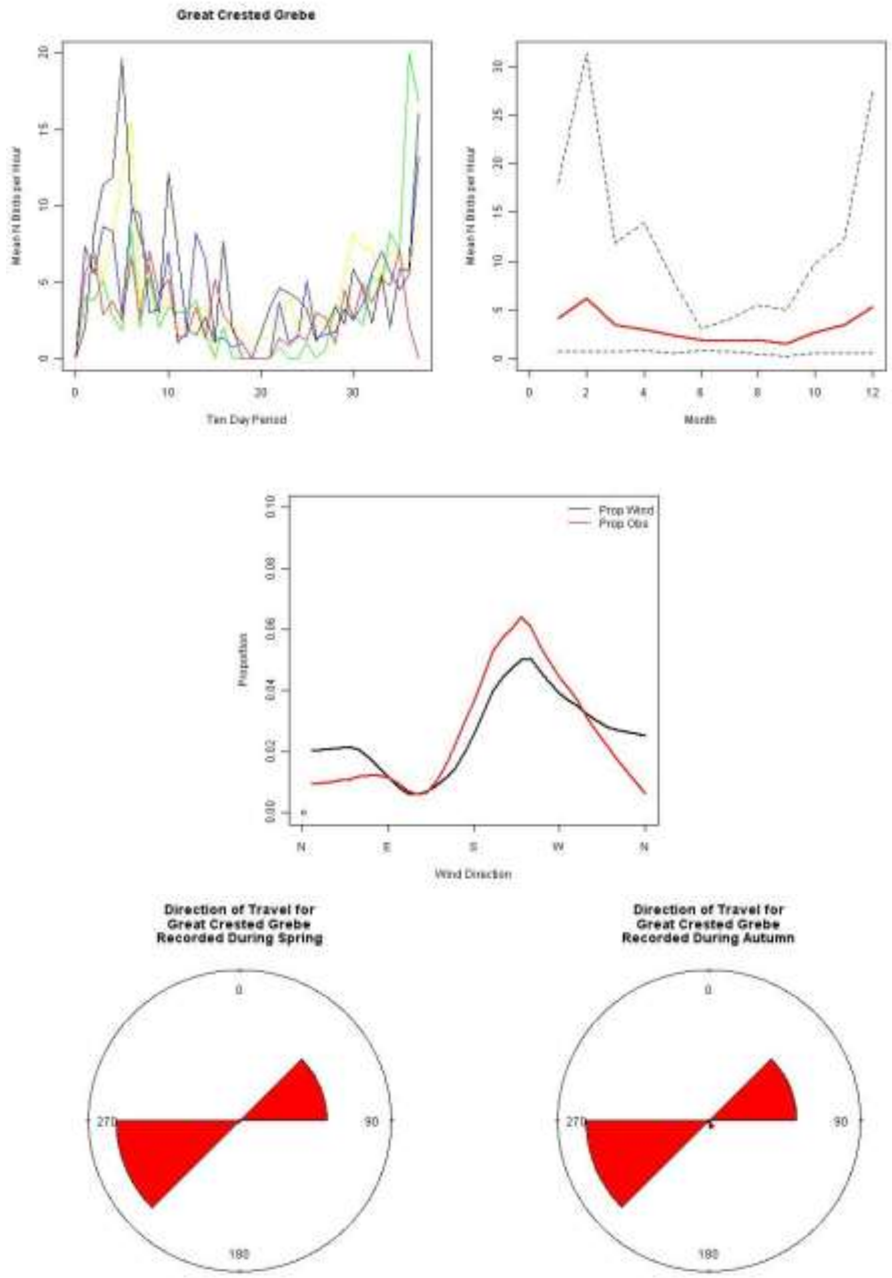


Figure 6 (Clockwise From Top Left) Seasonal variation in the numbers of Great Crested Grebes per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Great Crested Grebes recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Great Crested Grebes recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Great Crested Grebes were recorded throughout the year. Numbers peaked in December and January at 15-20 birds per hour. During the summer, they were recorded in much lower numbers at a rate of around 1-2 per hour.

The Numbers of Great Crested Grebes recorded in response to different wind directions were roughly proportional to the prevailing wind conditions.

Slightly more Great Crested Grebes were recorded flying west than east during both the autumn and spring migration periods.

2.2.2.5 Slavonian Grebe **Podiceps auritus**

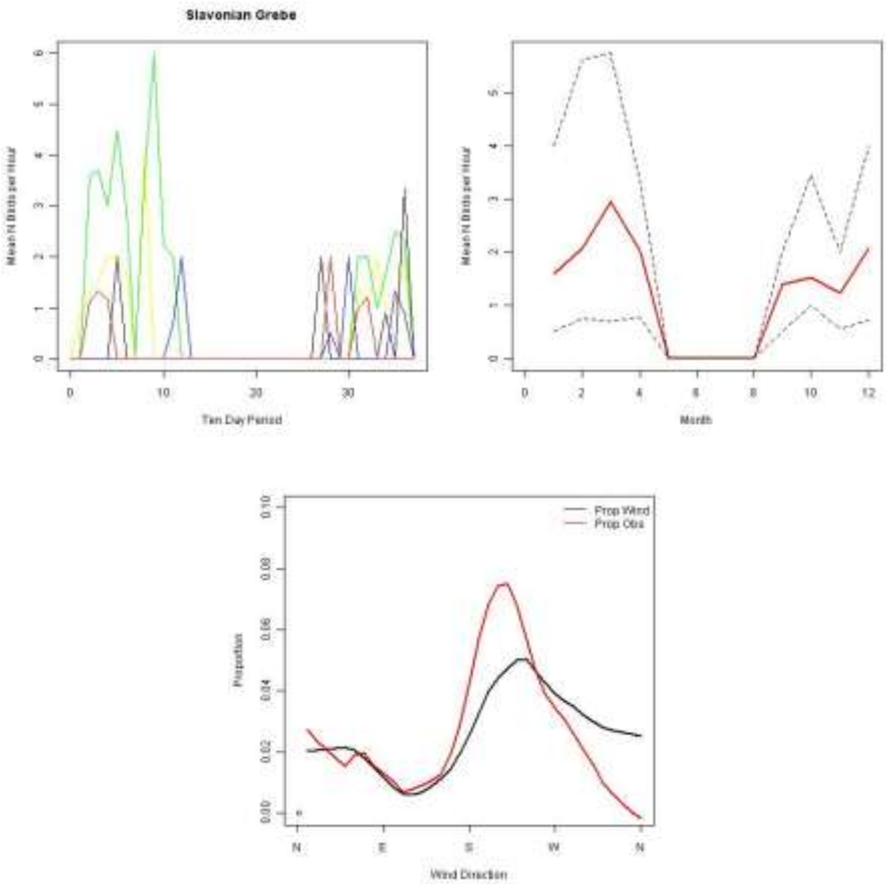


Figure 7 (Clockwise From Top Left) Seasonal variation in the numbers of Slavonian Grebes per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Slavonian Grebes recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Slavonian Grebes recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Most Slavonian Grebes are observed on the sea surface, rather than flying. Numbers peak over the winter with rates of 4-6 birds per hour. There were particularly noticeable peaks during early 2006 and early 2007. No birds were recorded over the summer months in any year.

Greater numbers of Slavonian Grebes were recorded in response to southerly and south-westerly winds than would be expected under prevailing conditions.

2.2.2.6 Red-necked Grebe **Podiceps grisegena**

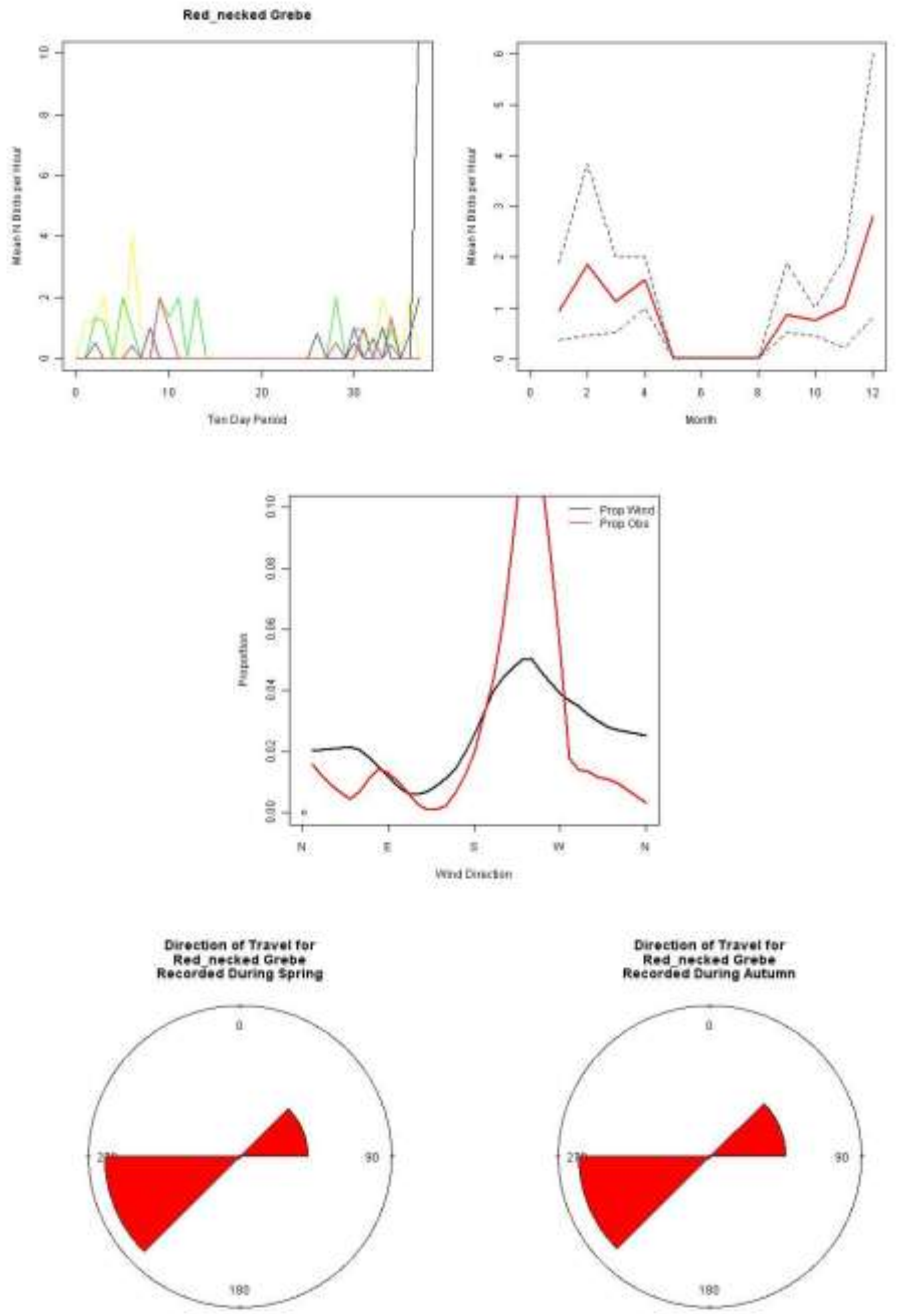


Figure 8 (Clockwise From Top Left) Seasonal variation in the numbers of Red-necked Grebes per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Red-necked Grebes recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Red-necked Grebes recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

The number of Red-necked Grebes recorded peaked over the winter. Noticeable peaks were recorded in January 2007 with up to 4 per hour recorded and December 2008 with up to 10 per hour recorded.

More Red-necked Grebes were recorded in response to south-westerly winds than would be expected under prevailing conditions.

In both spring and autumn Red-necked Grebes showed a preference showed a greater tendency to fly in a easterly, rather than westerly direction.

2.2.2.7 *Fulmar* **Fulmarus glacialis**

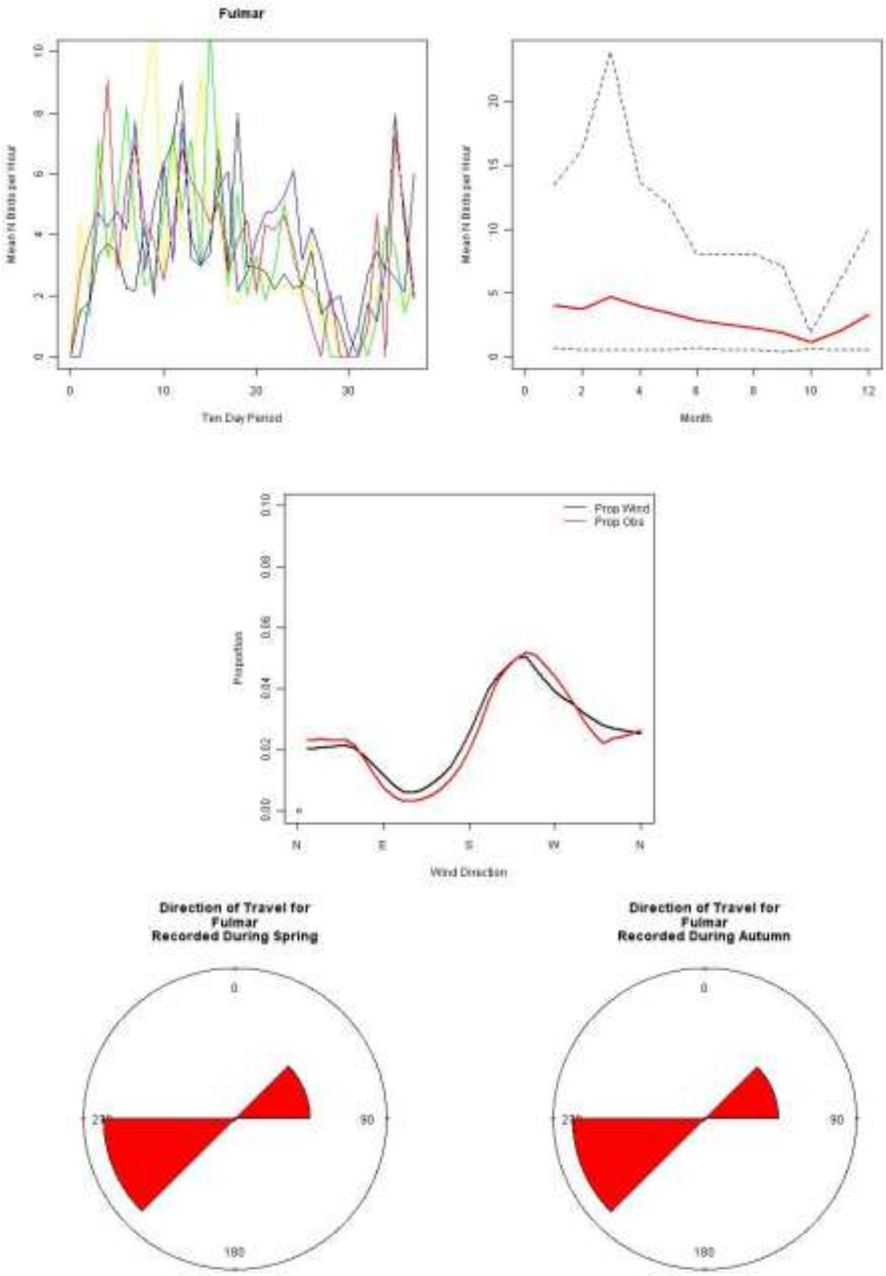


Figure 9 (Clockwise From Top Left) Seasonal variation in the numbers of Fulmar per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Fulmar recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Fulmar recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Fulmars were most commonly recorded during late winter and spring with birds recorded at a rate of up to 10 per hour. During the summer, many of the Fulmars observed are likely to be associated with the nearby breeding colony at Hunstanton Cliffs. Numbers appear to be closely associated with their breeding cycle, and they are often recorded during feeding flights. Numbers declined from the late summer and by October Fulmar records were restricted to less than one per hour. During December, the rate at which Fulmars were recorded increased, this increase continued through to the spring.

The numbers of Fulmar recorded in response to different wind directions appeared to be consistent with the prevailing conditions.

During both spring and autumn, Fulmar appeared to show a bias towards flying in a westerly direction. This appears to be because the birds leave the breeding cliffs and move straight out into the open sea, whereas on their return they come along the coast.

2.2.2.8 Manx Shearwater **Puffinus puffinus**

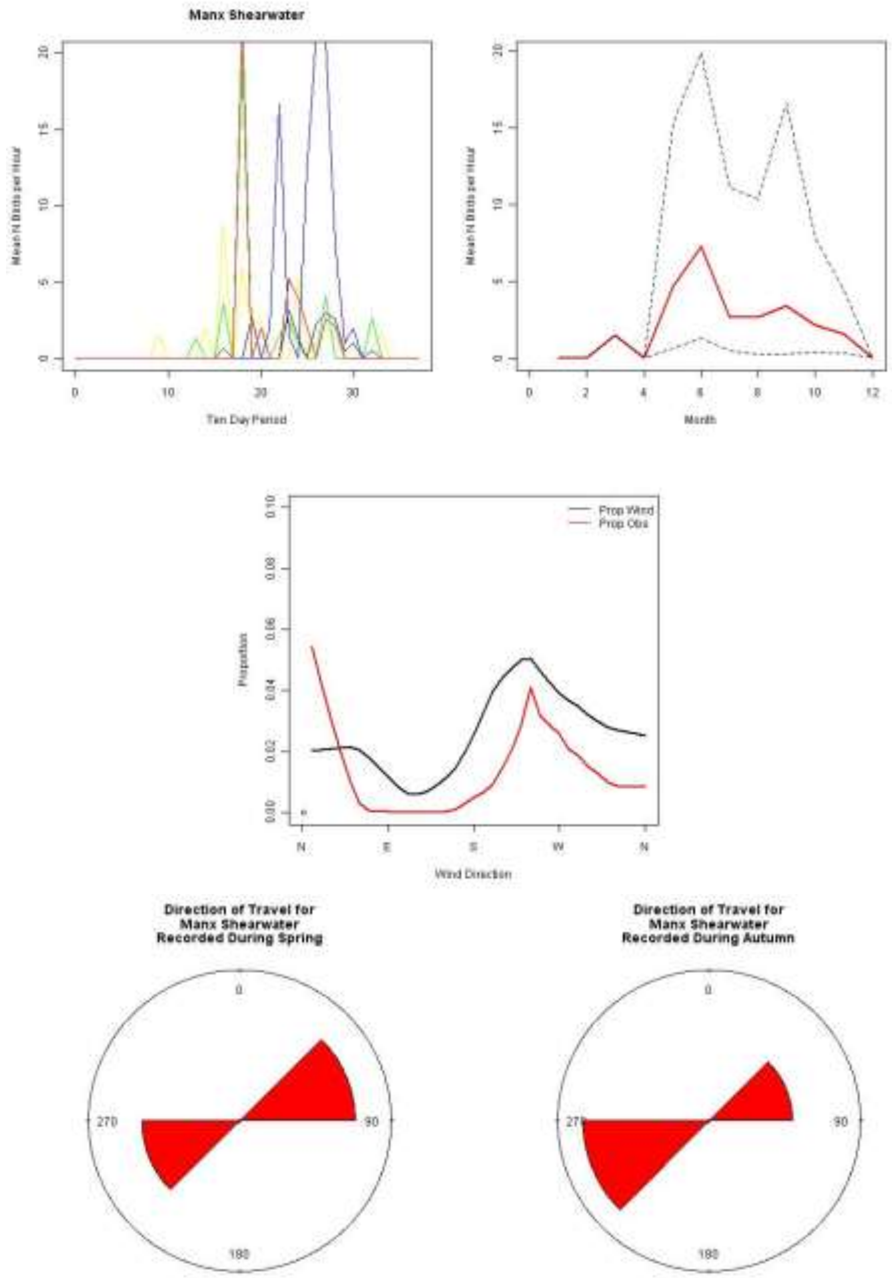


Figure 10 (Clockwise From Top Left) Seasonal variation in the numbers of Manx Shearwater per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Manx Shearwater recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Manx Shearwater recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Manx Shearwaters were commonly recorded in low numbers throughout the summer. In 2007 and 2008 they were recorded at a rate of up to 5 per hour, in 2006, 2009 and 2010 greater numbers were seen, with up to 25 per hour recorded.

Manx Shearwaters were predominantly recorded during periods of northerly winds.

During the spring, Manx Shearwater were most commonly recorded flying in an easterly direction, during the autumn, flight was more often in a westerly direction.

2.2.2.9 Gannet Morus bassanus

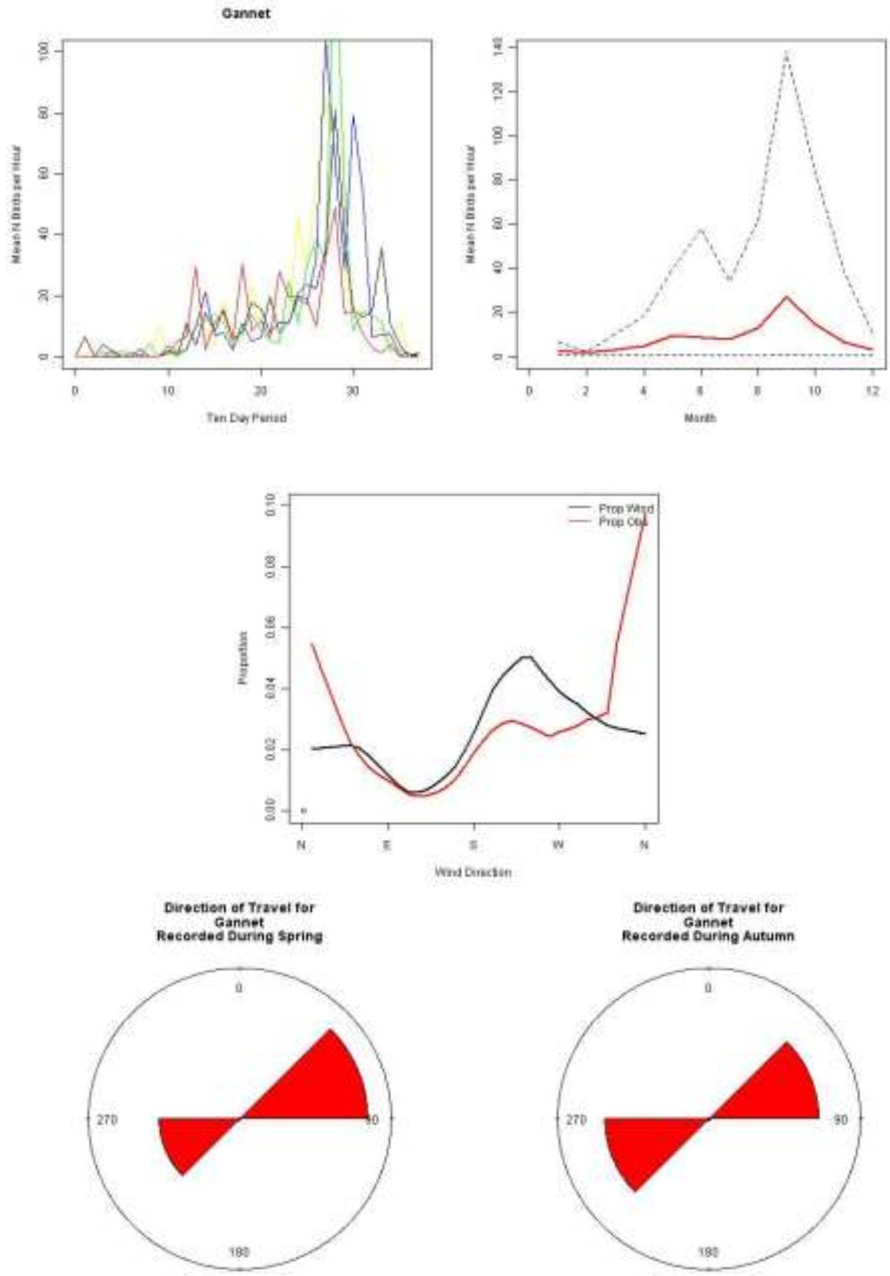


Figure 11 (Clockwise From Top Left) Seasonal variation in the numbers of Gannet per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Gannet recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Gannet recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Gannets can be seen throughout the year. However, towards the end of the summer numbers increase, building to a peak of up to 100 birds per hour during the autumn. The rate at which Gannets were recorded then declines rapidly during the winter with an average of 1-2 per hour recorded until the following summer.

The numbers of Gannets recorded in response to different wind directions appeared to peak in response to northerly winds. This is likely to reflect the movement of birds away from the nearby breeding colony at Flamborough Head and Bempton Cliffs.

During both spring and autumn Gannets were more commonly recorded flying in an easterly direction during the spring, although there was little evidence of a spring migration.

2.2.2.10 *Cormorant* Phalacrocorax carbo

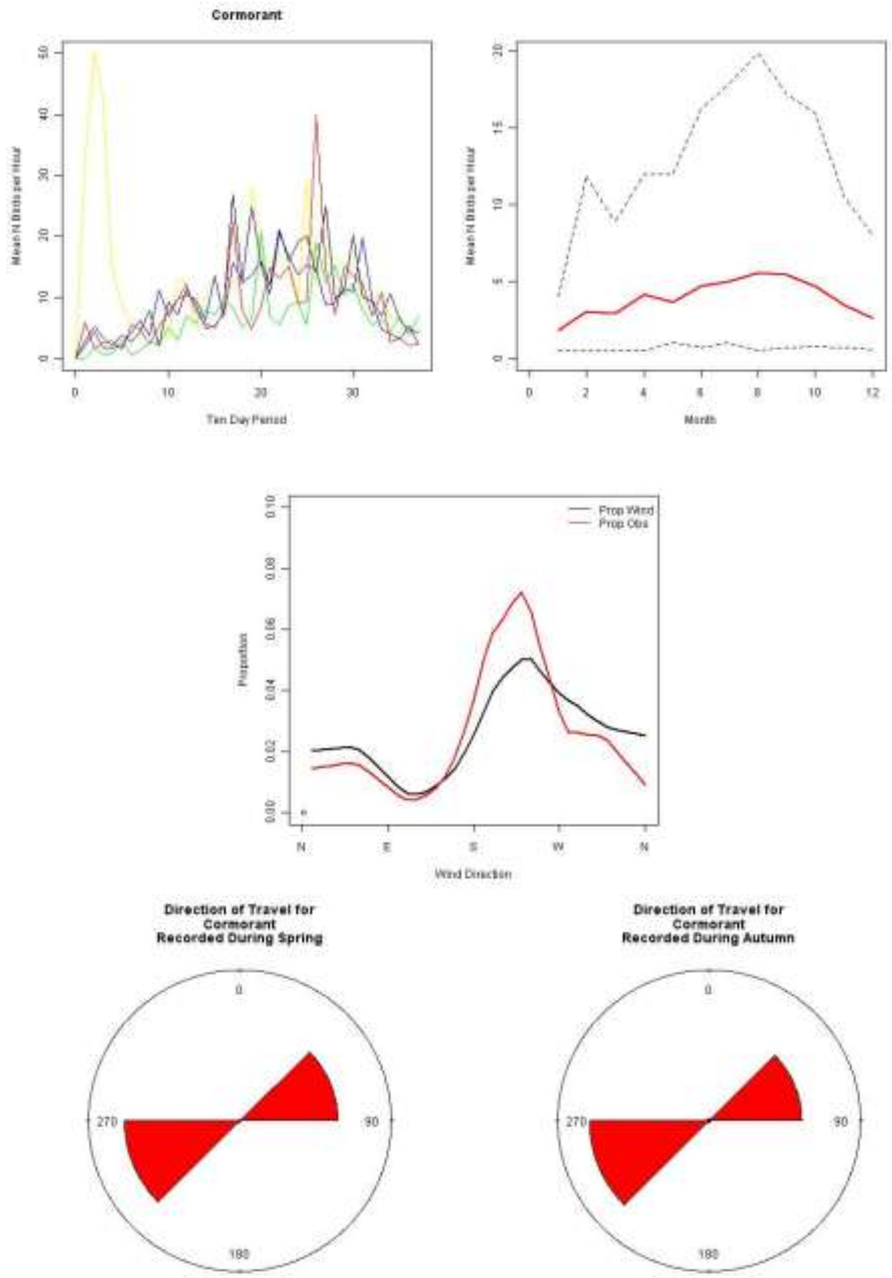


Figure 12 (Clockwise From Top Left) Seasonal variation in the numbers of Cormorant per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Cormorant recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Cormorant recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Cormorants were recorded throughout the year. Numbers peak during the summer with up to 20 recorded every hour. Smaller numbers were typically recorded during the winter, although January 2007 saw an influx during which up to 55 were recorded each hour.

The number of cormorants recorded in response to different wind directions appeared to be consistent with the prevailing conditions.

During both spring and autumn showed a slight tendency towards more westerly flights.

2.2.2.11 *Wigeon* Anas penelope

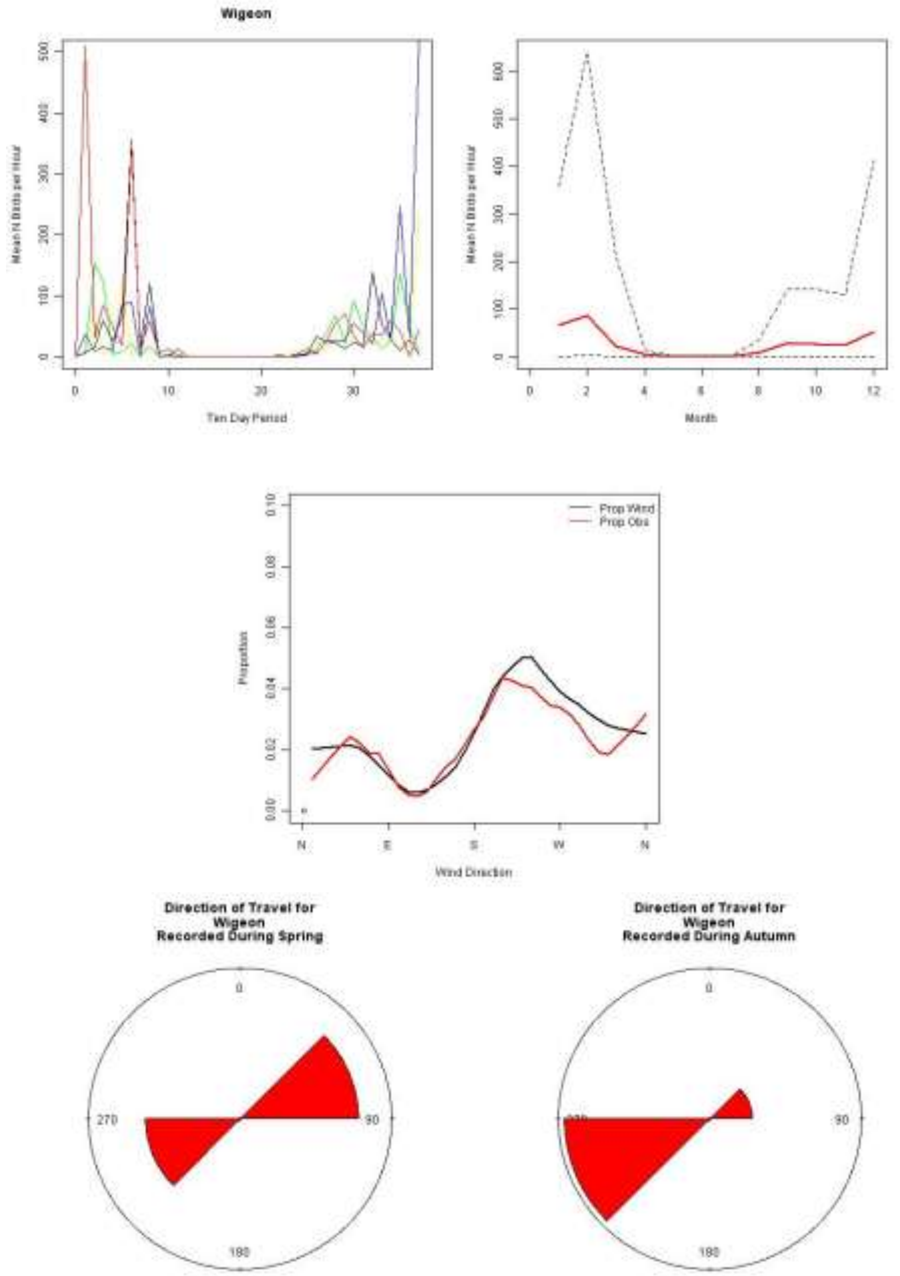


Figure 13 (Clockwise From Top Left) Seasonal variation in the numbers of Wigeon per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Wigeon recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Wigeon recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Wigeon were first recorded in significant numbers during the autumn. The rate at which they were recorded gradually increases, reaching a plateau during the winter, before declining rapidly during the spring. They were only rarely recorded during the summer. Particularly high numbers of Wigeon were recorded during early 2008 and late 2009 when an average of up to 500 birds were recorded per hour.

The number of Wigeon recorded in response to different wind directions appeared to be consistent with the prevailing conditions.

During the spring flight was most commonly recorded in an easterly direction. Over the autumn, there was a strong tendency for flight to be recorded in a westerly direction. This presumably reflects the arrival of birds after their sea crossing from Continental Europe and a concentration along the coast. Many of these birds subsequently disperse to other parts of UK or beyond. A strong peak of easterly flying birds during the spring would not be expected since they presumably depart from several widely scattered locations and may well leave UK in hours of darkness. Many of the high counts in spring are local wintering birds.

2.2.2.12 *Teal* Anas crecca

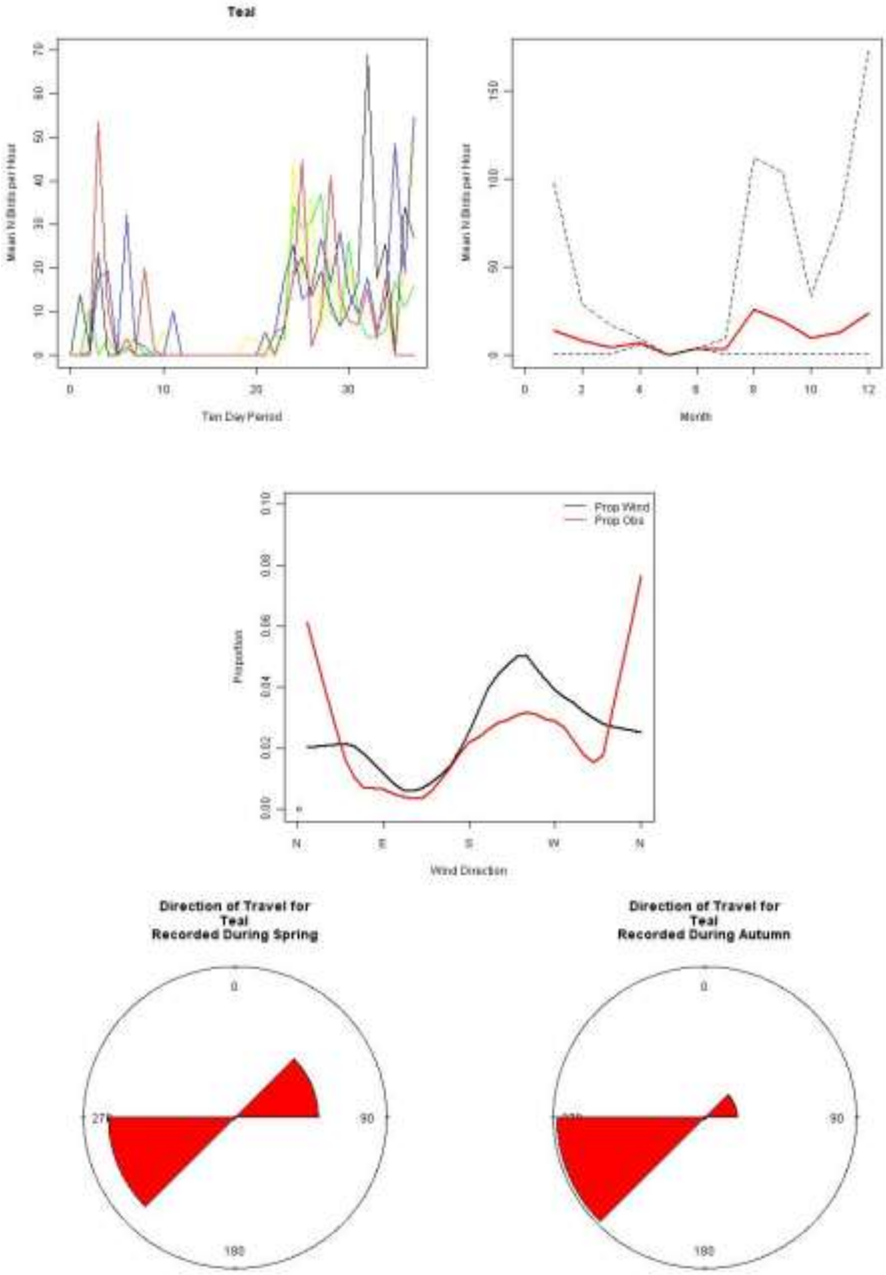


Figure 14 (Clockwise From Top Left) Seasonal variation in the numbers of Teal per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Teal recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Teal recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Teals were first recorded in significant numbers during the autumn. The rate at which they were recorded gradually increases, reaching a plateau during the winter, before declining rapidly during the spring. They were only rarely recorded during the summer.

The number of Teal recorded appeared to peak in response to northerly winds, perhaps reflecting a movement of birds from the continent during favourable wind conditions.

During the spring flight was most commonly recorded in an easterly direction. Over the autumn, there was a strong tendency for flight to be recorded in a westerly direction. As with Wigeon, this presumably reflects the arrival of birds after their sea crossing from Continental Europe and a concentration along the coast. Many of these birds subsequently disperse to other parts of UK or beyond. A strong peak of easterly flying birds during the spring would not be expected since they presumably depart from several widely scattered locations and may well leave UK in hours of darkness. Many of the high counts in spring are local wintering birds.

2.2.2.13 *Eider* Somateria mollissima

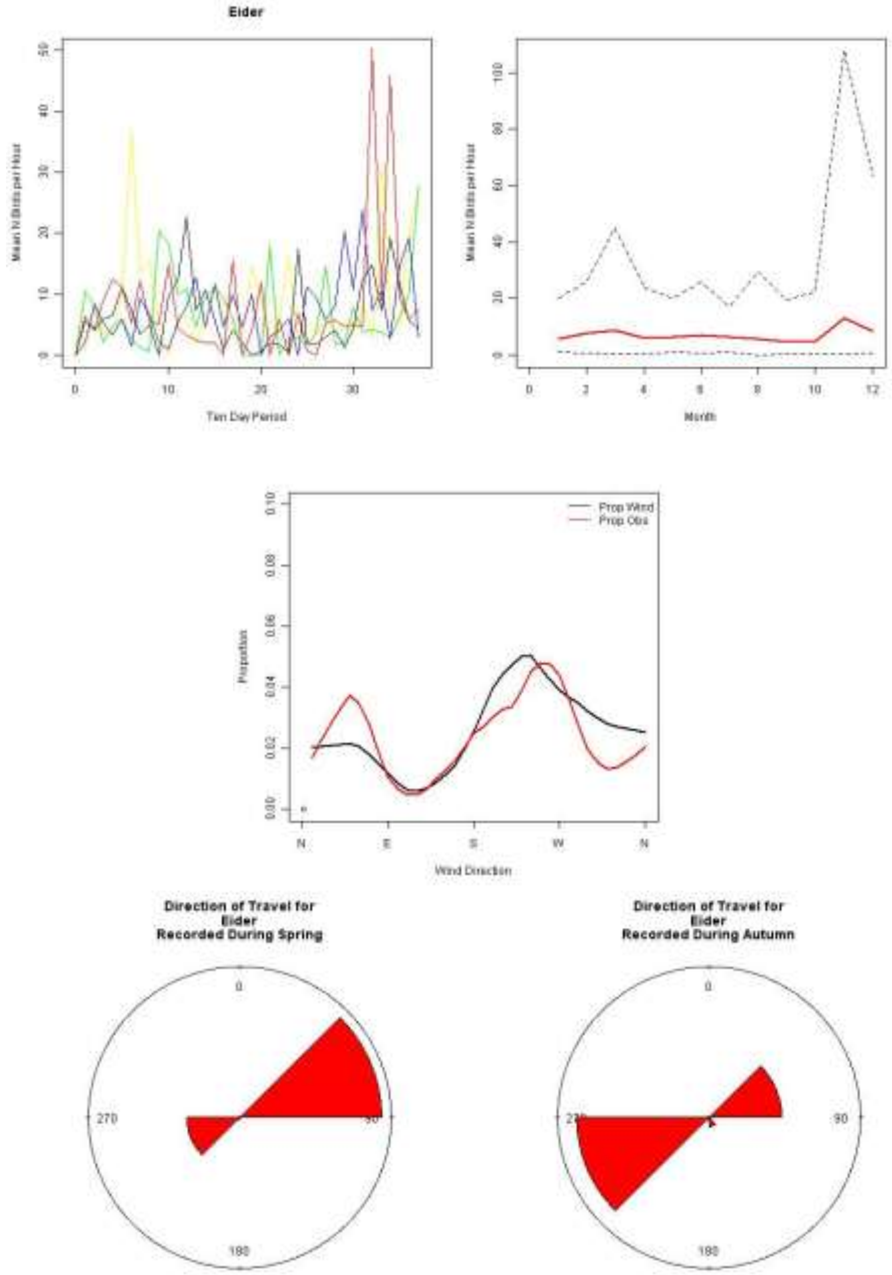


Figure 15 (Clockwise From Top Left) Seasonal variation in the numbers of Eider per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Eider recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Eider recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Eiders were recorded throughout the year, with a slight of around 20-30 birds per hour during November and December. Throughout the rest of the year they were recorded at a rate of around 10 birds per hour. There was a noticeable peak during spring 2007 when an average of 35 birds per hour was recorded.

The numbers of Eider recorded in response to different wind directions appeared to be consistent with the prevailing conditions.

During the spring, there was a strong tendency for Eider to be recorded flying in an Easterly direction, in contrast, over the autumn, birds were more likely to be flying west. This is likely to reflect migratory movements into and out of the country from continental Europe.

2.2.2.14 *Long-tailed Duck* **Clangula hyemalis**

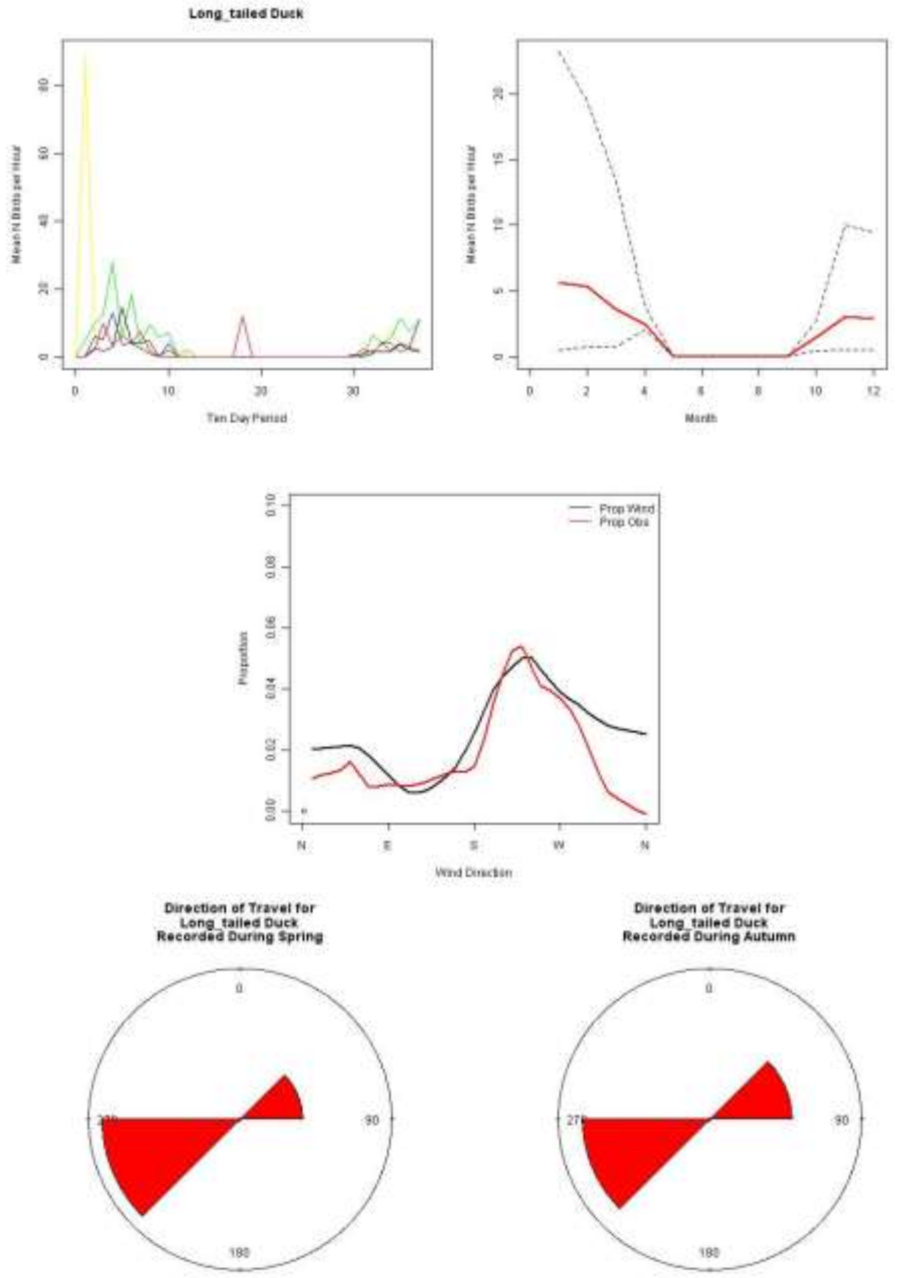


Figure 16 (Clockwise From Top Left) Seasonal variation in the numbers of Long-tailed Ducks per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Long-tailed Ducks recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Long-tailed Ducks recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Long-tailed Ducks were most commonly recorded during the winter when numbers typically peak at a mean of 10-20 birds per hour. An influx was recorded during January 2007 when an average of up to 60 birds per hour were recorded. During this period, several other species also showed an uncharacteristic increase. They were only rarely recorded between the end of March and November.

Long-tailed Ducks appear to show little variation in response to prevailing wind direction. During both spring and autumn, most birds appeared to be travelling in a westerly direction.

2.2.2.15 *Common Scoter* **Melanitta nigra**

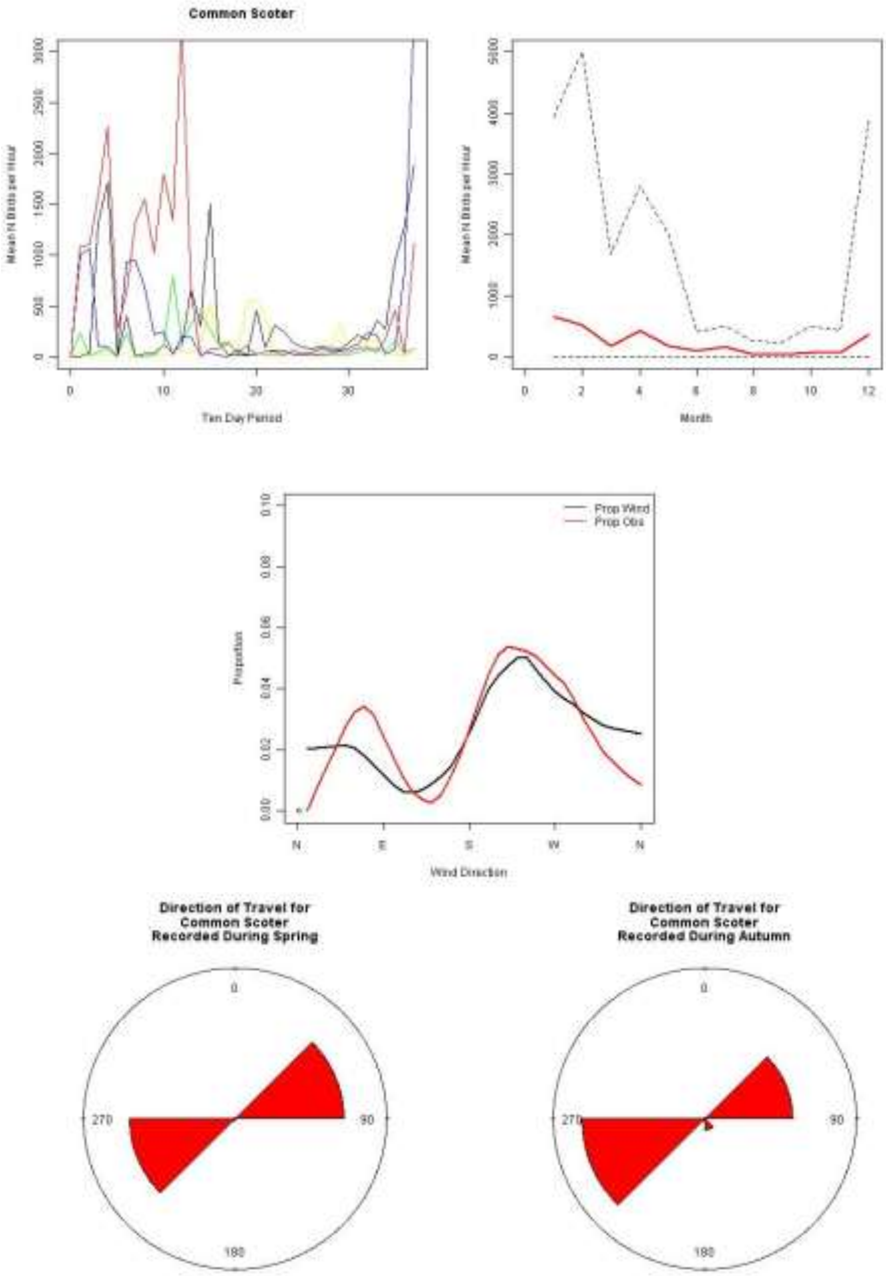


Figure 17 (Clockwise From Top Left) Seasonal variation in the numbers of Common Scoter per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Common Scoter recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Common Scoter recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Common Scoters were recorded throughout the year. Numbers tended to peak during the winter and spring, with records in excess of 2000 birds per hour in some months. Common Scoters were recorded in relatively low numbers throughout the summer, before the recording rate increased again during the winter.

Common Scoters appear to show little variation in response to prevailing wind direction.

2.2.2.16 *Goldeneye* **Bucephala clangula**

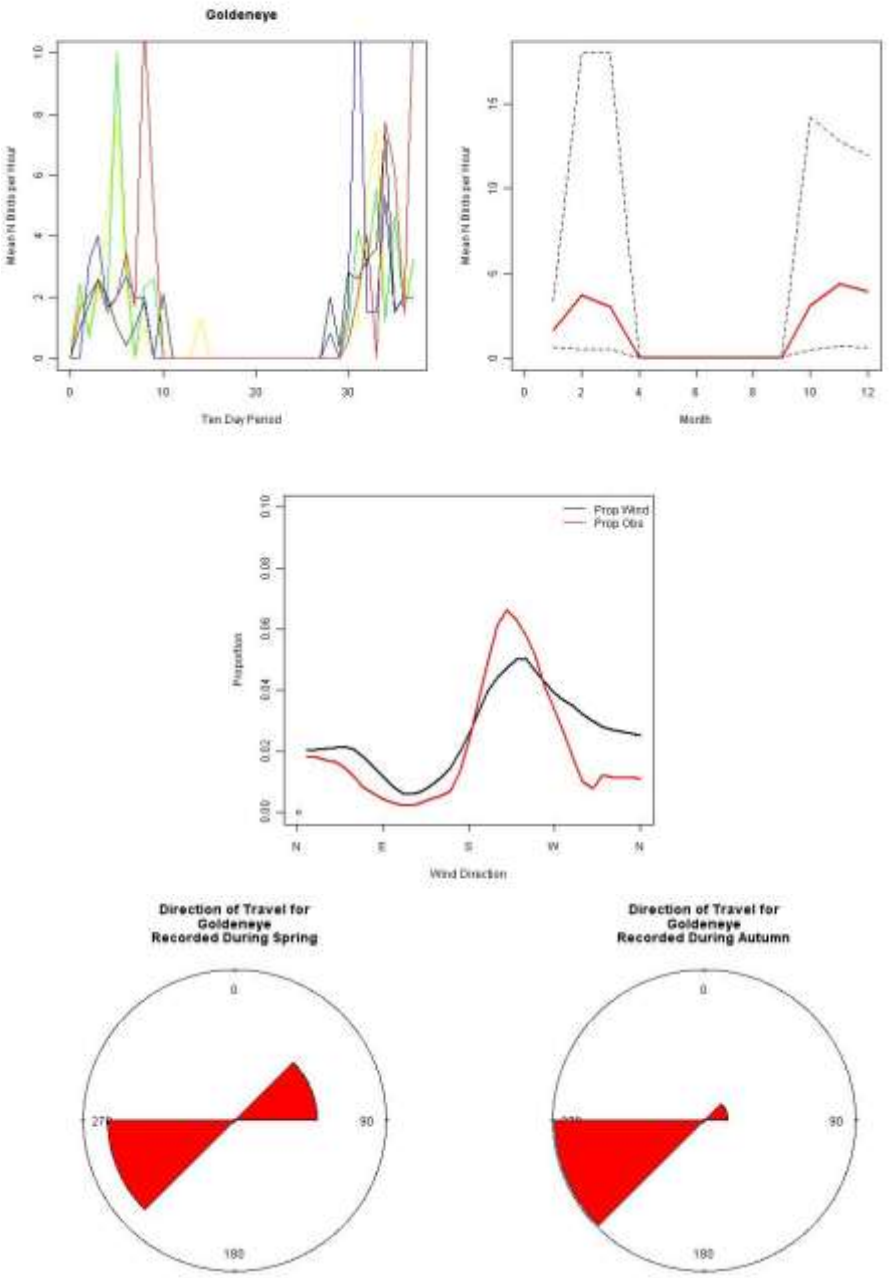


Figure 18 (Clockwise From Top Left) Seasonal variation in the numbers of Goldeneye per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Goldeneye recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Goldeneye recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Goldeneyes were recorded throughout the winter, but largely absent during the summer. During winter, numbers rose to a peak of around 8-10 birds per hour in December and January.

Goldeneye numbers show a peak in response to north-westerly winds.

Whilst similar numbers of Goldeneye were recorded flying in an easterly and westerly direction in the spring, there was a strong tendency for birds recorded in the autumn to be travelling in a westerly direction. This may well reflect a migratory movement.

2.2.2.17 Red-breasted Merganser **Mergus serrator**

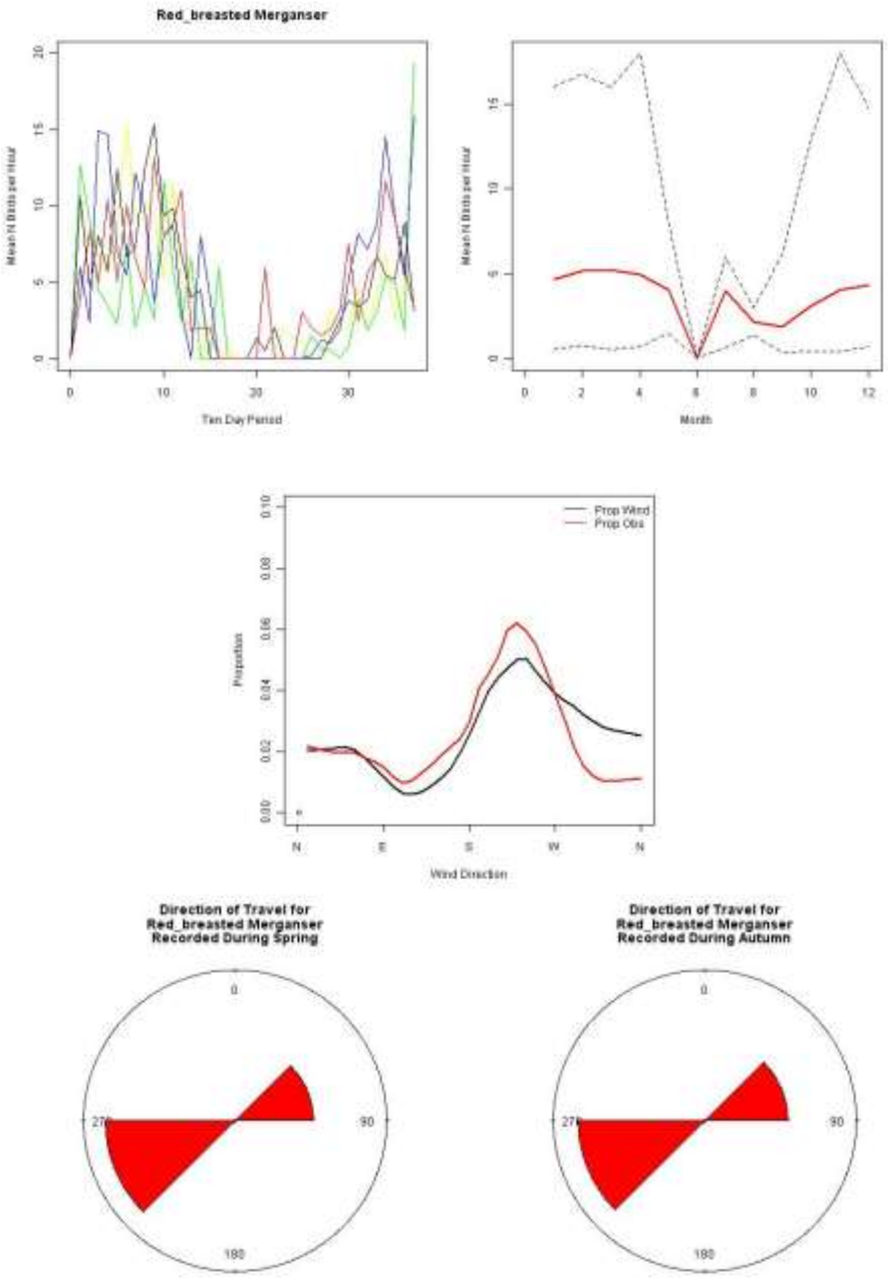


Figure 19 (Clockwise From Top Left) Seasonal variation in the numbers of Red-breasted Merganser per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Red-breasted Merganser recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Red-breasted Merganser recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

Red-breasted Mergansers, aside from a few isolated records, were largely absent from the area over the summer. During winter, numbers rise to a peak of around 10-15 birds per hour. The rate at which birds were recorded declines during the spring and around 3-5 birds per hour were recorded over the summer. The hourly rate increased again towards the autumn, rising to a peak during the winter.

Red-breasted mergansers show little variation in response to prevailing wind directions. During both spring and autumn Red-breasted Mergansers showed a slight tendency for flight in a westerly direction.

2.2.2.18 *Pomarine Skua* **Stercorarius pomarinus**

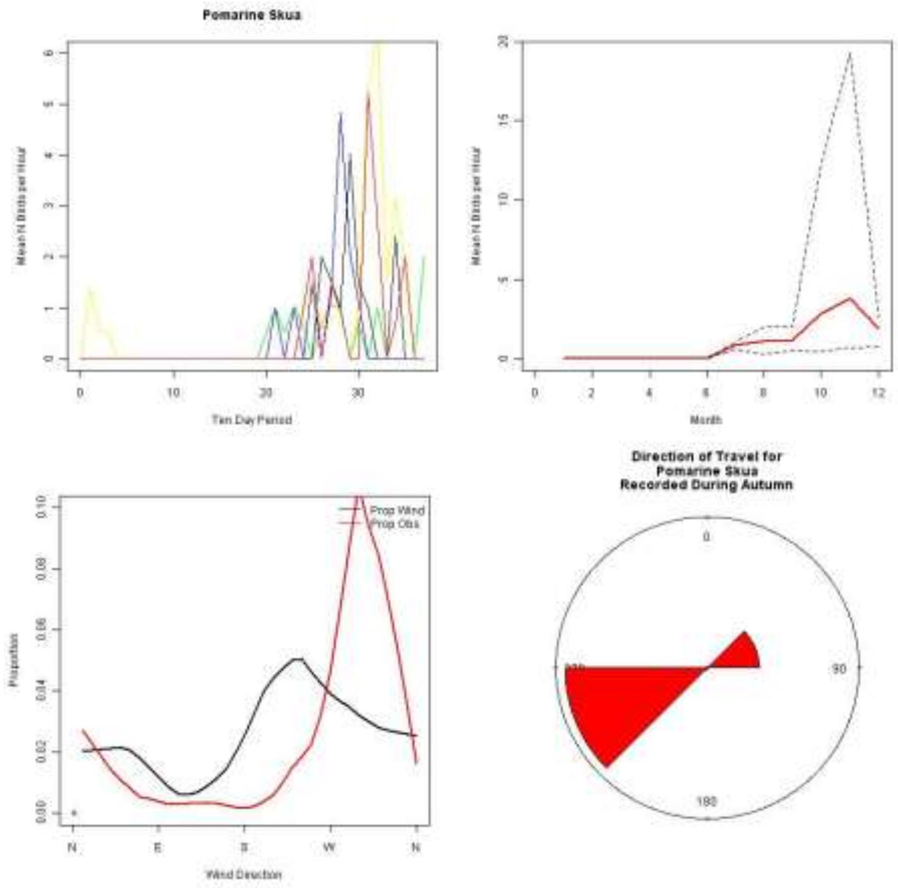


Figure 20 (Clockwise From Top Left) Seasonal variation in the numbers of Pomarine Skuas per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Pomarine Skuas recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Pomarine Skuas recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Pomarine Skuas were predominantly recorded during the autumn and early winter. Whilst they were recorded at a rate of just under one per hour throughout 2007, this was an exception rather than a rule. Typically Pomarine Skuas were recorded at a rate of around 1 per hour from the end of the summer, rising gradually, reaching up to 6 per hour during late autumn, before declining in frequency at the start of winter.

Pomarine Skuas were most commonly recorded during periods of northwesterly winds. During the autumn they were predominantly recorded flying in westerly direction. They are the latest of the skuas to move through the region.

2.2.2.19 *Arctic Skua* **Stercorarius parasiticus**

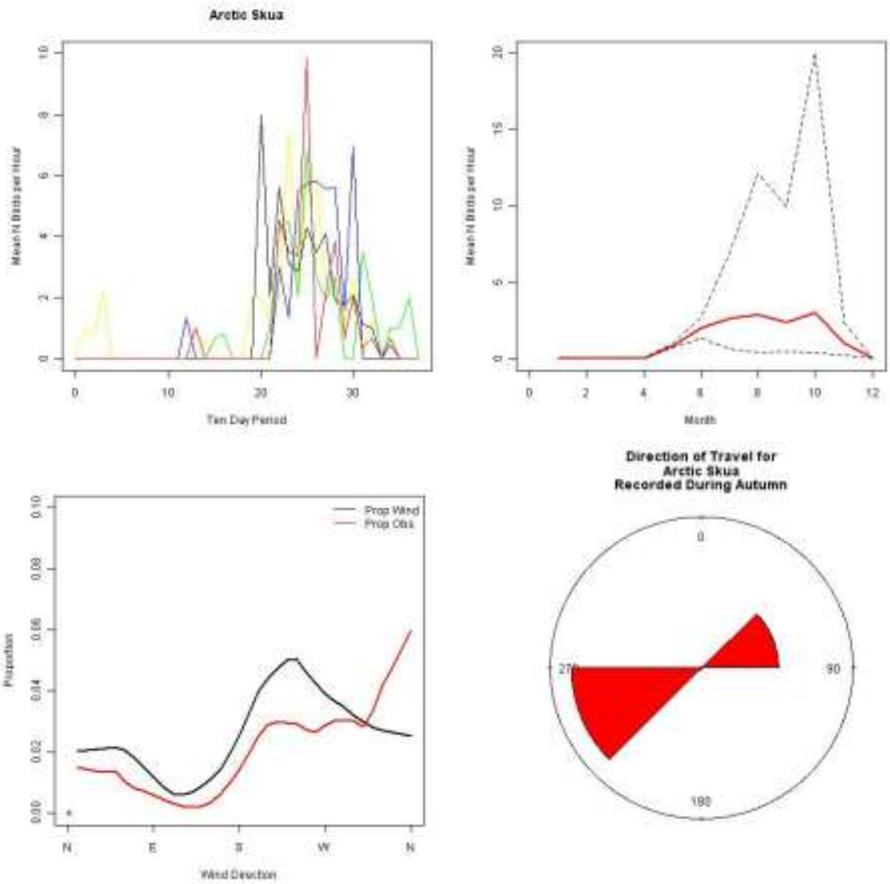


Figure 21 (Clockwise From Top Left) Seasonal variation in the numbers of Arctic Skuas per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Arctic Skuas recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Arctic Skuas recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Arctic Skuas were predominantly recorded during the late summer and autumn. They were recorded at a rate of 1-2 per hour during the early parts of 2006, 2007 and 2009. This rate rose towards the end of the summer, typically reaching around 5-6 birds per hour by the autumn, and up to 10 birds per hour in autumn 2009. Towards the end of the autumn numbers declined and by the start of the winter, the rate was around 1-2 birds per hour again.

Arctic Skuas were most commonly recorded during periods of northerly winds.

During the spring birds were most commonly recorded flying in an easterly direction, albeit based on a sample size of 8 birds. Over the autumn, birds were most commonly recorded travelling in a westerly direction.

2.2.2.20 *Great Skua* **Stercorarius skua**

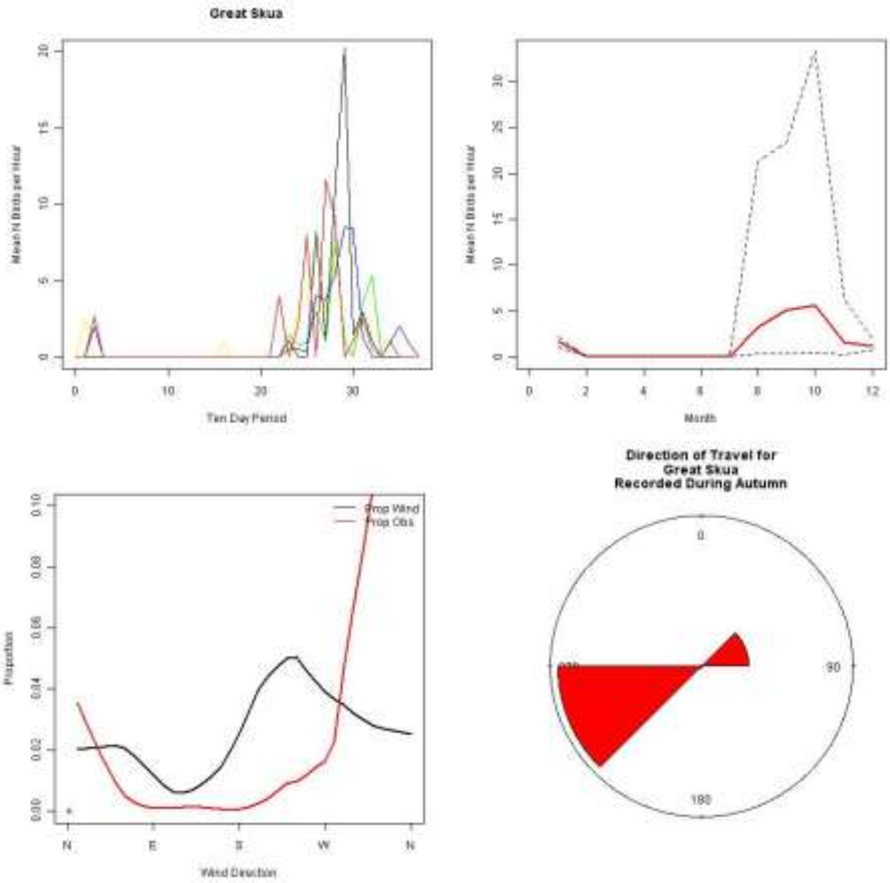


Figure 22 (Clockwise From Top Left) Seasonal variation in the numbers of Great Skuas per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Great Skuas recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Great Skuas recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Great Skuas were predominantly recorded during the autumn, when they were typically recorded at a rate of 5-10 birds per hour, with a peak of around 20 birds per hour in 2008. They were rarely recorded throughout the rest of the year.

Great Skuas were most commonly recorded during periods of northwesterly winds.

The majority of Great Skuas recorded at Holme Bird Observatory during the autumn were flying in a westerly direction.

2.2.2.21 ***Black-headed Gull*** **Chroicocephalus ridibundus**

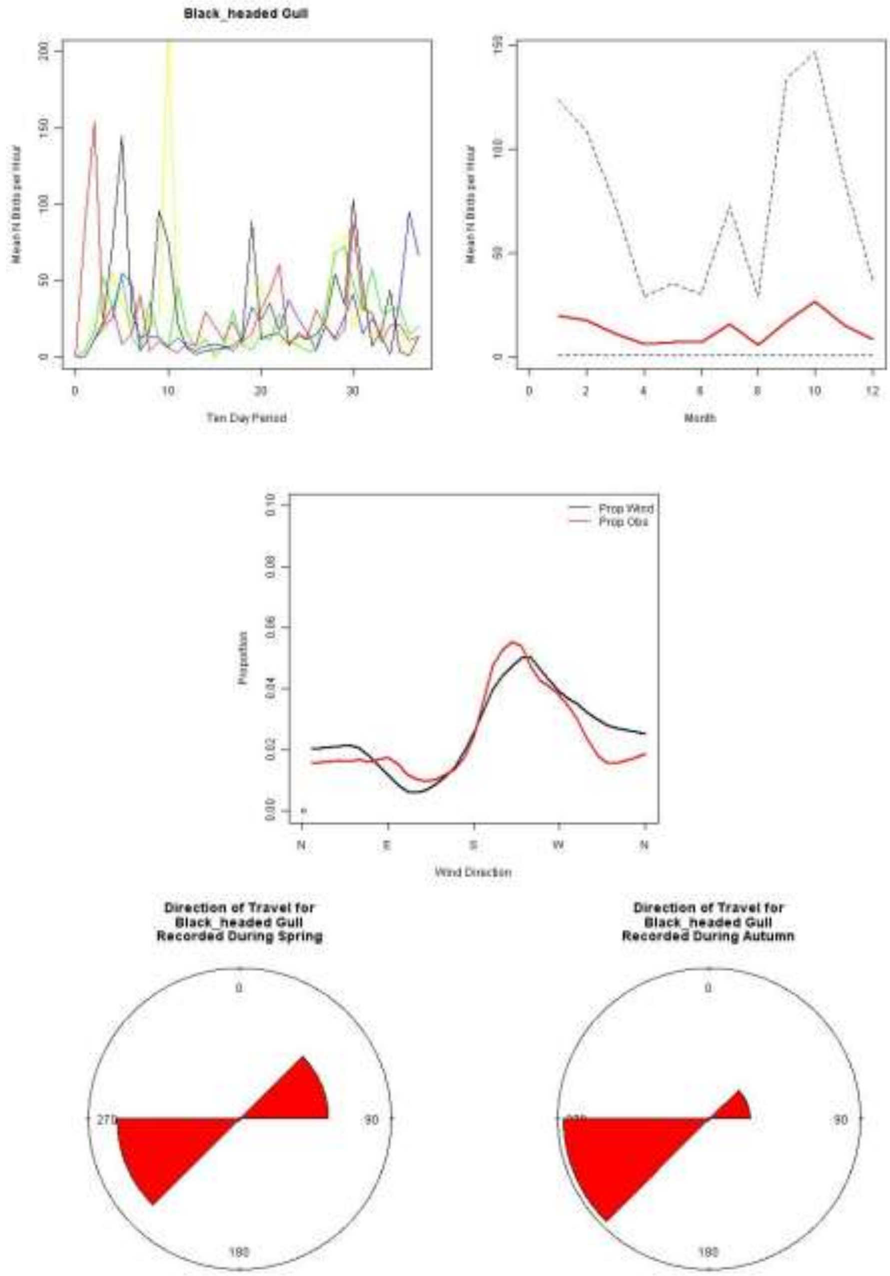


Figure 23 (Clockwise From Top Left) Seasonal variation in the numbers of Black-headed Gulls per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Black-headed Gulls recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Black-headed Gulls recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Black-headed Gulls were recorded throughout the year. Numbers tend to peak during the winter with around 50 birds recorded per hour, and around 250 during early 2007. Numbers declined at the start of spring and through the summer when many of the winter visitors leave, leaving many locally breeding birds.

Black-headed Gulls show little response to the prevailing wind conditions.

Flight direction in the gulls is difficult to interpret, because of a confusion between diurnal from seasonal movements. During both spring and autumn, there was a tendency for more black-headed gulls to be recorded flying in a westerly direction, although this was more pronounced during the autumn than during the spring, which may reflect an influx of birds from continental Europe.

2.2.2.22 *Common Gull* Larus canus

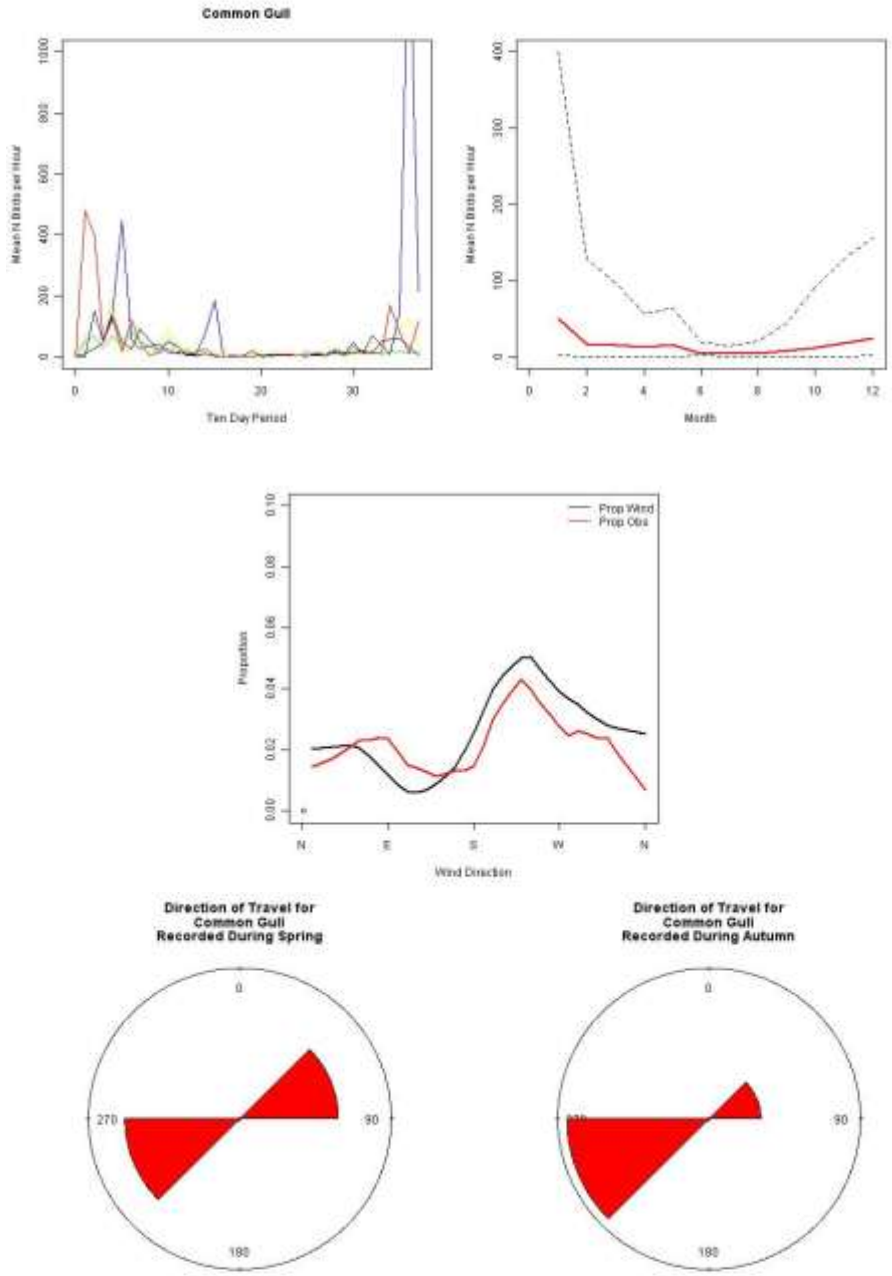


Figure 24 (Clockwise From Top Left) Seasonal variation in the numbers of Common Gulls per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Common Gulls recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Common Gulls recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Common Gulls were most commonly recorded during the winter, with a typical rate of around 100 birds per hour. There was a large influx of Common Gulls in December 2009 when up to 2000 birds per hour were recorded.

Common Gulls show little response to the prevailing wind conditions.

During the spring, Common Gulls were recorded in roughly equal numbers flying east and west. However, during the autumn the tendency for birds to be recorded flying in a westerly direction may reflect an influx of migrant birds from continental Europe.

2.2.2.23 *Lesser Black-backed Gull* Larus fuscus

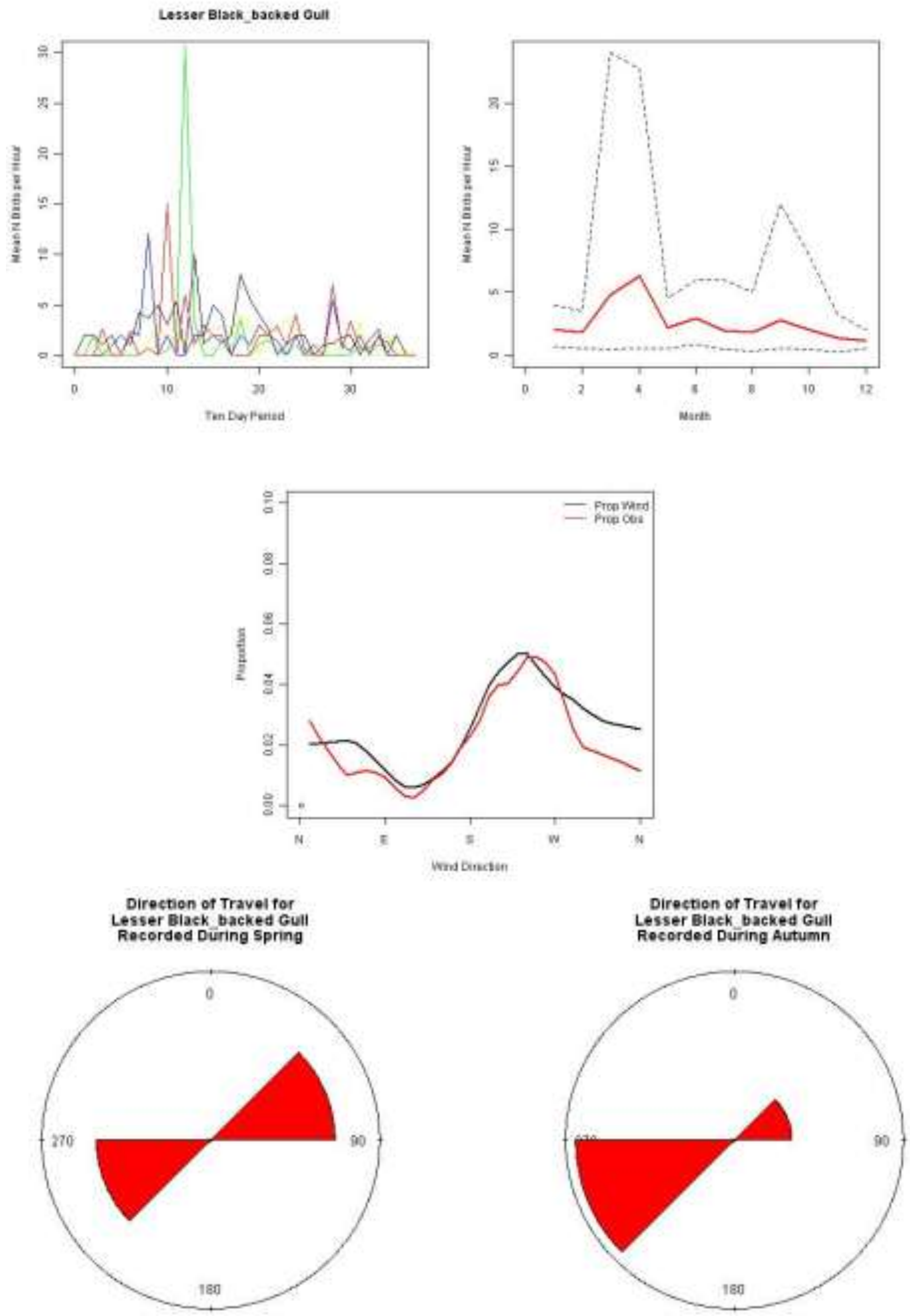


Figure 25 (Clockwise From Top Left) Seasonal variation in the numbers of Lesser Black-backed Gulls per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Lesser Black-backed Gulls recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Lesser Black-backed Gulls recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Lesser Black-backed Gulls were recorded throughout the year. Numbers tended to peak during the spring with typical records of 5-10 birds per hour, and up to 30 birds per hour recorded during spring 2006. Low numbers are recorded throughout the rest of the year.

Lesser Black-backed Gulls showed little response to the prevailing wind conditions.

During the autumn, Lesser Black-backed Gulls were recorded more commonly flying in a westerly direction, again suggesting an influx of birds at that time.

2.2.2.24 Herring Gull **Larus argentatus**

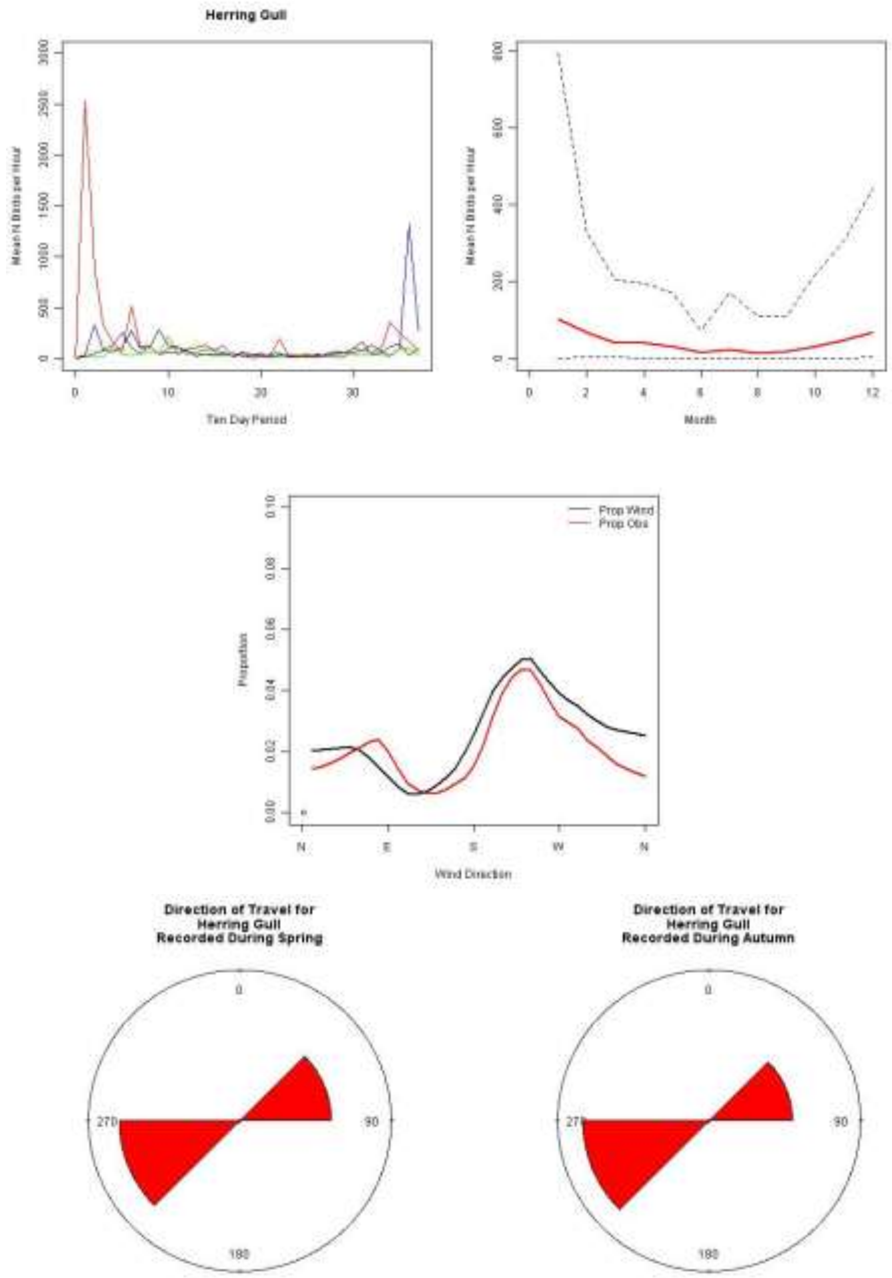


Figure 26 (Clockwise From Top Left) Seasonal variation in the numbers of Herring Gulls per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Herring Gulls recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Herring Gulls recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Herring Gulls were recorded throughout the year. Numbers tended to peak in the winter, when rates in excess of 100 birds per hour were common. There was a large influx of birds in December 2009 when a mean rate of 1500 birds per hour was recorded during one ten day period.

Herring Gulls show little response to prevailing wind conditions.

During both spring and autumn, Herring Gulls slightly more birds were recorded flying west than east.

2.2.2.25 Great Black-backed Gull Larus marinus

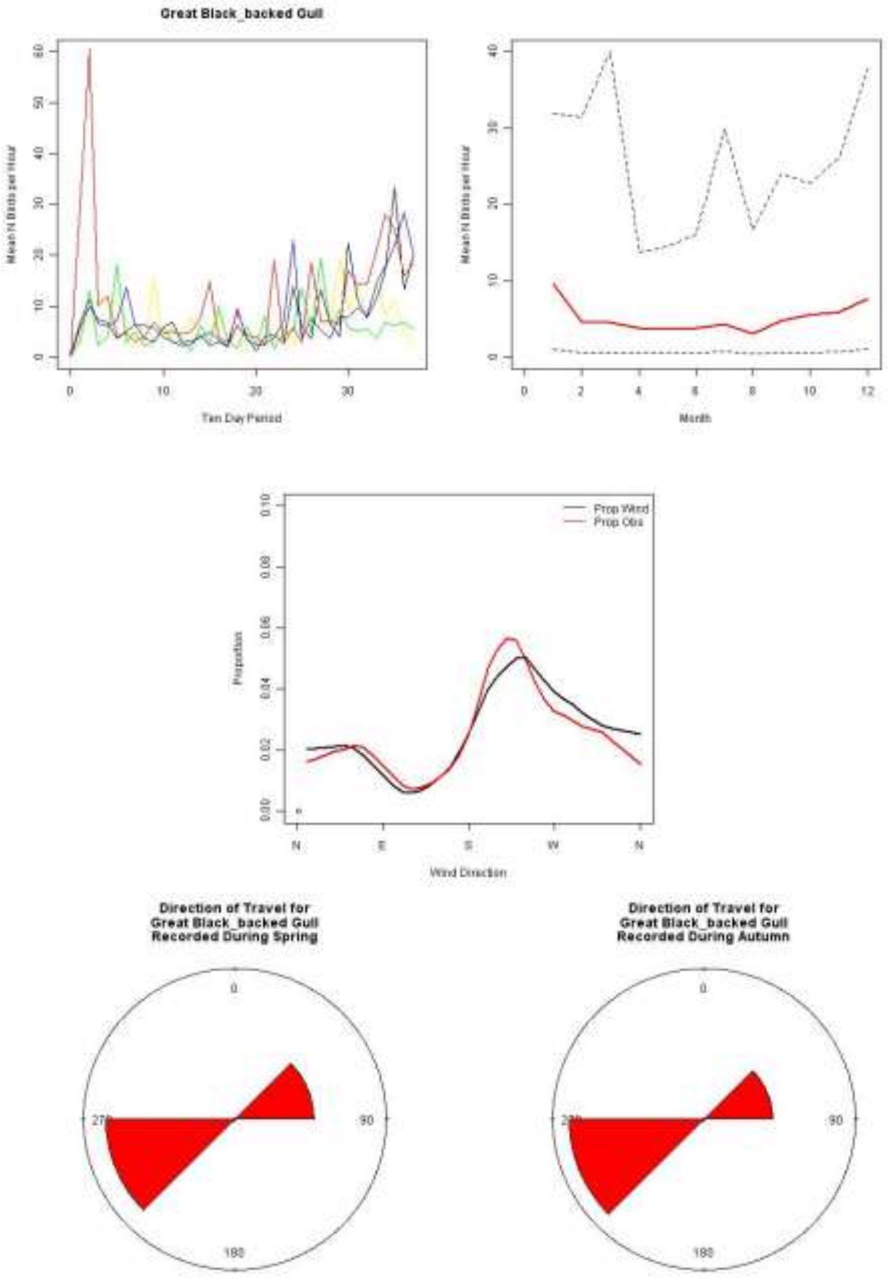


Figure 27 (Clockwise From Top Left) Seasonal variation in the numbers of Great Black-backed Gulls per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Great Black-backed Gulls recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Great Black-backed Gulls recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Great Black-backed Gulls were recorded throughout the year. Numbers tended to peak during the winter with rates of up to 40 birds per hour recorded during December 2009. During the spring and summer, lower numbers of Great Black-backed Gulls were recorded, with typical rates of 5-10 birds per hour. This is despite the fact that there are no local breeding colonies. Numbers tended to rise towards the end of the summer and the beginning of autumn, reaching a peak during the winter.

Great Black-backed Gulls showed little response to prevailing wind direction.

During both autumn and spring Great Black-backed Gulls showed a tendency towards westerly flight.

2.2.2.26 ***Kittiwake* Rissa tridactyla**

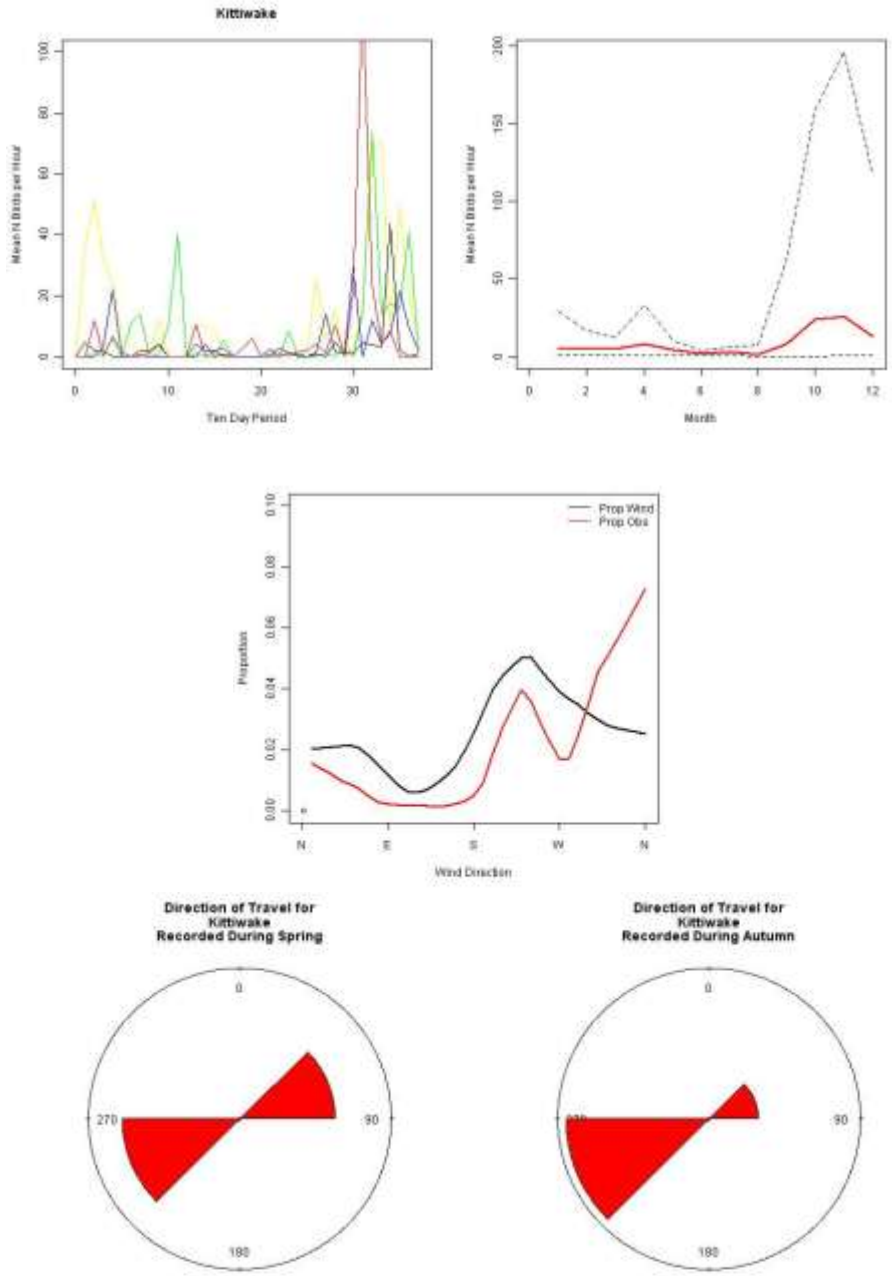


Figure 28 (Clockwise From Top Left) Seasonal variation in the numbers of Kittiwakes per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Kittiwakes recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Kittiwakes recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Kittiwakes were rarely recorded during the summer. Numbers typically started to rise during the autumn, peaking over the winter, when they were commonly recorded at rates in excess of 50 birds per hour, and up to 70 in 2007 during the interval when several other species showed unusual numbers. The rate at which Kittiwakes were recorded declined over winter, and by the start of spring, they were only infrequently recorded.

Kittiwakes were most commonly recorded in response to north-westerly winds.

During spring, Kittiwakes were recorded in equal numbers flying in an easterly and westerly direction. During the autumn, Kittiwakes were more commonly recorded flying in a westerly direction, perhaps because they frequently followed incoming fishing boats..

2.2.2.27 *Sandwich Tern* **Sterna sandvicensis**

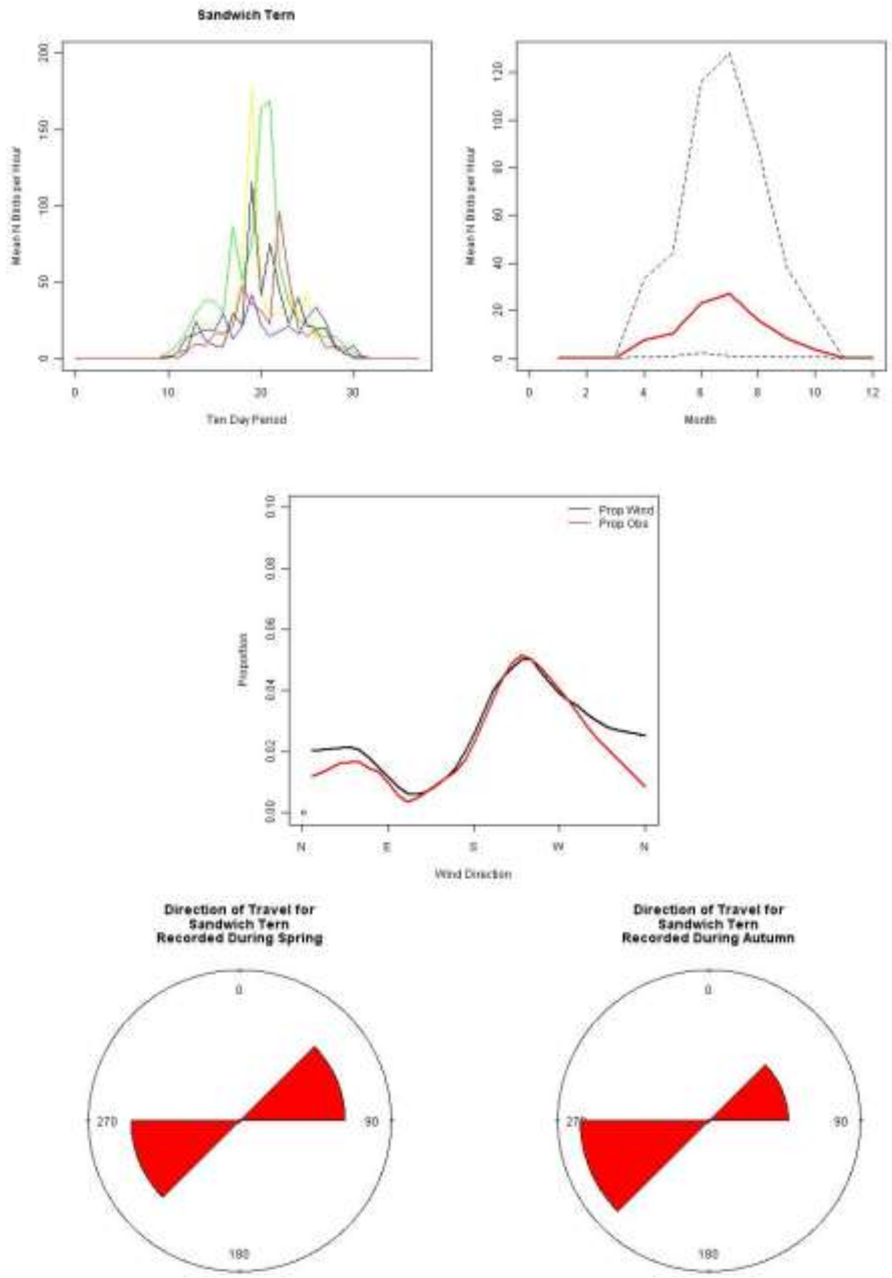


Figure 29 (Clockwise From Top Left) Seasonal variation in the numbers of Sandwich Terns per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Sandwich Terns recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Sandwich Terns recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Sandwich Terns were not recorded during the winter. Each year, the earliest records come from the spring, rapidly building up to a peak of around 150 birds per hour recorded during the summer. Numbers then decline rapidly and by the start of the winter, none were recorded.

Sandwich Terns appear to show little response to the prevailing wind directions.

Most Sandwich terns are local breeders with no perceptible rise during the migration period. During both spring and autumn, Sandwich Terns were recorded flying in roughly equal numbers east and west.

2.2.2.28 *Common Tern* **Sterna hirundo**

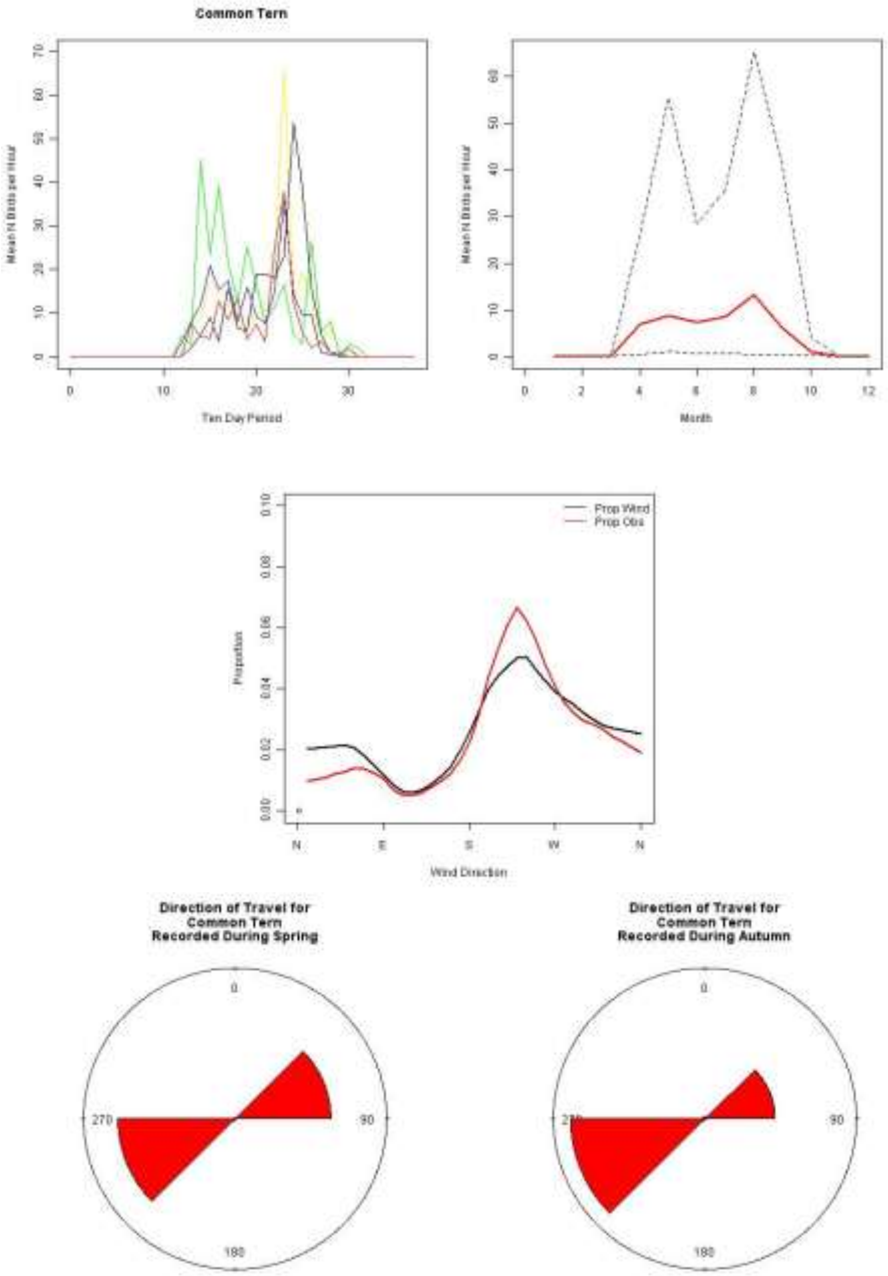


Figure 30 (Clockwise From Top Left) Seasonal variation in the numbers of Common Terns per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Common Terns recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Common Terns recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Common Terns were not recorded during the winter, but large breeding colonies occur along the Norfolk coast. In all years, peaks are observed in both the spring and autumn, with fewer birds recorded over the summer, suggesting some of the birds recorded were migrating through. Between 2007 and 2009 the main peak occurs during the autumn when up to 60 birds per hour are recorded during each ten day period, in 2006, the main peak occurred during the spring when birds were recorded at a rate of around 40 birds per hour.

Common Terns appear to show little response to the prevailing wind directions.

During both spring and autumn, Common Terns were recorded flying in roughly equal numbers east and west.

2.2.2.29 *Little Tern* **Sternula albifrons**

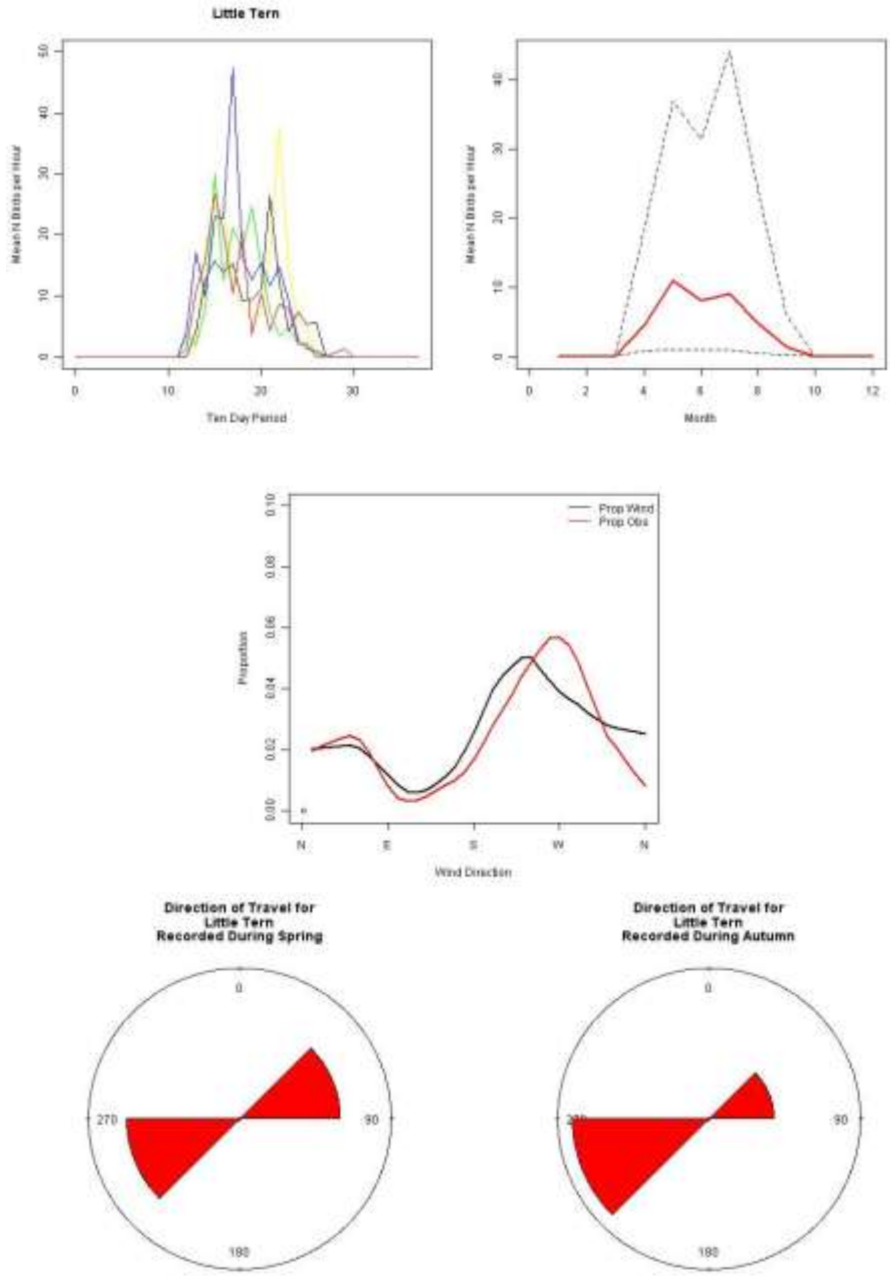


Figure 31 (Clockwise From Top Left) Seasonal variation in the numbers of Little Terns per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Little Terns recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Little Terns recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

Little Terns were not recorded during the winter. In all years, the first birds were noted during the spring, with numbers typically increasing through till the start of the summer. They too are local breeders and over the summer, birds were typically recorded at a rate of 20-30 birds per hour, however, in 2009 a peak in excess of 40 birds per hour was noted. There is no evidence of migratory peaks

Little Terns appear to show little response to prevailing wind direction.

During the spring, Little Terns were recorded flying east and west in roughly equal numbers. During the autumn Little Terns were more commonly recorded flying in a westerly direction.

2.2.2.30 *Guillemot* Uria aalge

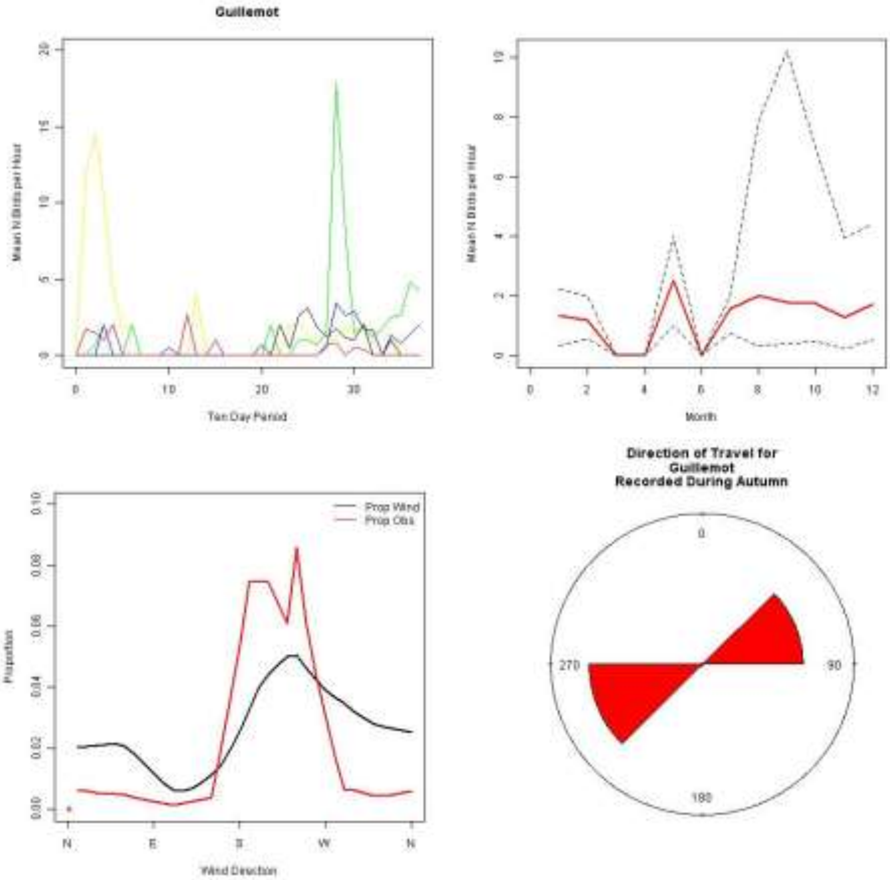


Figure 32 (Clockwise From Top Left) Seasonal variation in the numbers of Guillemots per hour recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Guillemots recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); Proportion of birds observed in response to different wind directions in comparison to the proportions that would be expected under prevailing conditions; direction of travel of Guillemots recorded at Holme Bird Observatory between 2006 and 2010 during the autumn.

In 2006 and 2007, Guillemots were recorded in small numbers throughout the year, typically peaking during the autumn with rates of 2-3 per hour.They and the next species appeared in very large numbers during the unusual feeding event in Jan 2007.

Guillemots were most commonly recorded during periods of southwesterly winds.

During the autumn, Guillemots were recorded in roughly equal numbers flying east and west This species and the next are difficult to identify individually, so generalisations often refer to Auk species, where the individual species are not differentiated

2.2.2.31 *Razorbill* **Alca torda**

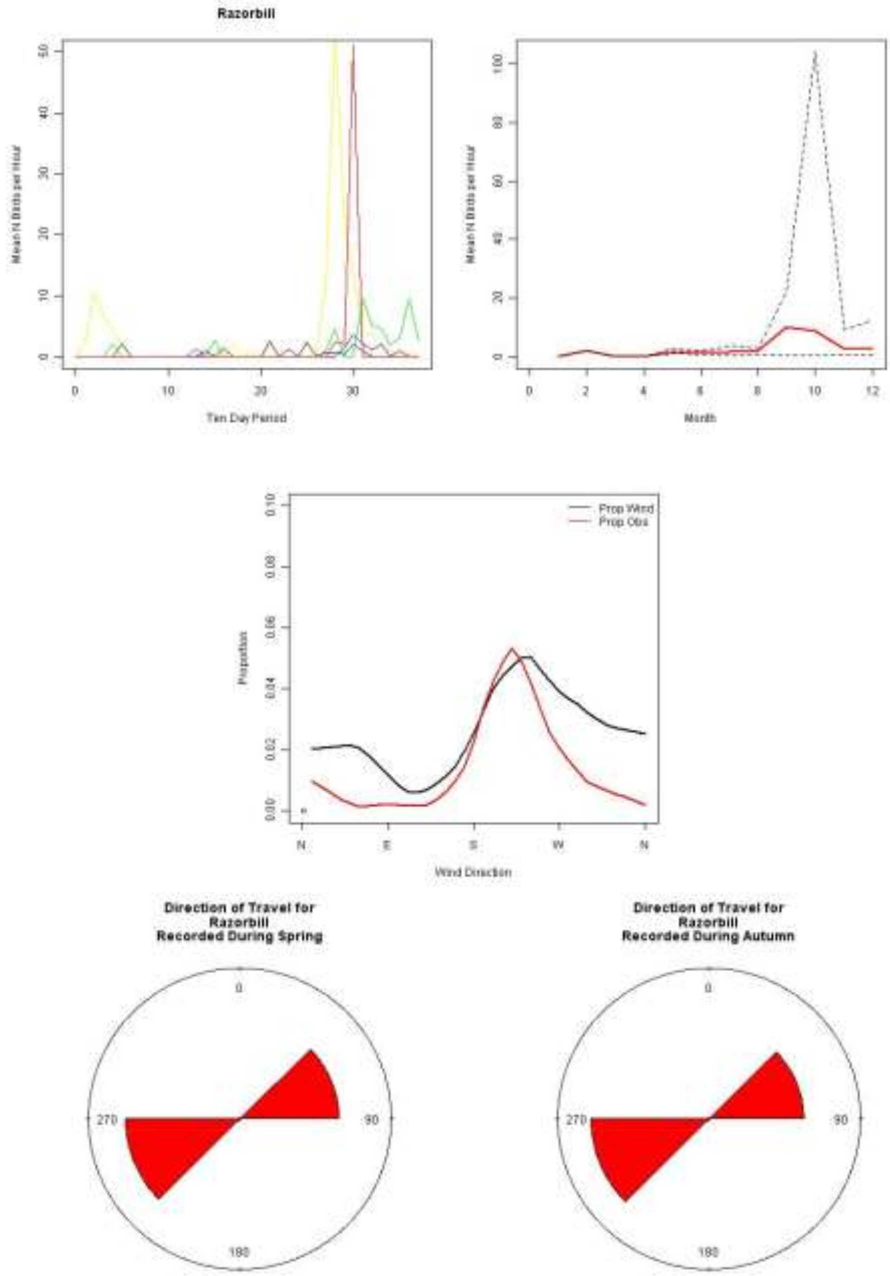


Figure 33 (Clockwise From Top Left) Seasonal variation in the numbers of Razorbills recorded during sea-watching activity at Holme Bird Observatory between 2006 and 2010. Lines represent 2006 2007 2008 2009 2010; Mean monthly variation in the number of Razorbills recorded per hour between 2006 and 2010 (± 95 % Confidence Intervals); numbers of Razorbills recorded during sea-watching activity at Holme Bird Observatory in response to prevailing wind conditions; direction of travel of Razorbills recorded at Holme Bird Observatory between 2006 and 2010 during the autumn and spring.

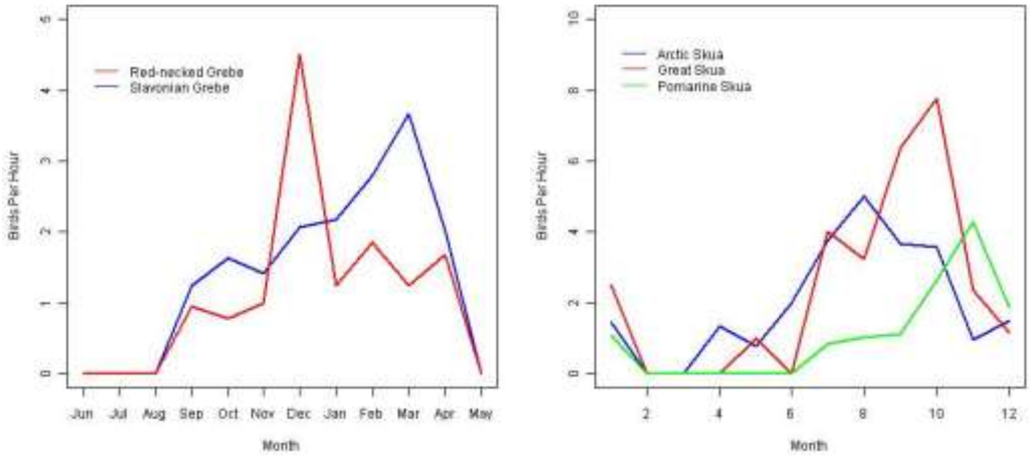
Razorbills were only rarely recorded during the summer. Numbers tended to peak during the late autumn and early winter, when an average of between 5 and 10 birds per hour were recorded.

Razorbills did not appear to show much response to the prevailing wind conditions.

During both spring and autumn, roughly equal numbers were recorded flying east and west.

2.2.3 General movement patterns

Data standardised in this fashion allow us to make more general comparisons and observations about the movements of birds past Holme Bird Observatory. For example, we can look at the relative peak in passage rates of closely related species.



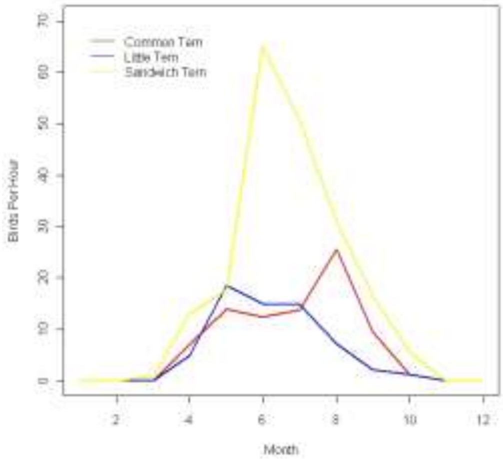


Figure 34 Variation in peak observation rates at Holme Bird Observatory for Grebes, Skuas and Terns between 2006 and 2010.

Amongst closely related species there can be strong variation in the timing of peak migration periods and the length of the migration period (Figure 34). A comparison of Red-necked Grebe and Slavonian Grebe shows that Slavonian Grebe numbers rise steadily through the autumn and winter, reaching a peak in the early spring. In contrast, Red-necked Grebes are rarer throughout the autumn, with numbers reaching a sharp peak over winter, before declining again in the spring (Figure 34).

With Skuas, Arctic Skuas are recorded earliest and more consistently over the autumn and winter with peak passage rates occurring in August. Great Skuas are the next to occur, with numbers peaking in October, before declining sharply over winter. Finally, a small number of Pomarine Skuas are recorded over autumn, with numbers peaking in November.

Different patterns are observed amongst the three tern species. All three species nest locally with Sandwich Terns showing the highest concentration. The peaks for Sandwich Terns and Little Terns are consistent with a peak of activity in the summer months. Common Terns are also present during the summer but in addition to evidence of local nesting also give evidence of probable migration peaks in May and August.,

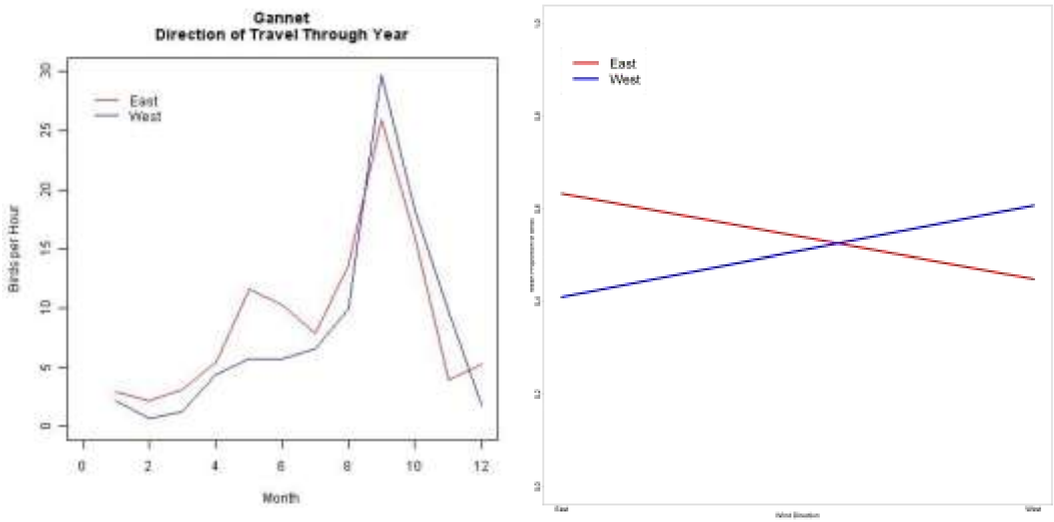


Figure 35 Numbers of Gannets recorded flying east and west in relation to month (left) and wind direction (right).

The data also allow us to investigate how different factors affect the direction of travel for some species. Gannets show a strong peak for birds flying both east and west during the autumn (Figure 35). However, there is also a smaller, secondary peak in the number of birds recorded flying east during the spring and early summer. This may reflect birds travelling away from the colony at Bempton Cliffs to forage. The data also reveal that Gannets have a tendency to fly into the wind (Figure 35), with a greater number of birds flying east during periods when the wind was coming from the east and west when the wind was coming from the west.

2.3 Summary

The number of birds recorded per hour at Holme Bird Observatory varies throughout the year. Several distinct patterns are apparent within the data and these patterns vary according to the species or group concerned. The first of these groups covers species such as the Sandwich Tern, which breed in the locality of Holme Bird Observatory and show a peak in numbers during the summer. The second group covers species, such as the Red-throated Diver, Kittiwake and Goldeneye, which are only rarely recorded during the summer and peak in number during the winter. The final group covers species, such as the skuas, Gannet, Common Tern and Lesser Black-backed Gull, which occur in the area during spring and/or autumn passage.

Initial exploratory analysis suggests that for most of the species routinely recorded during sea-watching at Holme Bird Observatory, prevailing wind direction has a limited impact on the numbers recorded. Of those that do respond to prevailing wind direction, most show an increase in numbers in response to winds from a northerly direction.

Amongst wildfowl, such as Teal and Wigeon, there was strong evidence of migratory movements during the autumn, when a high proportion of birds were recorded travelling west, presumably returning from their breeding grounds to winter in the UK. There was limited evidence of a spring migration, with only Eider and Wigeon showing a peak in the proportion of birds flying East, reflecting birds departing the UK for their breeding grounds.

3. CAN YOU DETECT COLD-WEATHER MOVEMENTS OF DUCKS FROM CONTINENTAL EUROPE TO THE WASH THROUGH SEA-WATCHING?

3.1 Introduction

Sea-watching at the Norfolk Ornithologists Association reserve at Holme, on the North Norfolk Coast, has been carried out in a systematic fashion since 2006. By recording counts of species observed and the duration of the count, it is possible to determine a standardised, hourly passage rate for each species throughout the year.

The movement of waterfowl in response to cold weather is a widely discussed phenomenon. In the United Kingdom, the counts recorded for many species of duck often increase in response to cold weather on continental Europe (Holt *et al.* 2011). However, evidence for the origin of these birds is often restricted to ringing recovery data from a limited number of individuals (i.e. Wernham *et al.* 2002; Keller *et al.* 2009; Sauter *et al.* 2010), offering little insight into potential routes into the country taken by these birds.

Many of the birds which move to Great Britain in response to cold weather are likely to originate in the Wadden Sea, a key area for many European waterbird species stretching from North West Germany to the Netherlands. The Wadden Sea area is often much cooler than coastal parts of the UK, such as The Wash, particularly over winter (Figure 36).

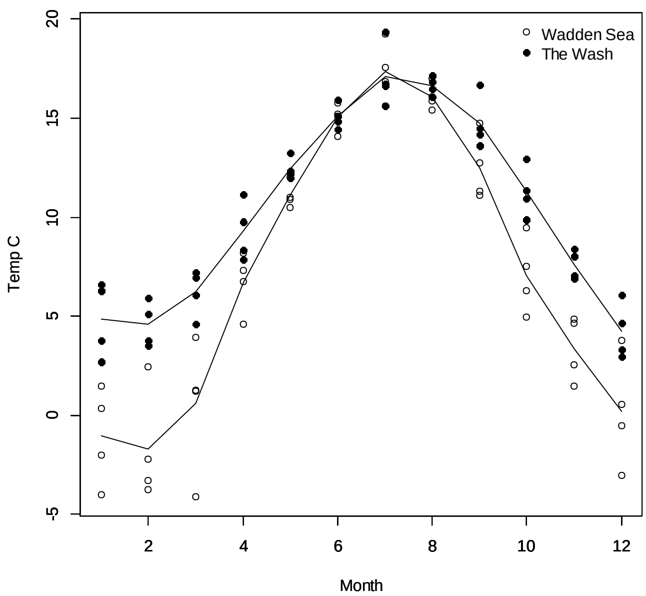


Figure 36. Mean monthly temperatures on The Wash and The Wadden Sea between 2006 and 2009.

3.2 Methodology

Passage rates for five of the most frequently recorded waterfowl species at Holme Bird Observatory – Common Scoter *Melanitta nigra*, Common Eider *Somateria mollissima*, Red-breasted Merganser *Mergus serrator*, Wigeon *Anas penelope and* Teal *Anas crecca* - were analysed within a Generalised Additive Mixed Model (GAMM) framework. Month was fitted as a random effect to take account of between years differences in monthly temperature and wind data. Wind direction was fitted as a smoothed term, temperature in the Wadden Sea area was fitted as a linear term and year was fitted as a factor.

Mean monthly temperature data were obtained for the Wadden Sea area for 2006 – 2009 from the CRU TS 3.1 dataset (CRU 2012). Wind data from the nearby Weybourne Met Office weather station were obtained from the Met Office MIDAS database (UK Meterological Office 2012). If cold temperatures on the Wadden Sea are causing more birds to cross the North Sea, to warmer areas on the East Coast of the UK, and this movement is detectable during sea-watches at Holme Bird Observatory, it would be expected that the number of birds observed would peak during colder winters on the Wadden Sea.

3.3 Results

3.3.1 Common Scoter

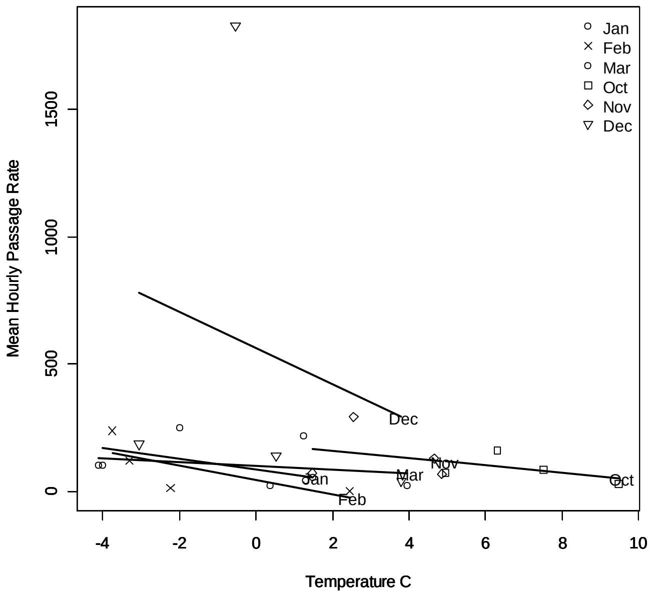


Figure 37 Mean monthly numbers of Common Scoter recorded at Holme Bird Observatory during the winter in relation to mean temperature (°C) on the Wadden Sea between 2006 and 2010.

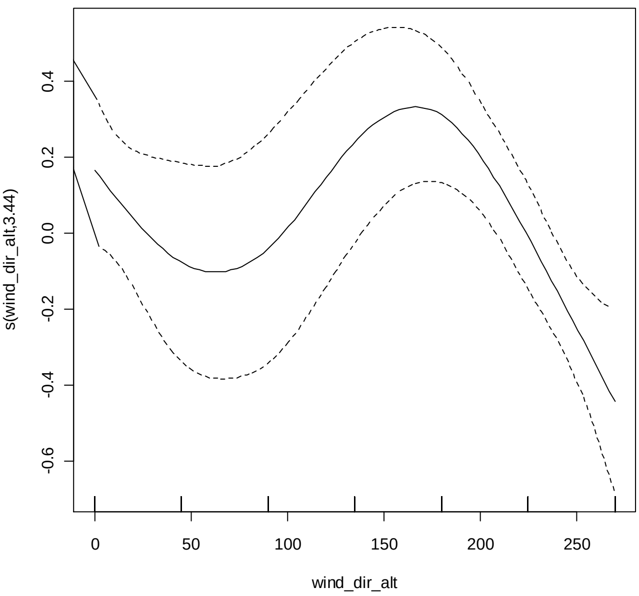


Figure 38 Smoothed relationship between wind direction and numbers of Common Scoter at Holme Bird Observatory between 2006 and 2009.

There was a consistent relationship between temperature in the Wadden Sea area and the passage rate of Common Scoters observed at Holme Bird Observatory. Comparing each month with the same month in other study years confirms that the hourly rate at which Common Scoter were recorded increased in response to decreases in temperature (coef. -0.15 ± 0.03, $P < 0.0001$) (Figure 37). Estimates of the random effects indicate that passage rates were highest during December and lowest during January. In 2008 the passage rates was significantly higher than in other years (coef. 1.54 ± 0.16, $P < 0.0001$). There was a slight increase in the hourly passage rate in response to Southerly winds (edf = 3.44, P = 0.0018) (Figure 38).

3.3.2 Common Eider

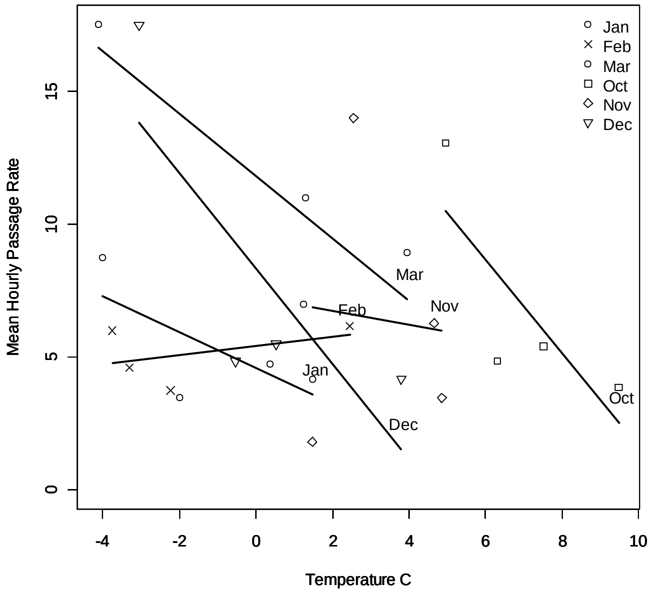


Figure 39 Mean monthly passage rate of Eider recorded during the winter in relation to mean temperature (°C) on the Wadden Sea between 2006 and 2010.

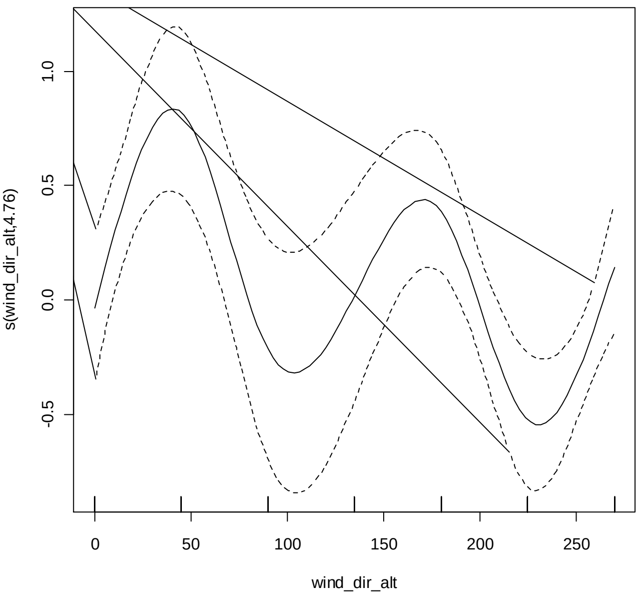


Figure 40 Smoothed relationship between wind direction and mean passage rate for Common Eider at Holme Bird Observatory between 2006 and 2009.

There was a consistent relationship between temperature in the Wadden Sea area and the passage rate of Common Eiders observed at Holme Bird Observatory. Comparing each month with the same month in other study years confirms that the hourly passage rate increased in response to decreases in temperature (coef. -0.06 ± 0.02, P = 0.0273) (Figure 39). Estimates of the random effects indicate that passage rates were highest during March and lowest during January. There was a slight increase in the hourly passage rate in response to southerly and north-easterly winds (edf = 4.76, P = 0.002) (Figure 40).

3.3.3 Red-breasted Merganser

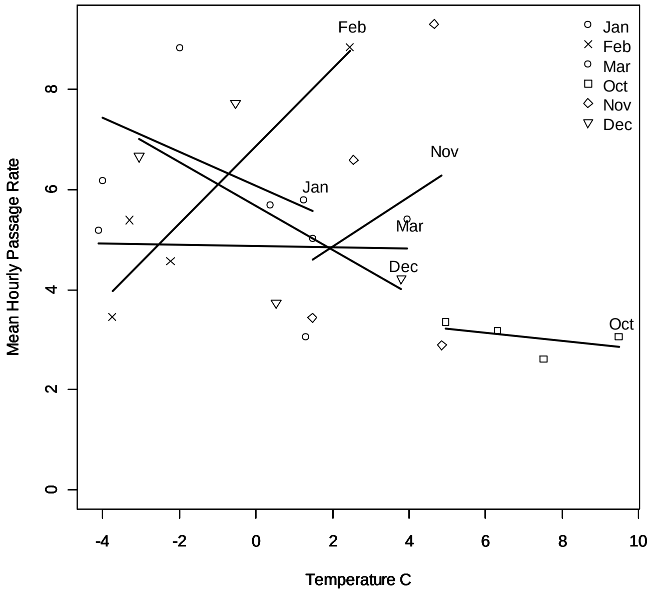


Figure 41 Mean monthly passage rate of Red-breasted Merganser recorded during the winter in relation to mean temperature (°C) on the Wadden Sea between 2006 and 2010.

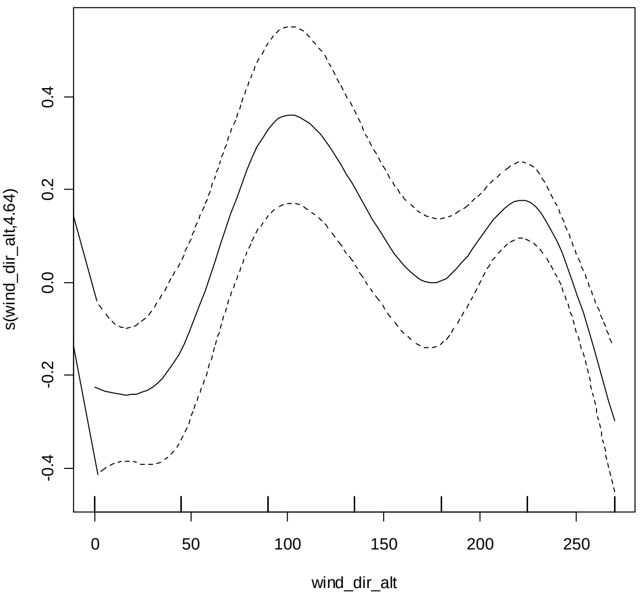


Figure 42 Smoothed relationship between wind direction and mean passage rate for Red-breasted Merganser at Holme Bird Observatory between 2006 and 2009.

There was a consistent relationship between temperature in the Wadden Sea area and the passage rate of Red-breasted Mergansers observed at Holme Bird Observatory. Comparing each month with the same month in other study years confirms that the hourly passage rate increased in response to decreases in temperature (coef. -0.03 ± 0.01, $P < 0.0001$) (Figure 41). Estimates of the random effects indicate that passage rates were highest during January and lowest during October. There was a slight increase in the hourly passage rate in response to Southerly and Easterly winds (edf = 4.49, $P < 0.0001$) (Figure 42).

3.3.4 Wigeon

There was no significant relationship between temperature and passage rate in Wigeon (Figure 43). However, there was a non-significant, negative trend (coef. -0.01 ± 0.04, $P > 0.05$). The passage rate was greatest during December and lowest during March. There were no significant differences between years.

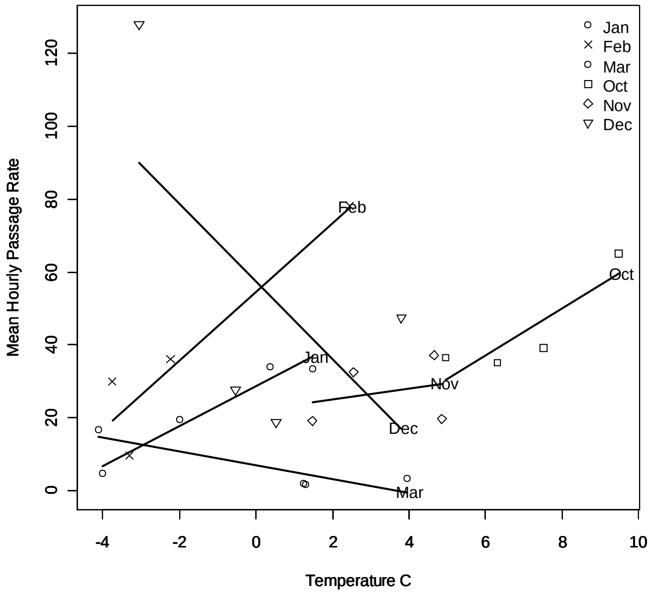


Figure 43. Mean monthly passage rate of Wigeon recorded during the winter in relation to mean temperature (°C) on the Wadden Sea between 2006 and 2010.

3.3.5 Teal

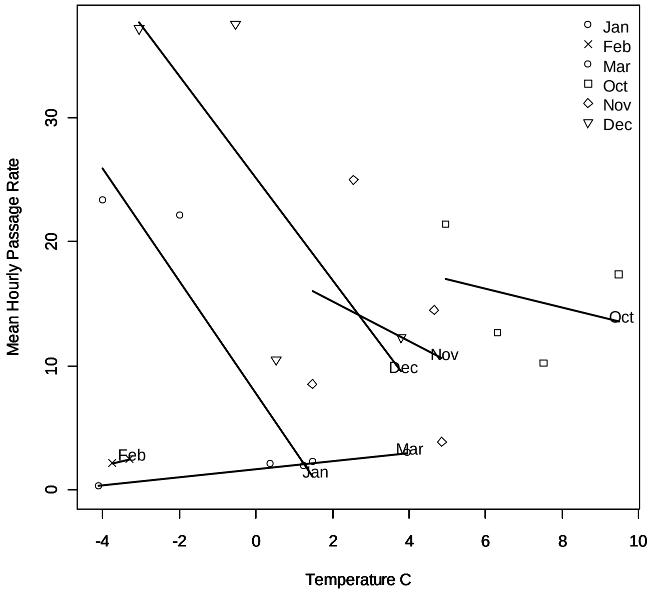


Figure 44. Mean monthly passage rate of Teal recorded during the winter in relation to mean temperature (°C) on the Wadden Sea between 2006 and 2010.

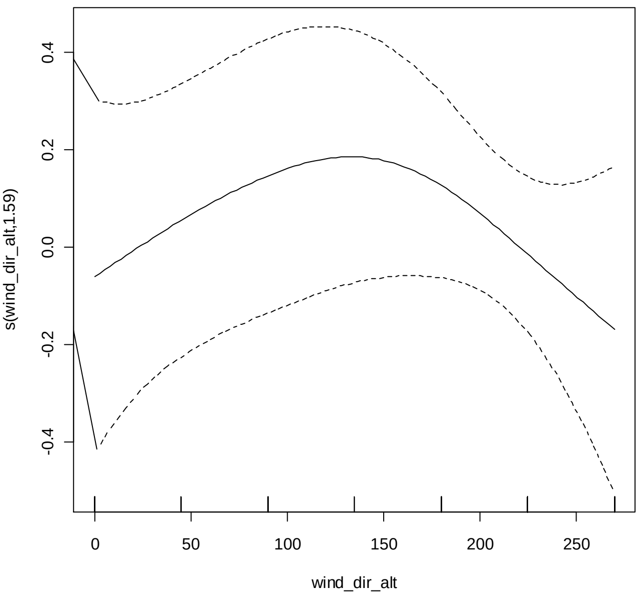


Figure 45. Smoothed relationship between wind direction and mean passage rate for Teal at Holme Bird Observatory between 2006 and 2009.

There was no significant relationship between temperature and passage rate in Teal (Figure 44). However, there was a non-significant, negative trend (coef. -0.05 ± 0.05, P > 0.05). The passage rate was greatest during December and lowest during February. The passage rates were higher in 2008 (coef. 0.77 ± 0.34, P 0.0250) and 2009 (coef. 0.82 ± 0.35, P 0.0197) than in 2006 and 2007. There was a non-significant increase in the hourly passage rate in response to Southerly and Easterly winds (edf = 1.58, P > 0.05) (Figure 45).

3.4 Discussion

Increased numbers of Common Scoter, Common Eider and Red-breasted Merganser at Holme Bird Observatory coincide with periods of colder weather in the Wadden Sea area. This supports the hypothesis that birds moving into Britain in response to cold weather on the continent. Further weight is given to this hypothesis by the peaks that were observed Red-breasted Merganser and Common Eider passage rates during periods of north-easterly or easterly winds, which may reflect birds taking advantage of favourable wind conditions to reach the UK. There was also evidence of movements of both Wigeon and Teal in response to periods of cold weather on the continent, although in the case of these species, the relationship was not significant.

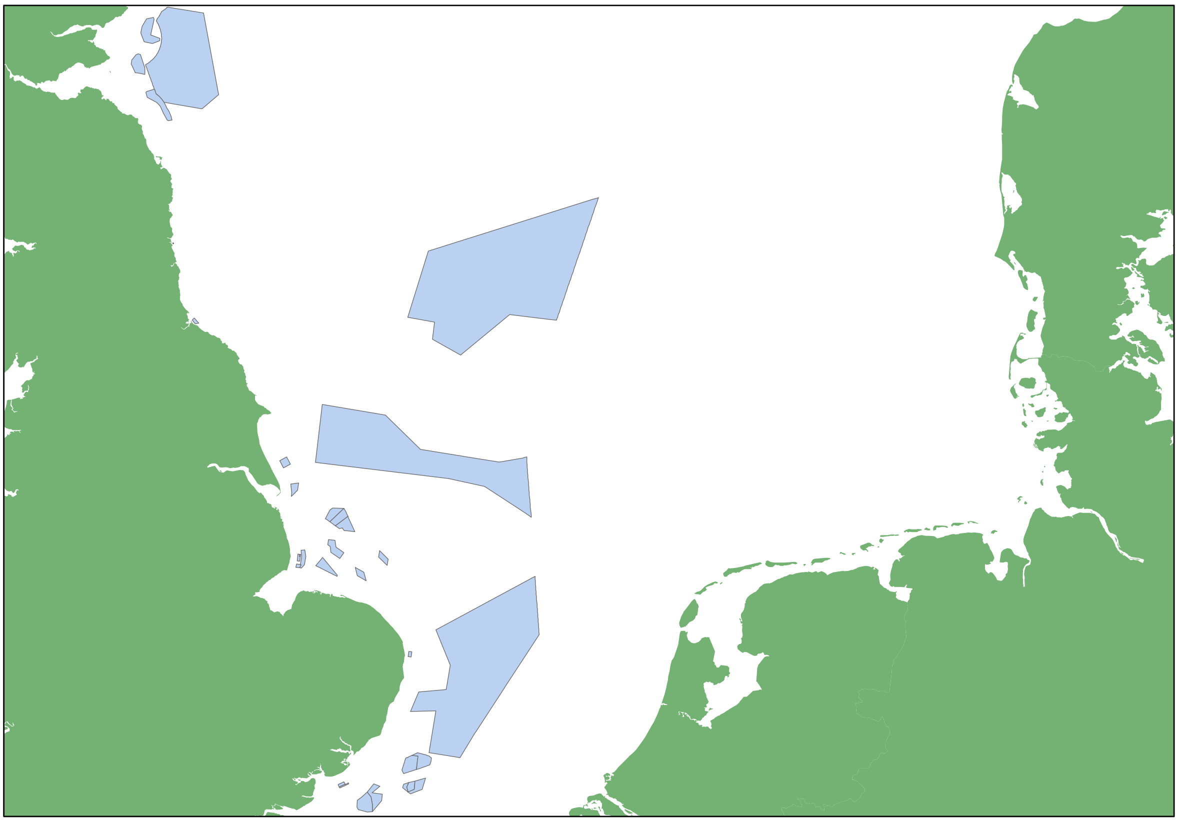


Figure 46. Map showing the locations of proposed wind farms which may potentially interfere with flight paths of waterfowl moving between The Wadden Sea and The Wash in response to cold weather.

Wind farms have been shown to act as a barrier to species such as Eider and Common Scoter (Desholm & Kahlert 2005; Masden *et al.* 2009). During migration, the energetic costs of avoiding a single wind farm have been shown to be relatively insignificant (Masden *et al.* 2009). However, there are concerns that the avoiding multiple wind farms would increase energetic costs substantially. Prior to migration periods, birds are likely to be close to peak physical condition and these increased costs may be more likely to impact on productivity than survival. However, body condition in Eiders and other ducks declines over winter, and this decline can be particularly severe in harsh winters (Fox *et al.* 1992, Loesch *et al.* 1992, Robb *et al.* 2001, Camphuysen *et al.* 2002, Merkel *et al.* 2006). Consequently, birds moving in response to cold weather are likely to be in a sub-optimal physical condition, and the additional energetic cost involved in avoiding wind farms between the Wadden Sea and The Wash (as well as elsewhere on the east coast of Britain) may result in a decrease in over-winter survival.

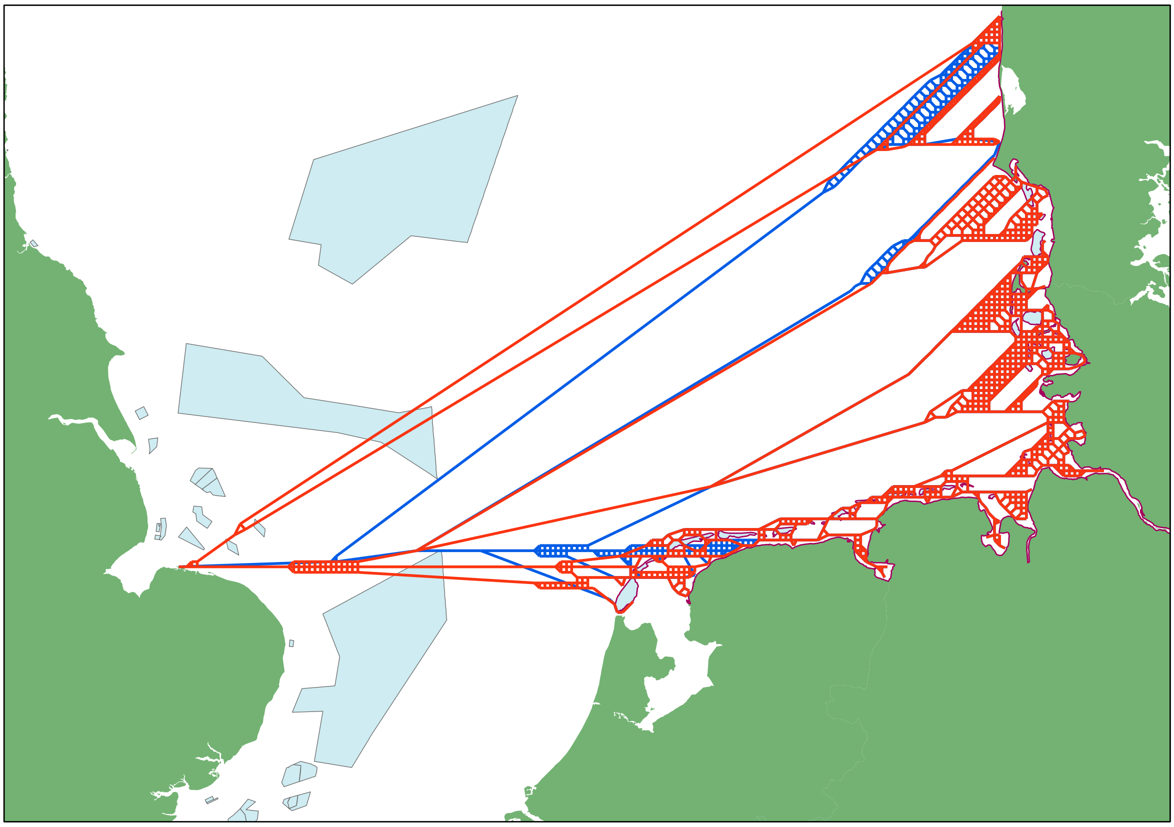


Figure 47 Representative flight paths between the Wadden Sea and the Wash in the absence (Red) and presence (Blue) of offshore wind farms.

Flight paths between locations on the Wadden Sea and the closest part of the Wash were calculated in GIS using cost-path analysis, which can be used to assess the least costly path between two locations in relation to distance. Paths for before and after wind farm construction were identified. Following Masden *et al.* (2009), Eider were taken as an example species with which to assess the potential impact of the additional distance travelled. The programme Flight 1.24 (Pennycuik 2008) was used to calculate the energy burned in response to each trip. Were all currently proposed offshore wind farms around the east coast of Britain to be built, it would only be necessary for Eider to burn an additional 1.5 % more energy to reach The Wash from the Wadden Sea. However, this is based on the assumption that birds are in peak physical condition, which is unlikely to be the case for birds moving in response to cold weather.

Initially it was assumed that fat as a proportion of an eiders body mass was around 50 % based on data from Robinson (2005) and Christensen (2008). Using these values, around 12.9 % of the birds fat would be burned on the path taken before wind farm construction and around 13.3 % would burned on the path taken after wind farm construction (Figure 48). However, waterfowl body conditions can drop substantially over winter, with some birds losing a substantial proportion of their mass and fat reserves (Fox *et al.* 1992, Camphuysen *et al.* 2002, Schummer *et al.* 2012). Ducks with reduced body fat over winter generally have lower survival probabilities (Haramis *et al.* 1986, Davis *et al.* 2011), consequently, any factor which negatively impacts fat reserves may also impact survival during a period when it would already be expected to be low. Additional research is required to properly quantify the fat that may be lost by birds during cold weather movements.

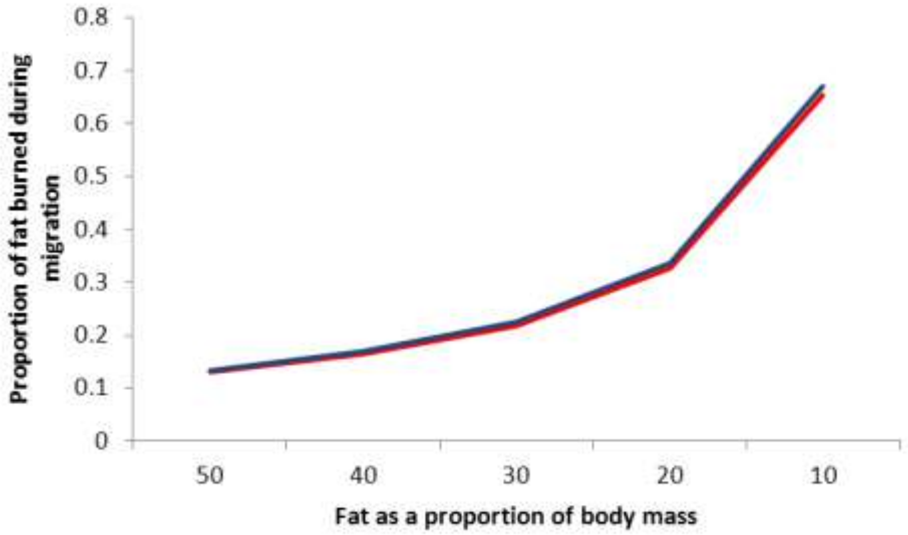


Figure 48 Proportion of fat burned by eider as a result of migration in response to cold weather on the Wadden Sea before (red) and after (blue) wind farm construction.

3.5 Benefit of Sea-watching data

This study demonstrates that data collected during sea-watching can be used to detect movements in some species as a result of cold weather. With the development of offshore wind farms, it is important to monitor populations of key species, particularly at times when they are most vulnerable, such as over winter. With a well-connected network of sea-watching sites, it would be possible to monitor the passage rate of species, such as eider, in response to cold weather and use this information as an "early-warning system" to demonstrate the impact offshore developments are having on important populations of key species.

4 DOES SEA-WATCHING DATA REFLECT WHAT IS HAPPENING WITH SEABIRD POPULATIONS AT A NATIONAL LEVEL?

4.1 Introduction

Sea-watching data provides a potentially valuable resource with which to monitor the status of the UK's seabird populations. However, at present the extent to which seabird passage rates accurately reflect population changes at a national level is largely unknown. To test this, we use standardised data collected from the Norfolk Ornithologists Association reserve at Holme, and investigate how passage rates relate to breeding success at a national level in a variety of species.

4.2 Methodology

Hourly passage rates were modelled using a Generalised Additive Model (GAM) within the R statistical package using the mgcv library (Wood 2008; R Core Development Team 2010). Models were fitted with a poisson error structure and year was fitted as a factor. To determine the value of correcting observed passage rates for environmental variation, two models were fitted for each species, the first with year as the only explanatory variable and the second with additional environmental variables. Wind speed and direction were obtained for the nearby Weybourne Weather Station from the Met Office MIDAS database (UK Meteorological Office 2012) and fitted as smoothed terms. Sea Surface Temperature (SST) data were obtained from the Hadley Centre's Ice and Sea Surface Temperature dataset (Rayner *et al.* 2003) and fitted as a linear term. Data regarding tidal height and state (rising or falling) were obtained for Cromer from the UK Tide Gauge Network (British Oceanographic Data Centre 2012) and fitted as a linear term and factor respectively. Tidal height and state were also fitted as an interaction term in order to consider the effect of time before or after high tide. Month and observation start time were also fitted as smoothed terms. Further interactions were fitted between wind speed and direction and between month and SST, wind speed and wind direction.

The coefficients for year in each model were then indexed and compared to national indices of breeding success and breeding numbers using data from the Seabird Monitoring Programme (SMP). For species which breed locally – Kittiwake, Sandwich Tern, Gannet – comparative indices were based on breeding numbers at local colonies, whilst for others indices were based on regional breeding success.

4.3 Results

4.3.1 Black-legged Kittiwake

The model for Black-legged Kittiwake was a reasonable fit for the data with an adjusted R^2 of 0.42. Black-legged Kittiwake passage rates peaked during the autumn, around the middle of the day (Figure 49). Passage rates were also influenced by tidal height and wind speed, with the highest rates recorded during periods of moderate-heavy winds with tide heights of around 2-3 m. There was a significant interaction between wind direction and month, indicating that numbers peaked during the autumn in periods of northerly winds (Figure 50).

Index values followed a similar pattern to the annual variation in apparently occupied nests recorded on the East Coast of England. However, a steeper increase was shown in the corrected index between 2009 and 2010 than was recorded in the observed data.

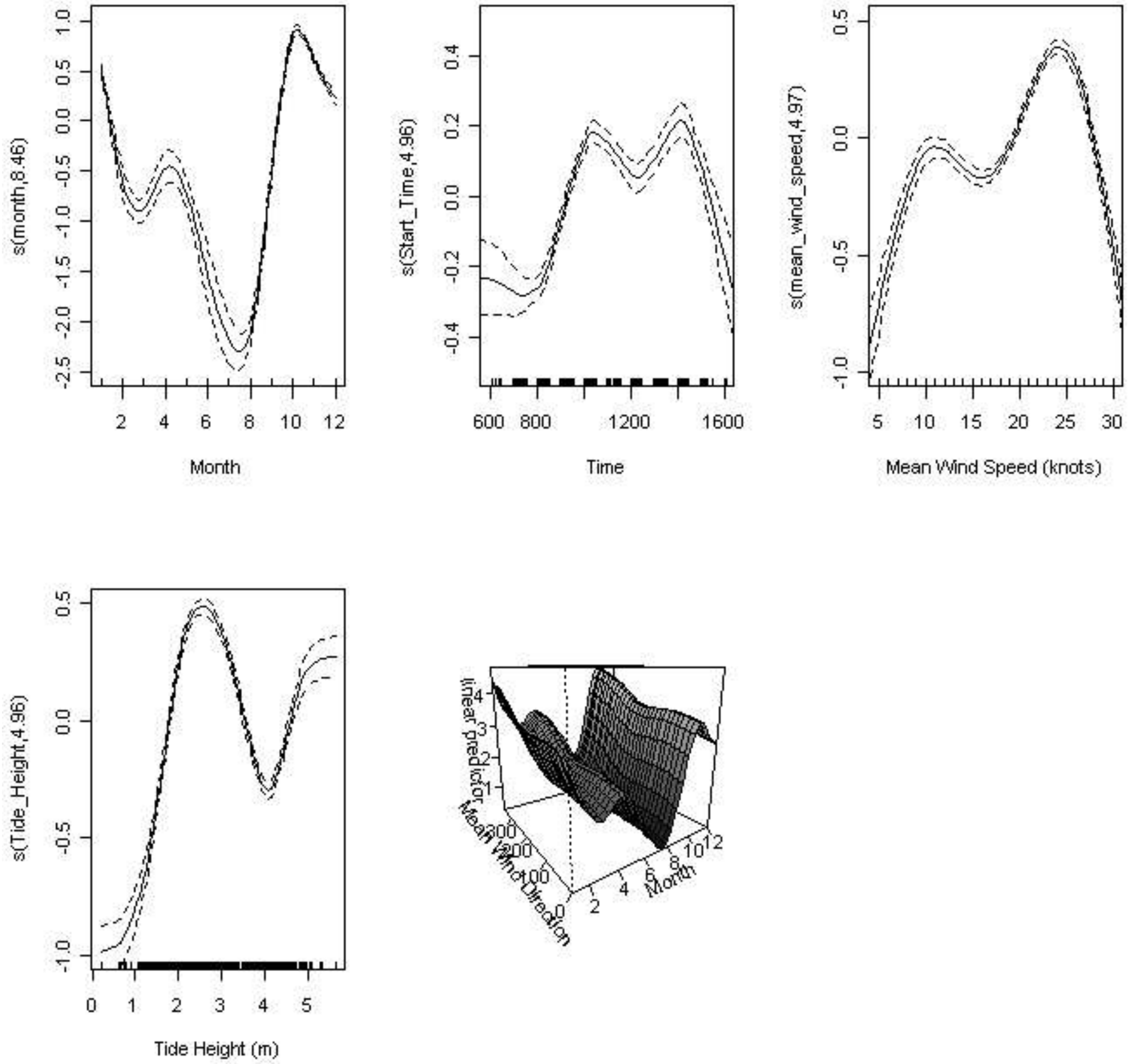


Figure 49 Smoothed Terms from model of Black-legged Kittiwake passage rate at Holme Bird Observatory (from top left) month, start time, wind speed (knots), tide height (m) and interactions between month and wind direction and month and SST.

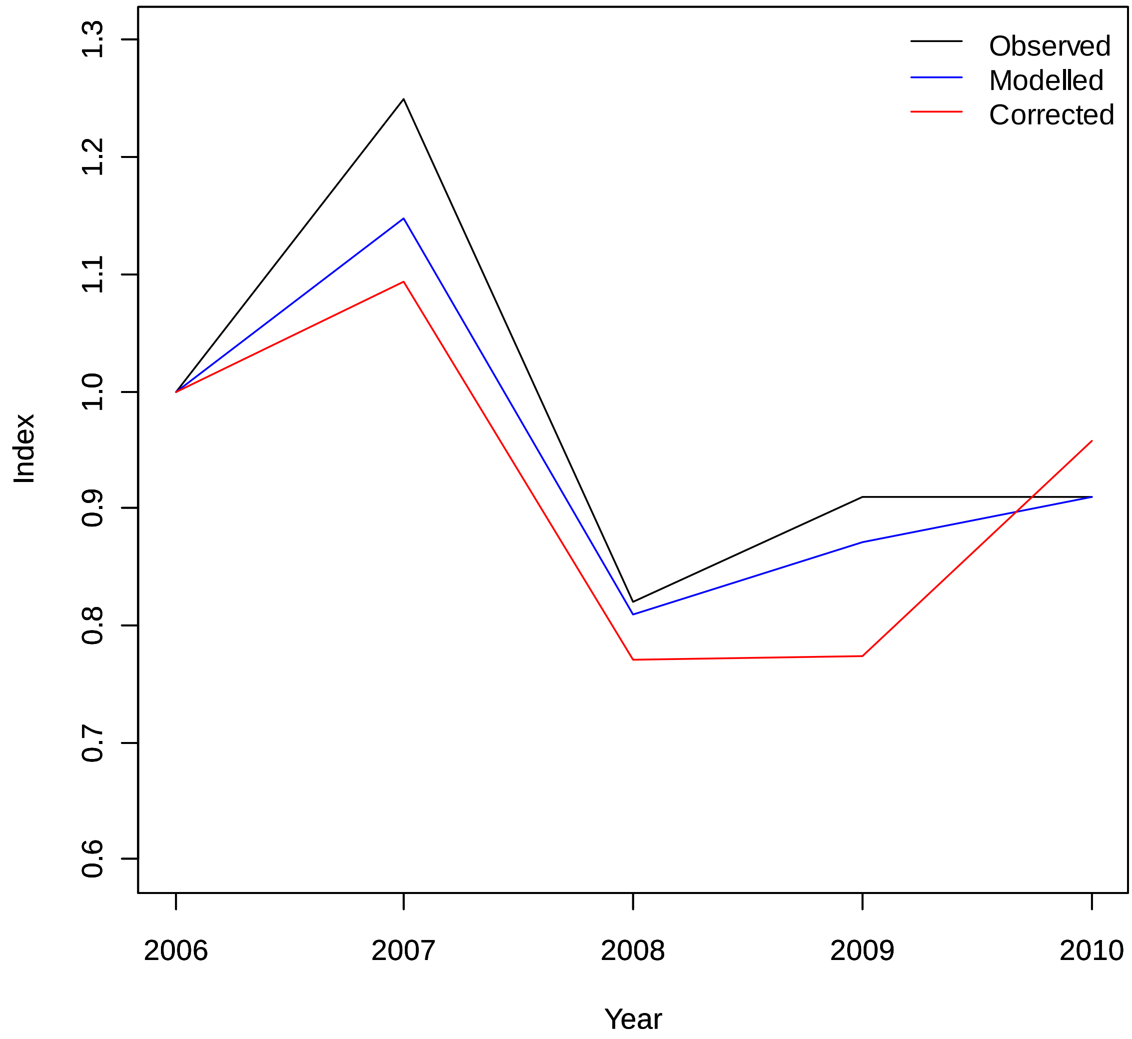


Figure 50 Comparison between observed the number of apparently occupied nests for Black-legged Kittiwake at colonies in Eastern England (Observed Index), and indices constructed from models of Black-legged Kittiwake passage rates at Holme Bird Observatory before (modelled) and after (corrected) correction for prevailing environmental conditions.

4.3.2 Sandwich Tern

The model for Sandwich Terns was a reasonable fit for the data with an adjusted R^2 value of 0.38. Passage rates were highest during the morning and late afternoon, in periods of moderate wind and with a tidal height of around 2-3 m (Figure 51). Significant interactions were observed between month and SST on the Wash and month and wind direction (Figure 51). These interactions indicated that observed passage rates were at their highest during warm periods of Southerly wind during April (Figure 51).

Index values followed a similar pattern to the annual variation in the number of Sandwich Terns observed breeding at the nearby Scolt Head National Nature Reserve. Whilst the variation in the index values was not as pronounced as the observed variation in apparently occupied nests, the pattern of the corrected index appeared a closer match than the pattern of the uncorrected index (52).

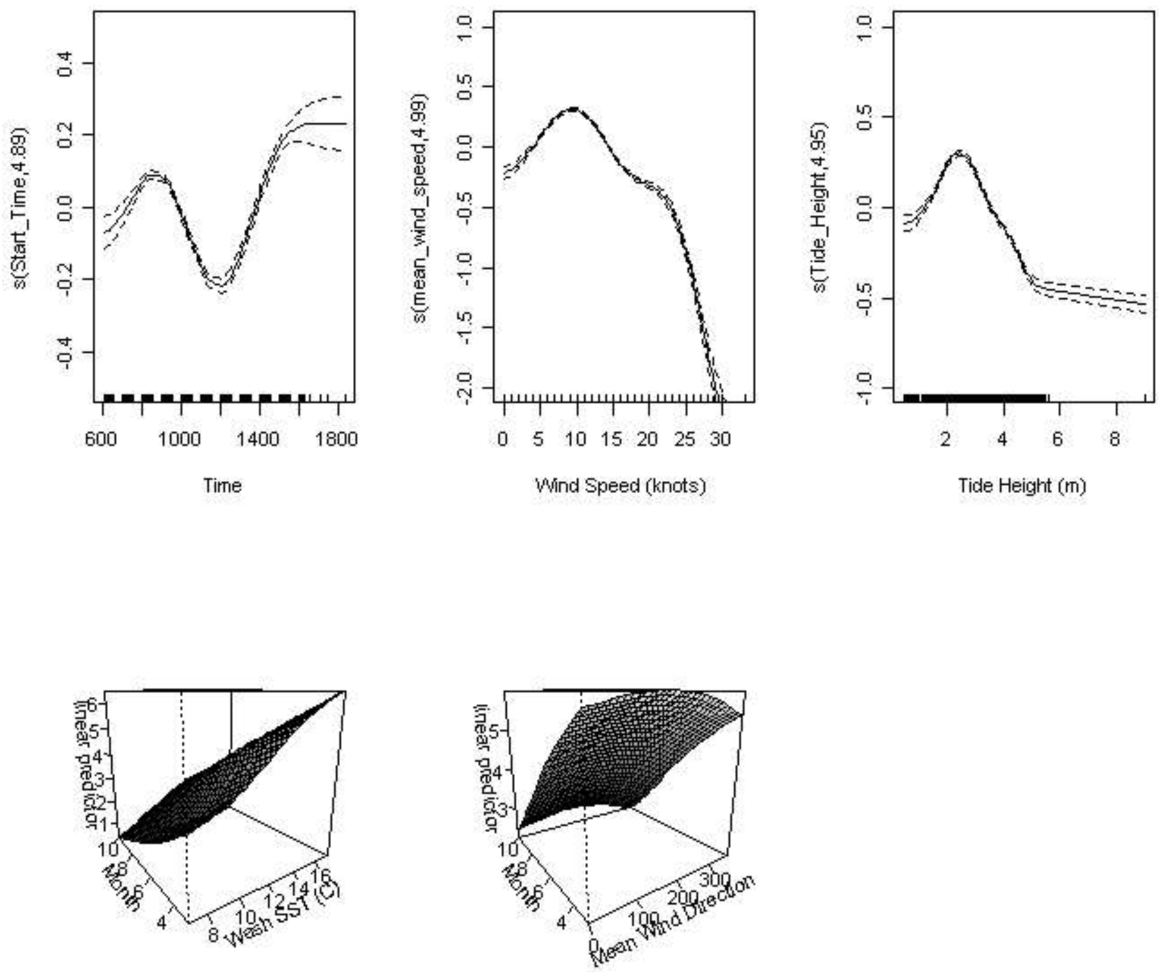


Figure 51 Smoothed Terms from model of Sandwich Tern passage rate at Holme Bird Observatory (from top left) start time, wind speed (knots), tide height (m) and interactions between month and wind direction and month and SST.

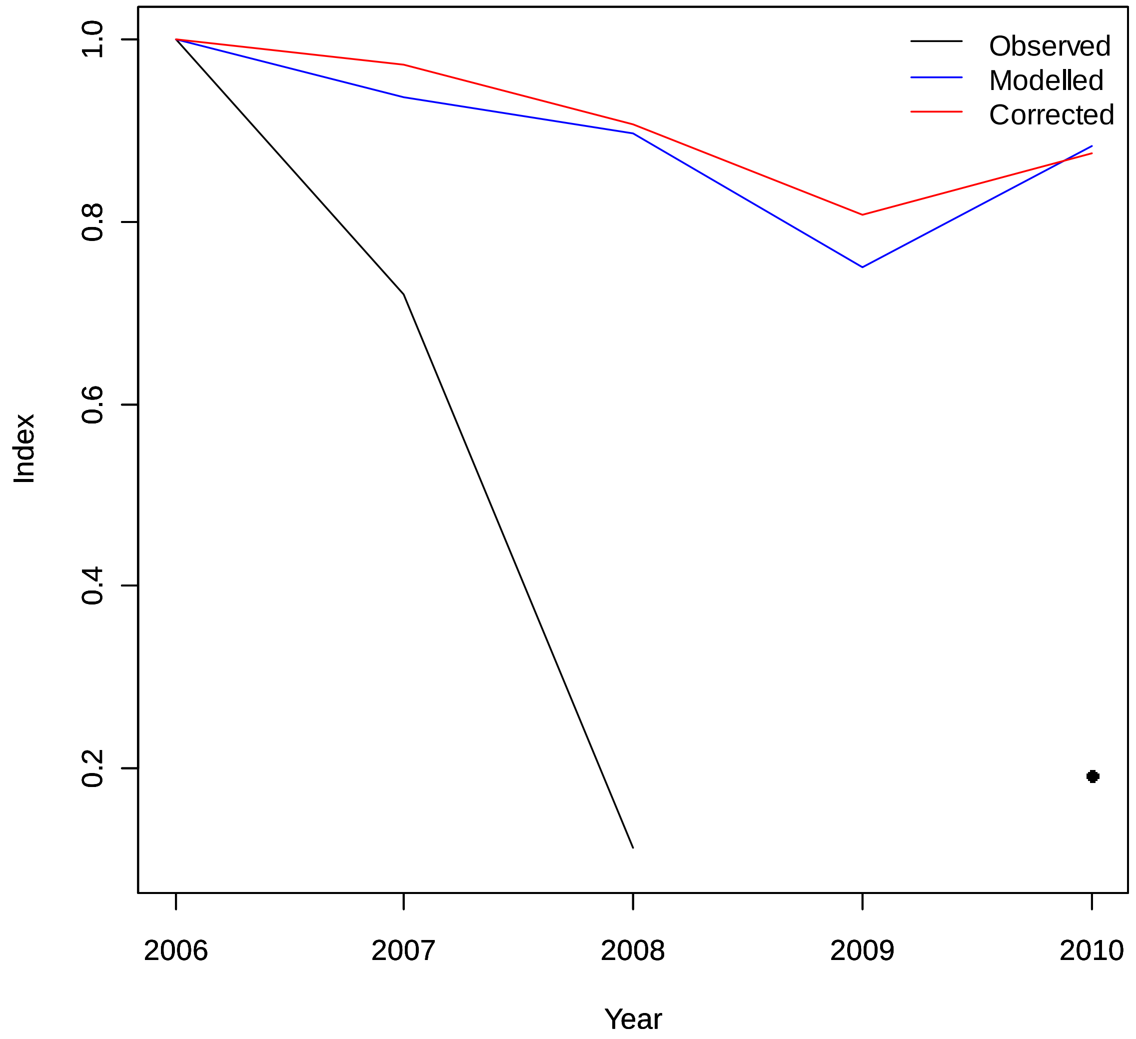


Figure 52 Comparison between observed Sandwich Tern apparently occupied nests at the nearby Scolt Head National Nature Reserve (Observed Index), and indices constructed from models of Sandwich Tern passage rates at Holme Bird Observatory before (modelled) and after (corrected) correction for prevailing environmental conditions. No breeding success data were available from Scolt Head in 2009.

4.3.3 Arctic Skua

The model for Arctic Skua was a reasonable fit for the data with an adjusted R^2 of 0.31. The model shows that Arctic Skua numbers peak during periods of strong wind, when the tide is relatively low (Figure 53). There were significant interactions between month and wind direction and between month and SST. These showed that the passage rate at Holme Bird Observatory was highest during the winter and autumn during periods of northerly or southerly winds and high SST.

Index values showed a similar pattern to the annual variation in Arctic Skua breeding success. Whilst the peak in the index values was not as pronounced in 2009 as it was in the observed data, the corrected index showed a strong correlation with the observed data between 2006 and 2008. The corrected index appeared a better match for the observed data than the uncorrected index (54).

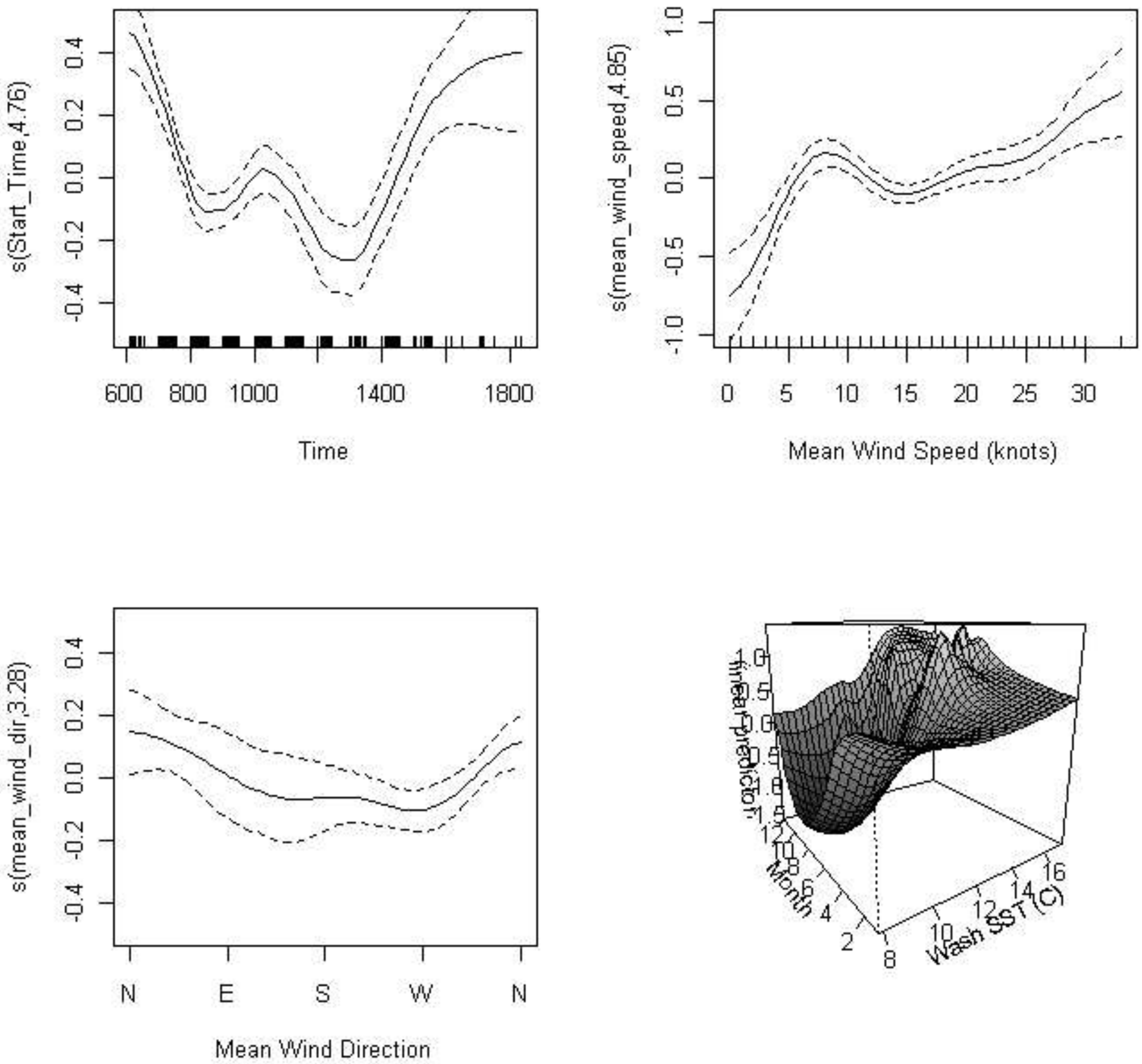


Figure 53 Smoothed Terms from model of Arctic Skua passage rate at Holme Bird Observatory (from top left) tide height (m), wind speed (knots) and interactions between month and wind direction and month and SST.

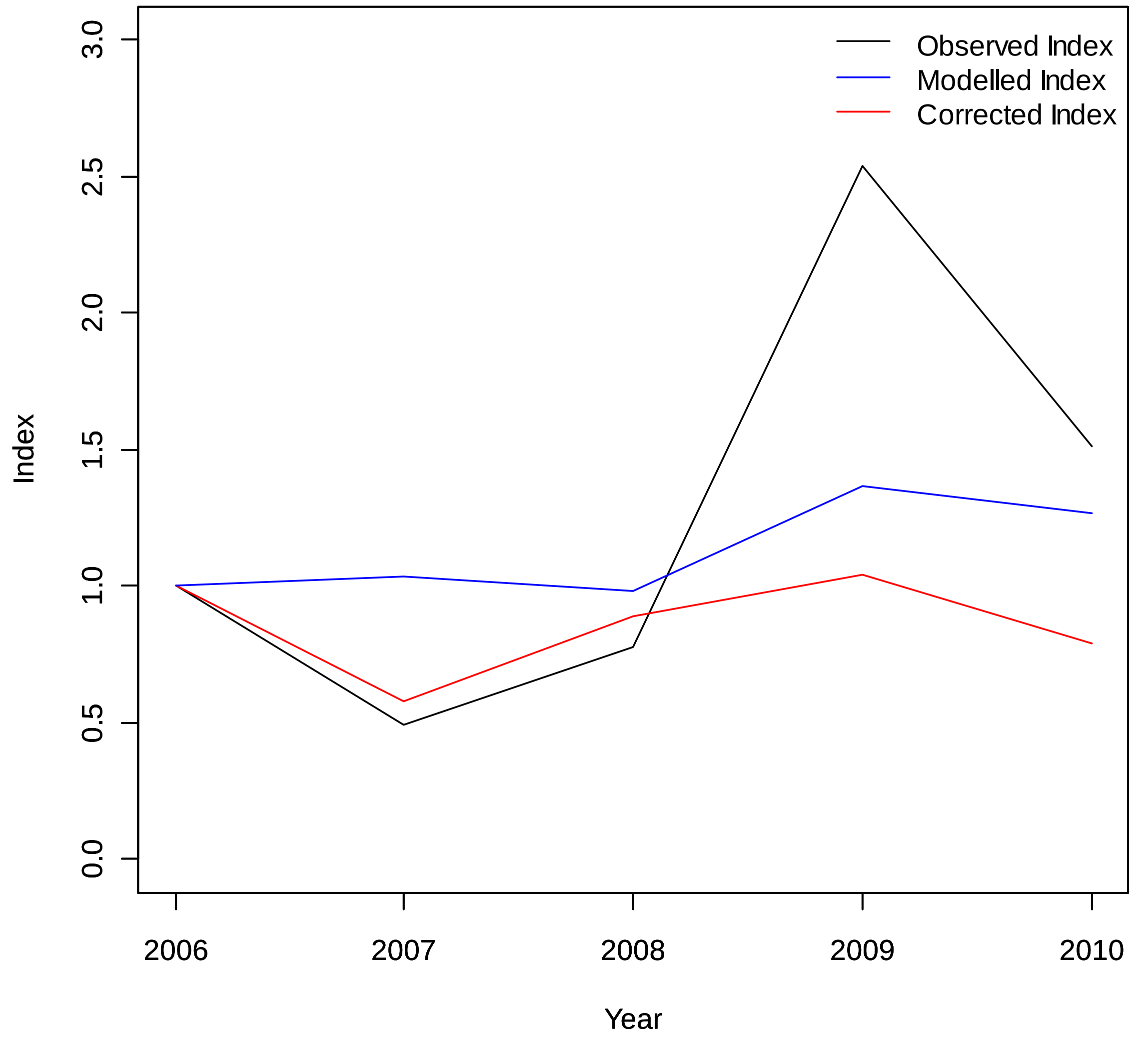


Figure 54 Comparison between Arctic Skua Breeding success, based on data from the Seabird Monitoring Programme (Observed Index), and indices constructed from models of Arctic Skua passage rates at Holme Bird Observatory before (modelled) and after (corrected) correction for prevailing environmental conditions.

4.3.4 Great Skua

The model for Great Skua was a reasonable fit for the data with an adjusted R^2 of 0.47. Great Skua passage rates at Holme Bird Observatory peaked during the afternoon in periods of strong northerly or easterly winds (Figure 55). There was also a significant interaction between month and SST, indicating that passage rates peaked during warm autumns (Figure 55).

Index values showed a similar pattern to the variation in Great Skua annual breeding success. The corrected index appeared a closer match for the observed data than the uncorrected index although, both the corrected and uncorrected indices showed an increase between 2009 and 2010, in contrast to the decrease seen in the observed data (Figure 56).

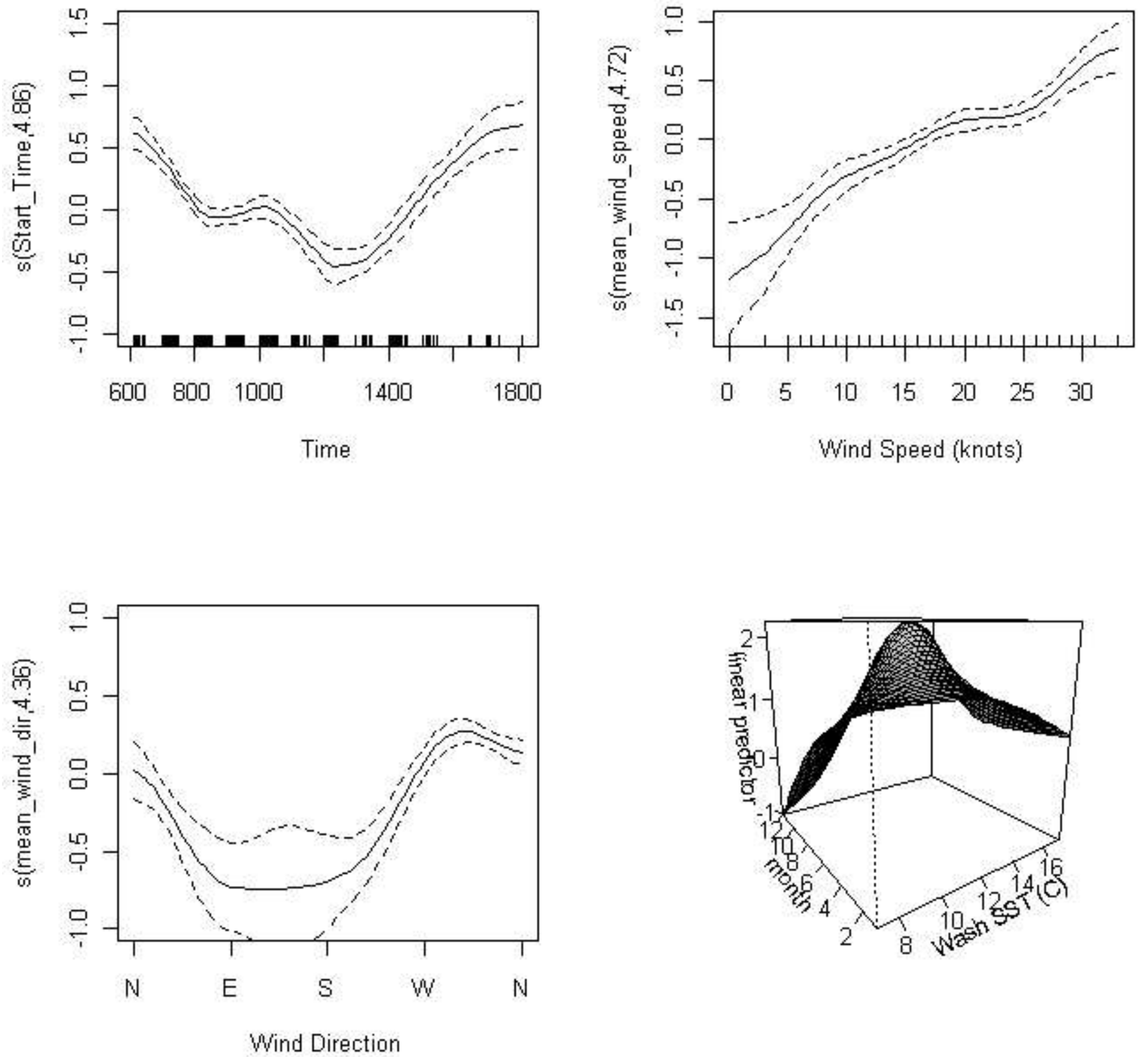


Figure 55 Smoothed Terms from model of Great Skua passage rate at Holme Bird Observatory (from top left) start time, wind direction, wind speed (knots) and an interaction between month and SST.

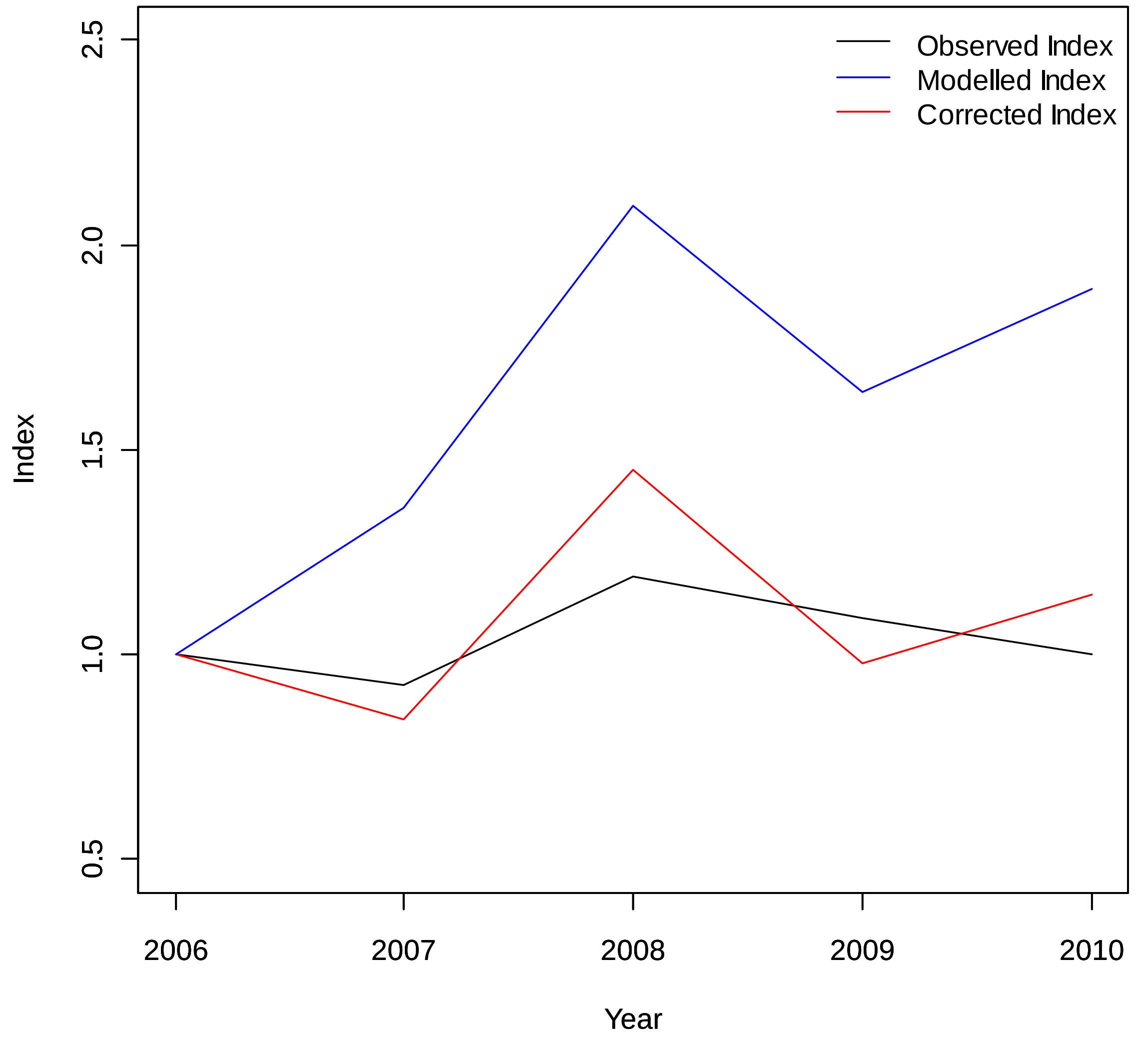


Figure 56 Comparison between Great Skua Breeding success, based on data from the Seabird Monitoring Programme (Observed Index), and indices constructed from models of Arctic Skua passage rates at Holme Bird Observatory before (modelled) and after (corrected) correction for prevailing environmental conditions.

4.3.5 Northern Fulmar

The model for Northern Fulmar was a reasonable fit for the data with an adjusted R^2 of 0.22. Observations of Northern Fulmar at Holme Bird Observatory peaked during the morning in periods of moderate wind. There were significant interactions between month and wind direction and month and SST (Figure 57). These interactions indicated that Northern Fulmar observations peaked during warm springs in periods of northerly winds (Figure 57).

Insufficient data were available from nearby breeding colonies in order to construct a population index, although many are likely to be associated with the nearby Hunstanton colony and patterns in abundance may reflect movements in and out of this colony. Consequently, an index was developed using breeding success data from colonies on the east coast of the UK. Index values showed a similar pattern to the observed variation in breeding success. The corrected index was a closer match for the observed data than the uncorrected index (Figure 58).

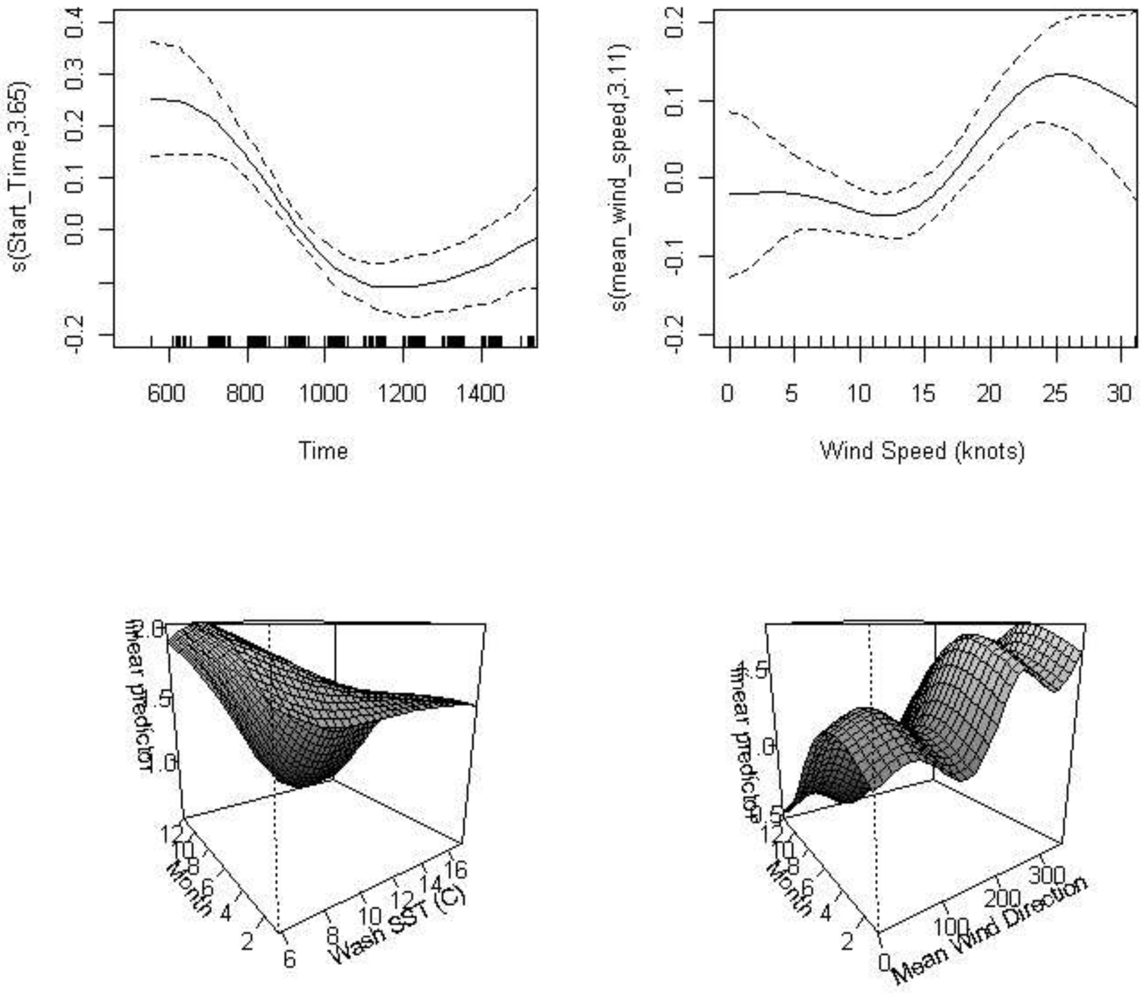


Figure 57 Smoothed Terms from model of Northern Fulmar observations at Holme Bird Observatory (from top left) start time, wind speed (knots) and an interaction between month and wind direction and month and SST.

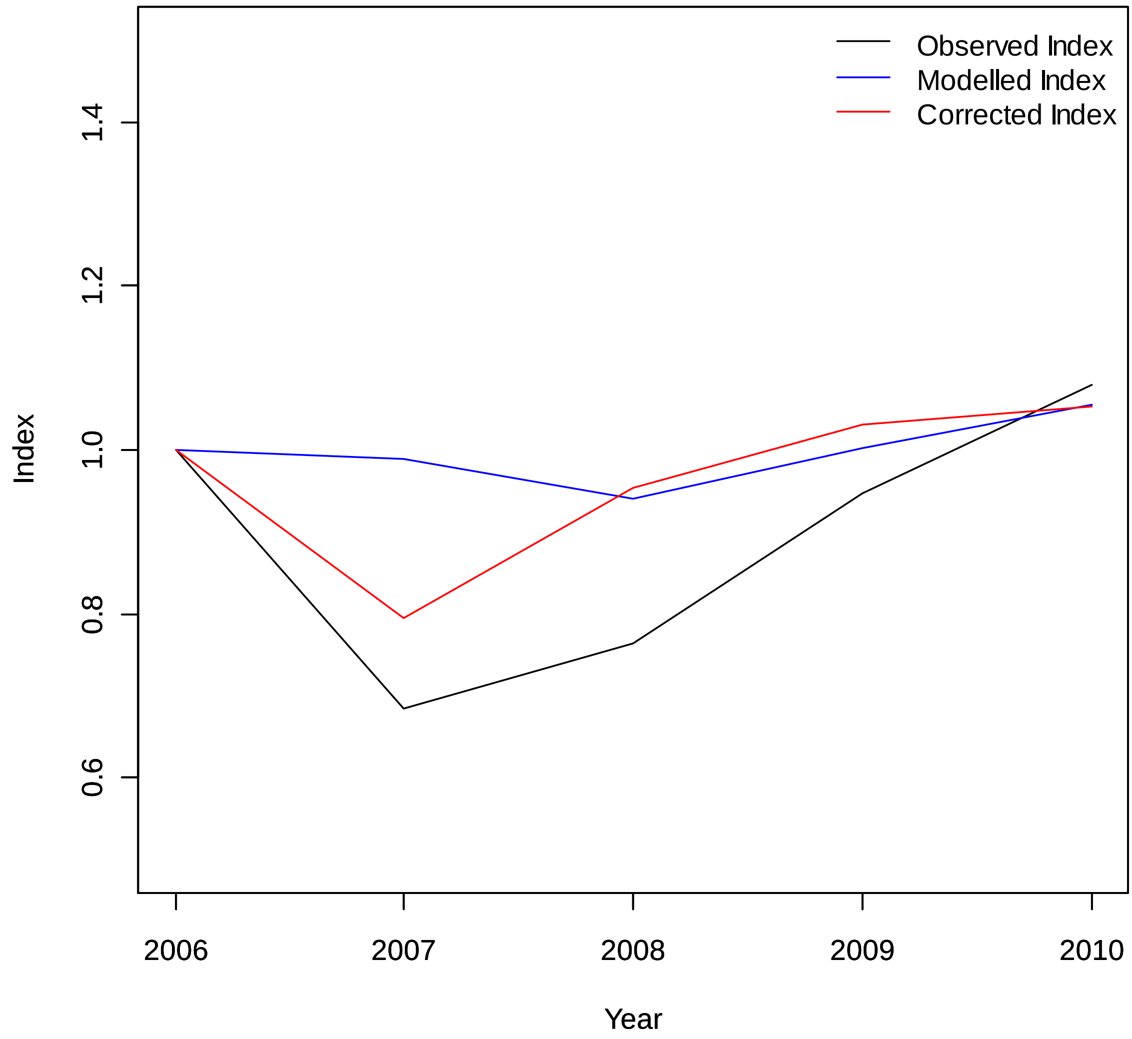


Figure 58 Comparison between Northern Fulmar Breeding success, based on data from the Seabird Monitoring Programme (Observed Index), and indices constructed from models of Northern Fulmar passage rates at Holme Bird Observatory before (modelled) and after(corrected) correction for prevailing environmental conditions.

4.3.6 Gannet

The model for Northern Fulmar was a reasonable fit for the data with an adjusted R^2 of 0.41. Gannet passage rates at Holme Bird Observatory peaked during the morning, and tailed off during the rest of the day. Numbers were greatest in the autumn, with few birds present in the beginning of the year. The greatest numbers were recorded during periods of strong northerly or easterly winds (Figure 59).

Breeding data were only available for Bempton Cliffs SPA in 2008 and 2009. Indices based on this information showed similar variation to both the modelled and corrected indices (Figure 60).

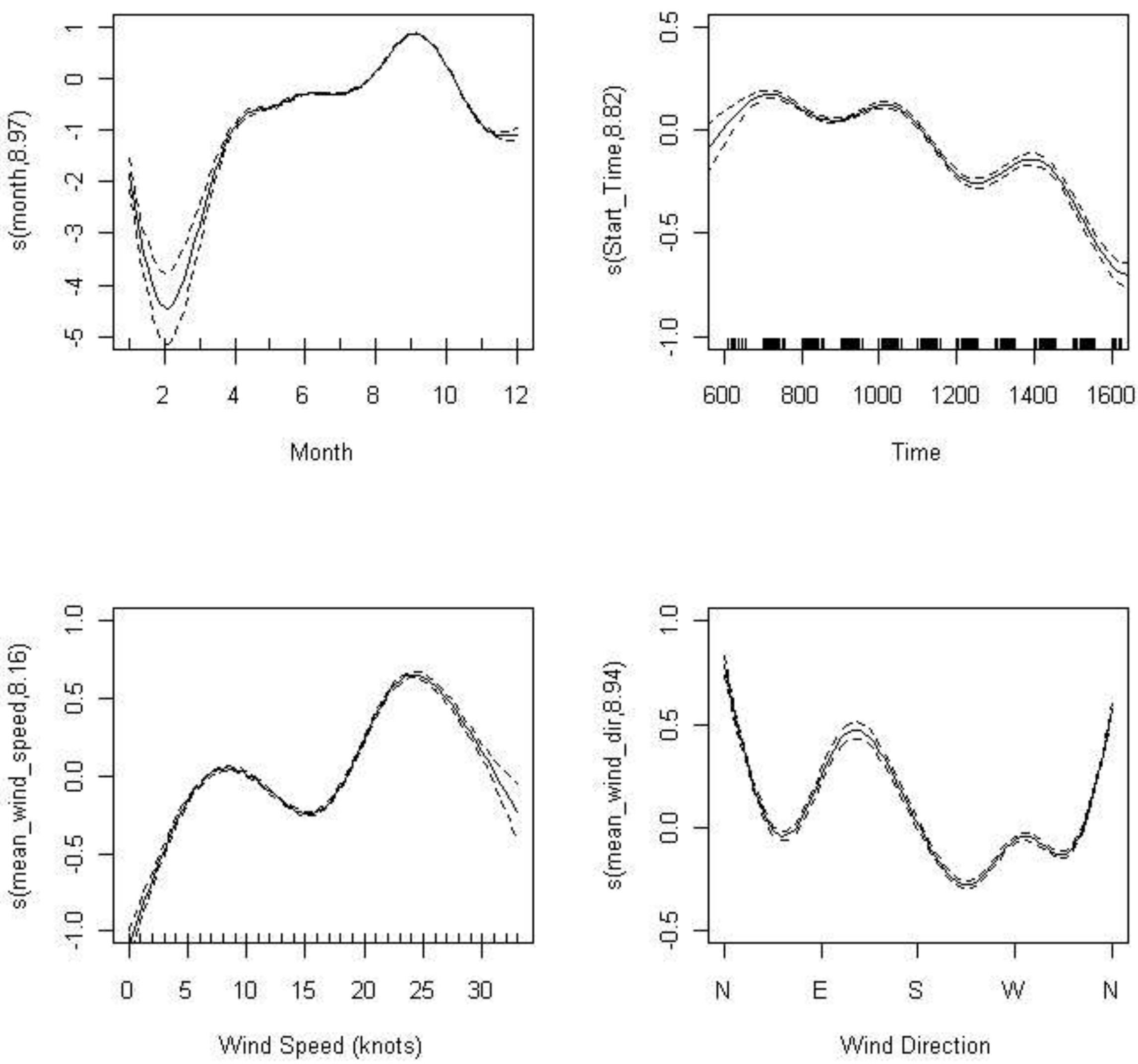


Figure 59 Smoothed Terms from model of Gannet passage rate at Holme Bird Observatory (from top left) month, start time, wind speed (knots) and wind direction.

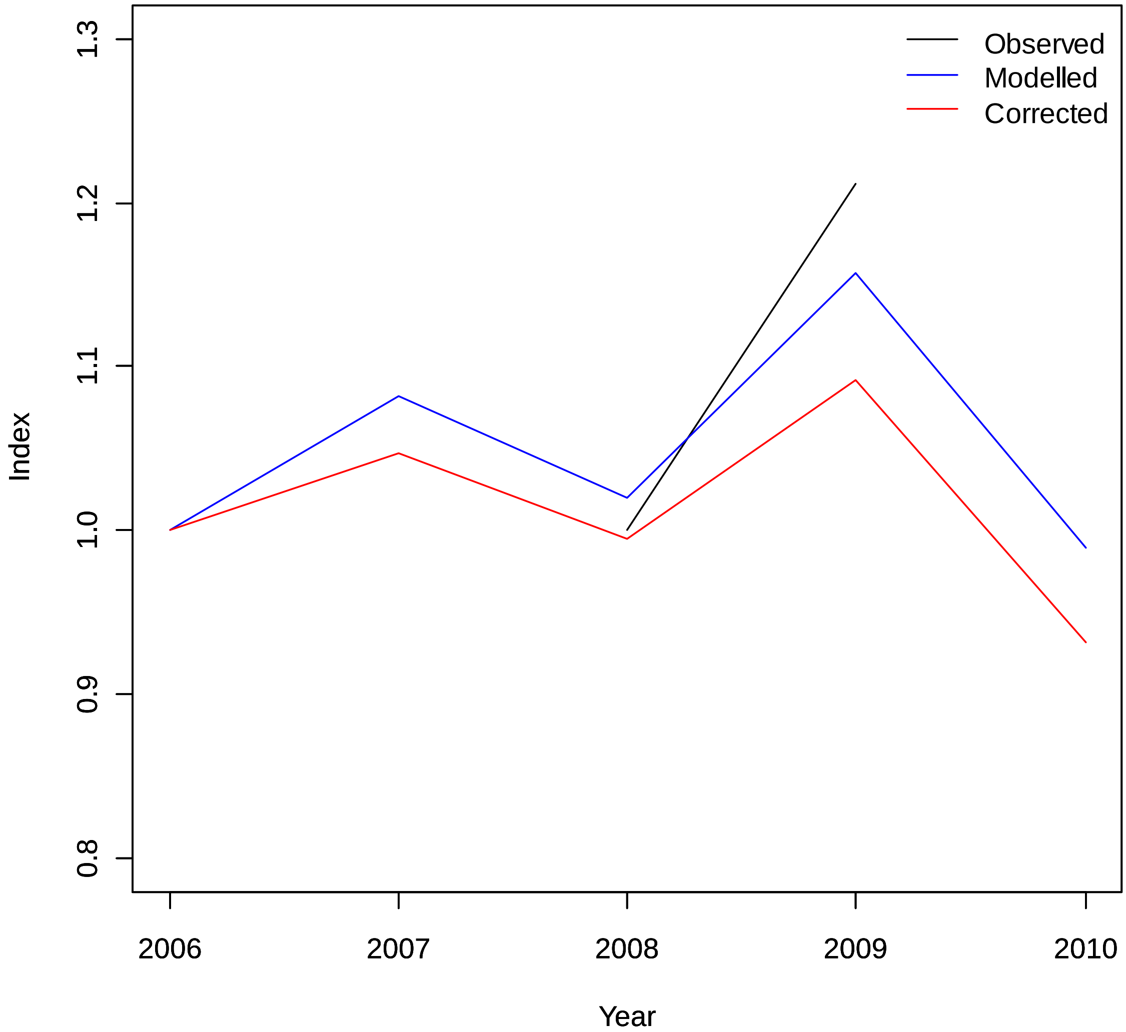


Figure 60 Comparison between indices based on apparently occupied nests for Gannet at Bempton Cliffs SPA (Observed Index), and indices constructed from models of Gannet passage rates at Holme Bird Observatory before (modelled) and after (corrected) correction for prevailing environmental conditions.

4.3.7 All Species

A final index was developed for all species. This provides an interesting comparison of year to year differences in the total number of birds, from all species, seen. However, the results should be interpreted with caution given the difficulties inherent in combining data in this fashion.

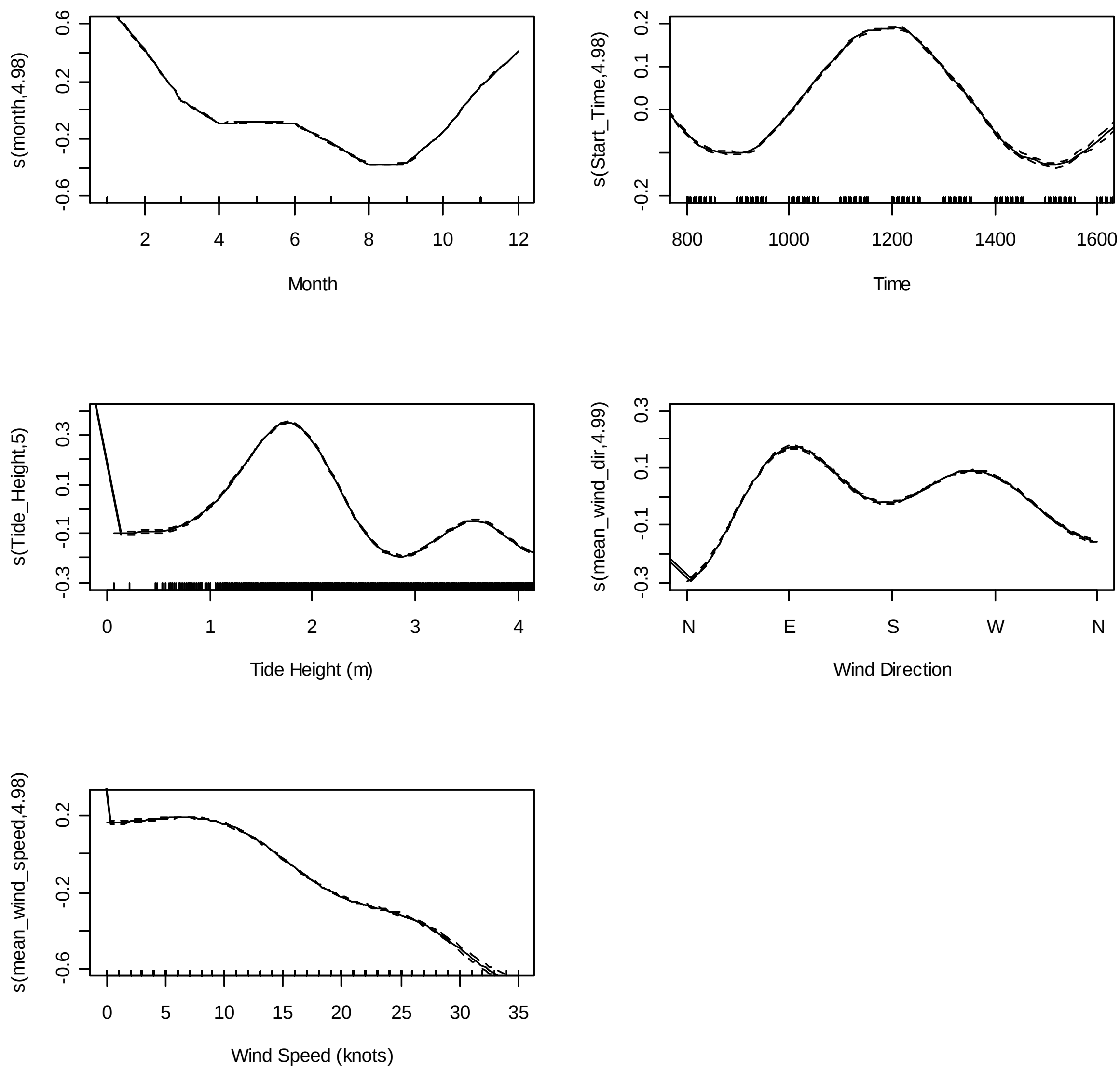


Figure 61 Smoothed Terms from model for the passage rate of all species at Holme Bird Observatory (from top left) month, start time, wind speed (knots) and wind direction.

The model for all species was a reasonable fit for the data, with an adjusted R^2 value of 0.23. The greatest volumes of birds were recorded during winter, in the middle of the day. Numbers appeared to peak during when the tide was around 1-2 m. There did not appear to be a strong effect of wind direction on the total numbers seen, however, numbers did appear to peak during periods of low-moderate wind. However, there are serious methodological issues with combining data from a variety of species with highly divergent ecologies in this manner. They may each respond in different ways to the explanatory variables, meaning that some of the variation within the data

Consequently, these results must be interpreted with extreme caution and used as a general rule of thumb, as opposed to a hard and fast rule about when the greatest number of birds will be recorded, this is likely to be determined by variations in local and national populations.

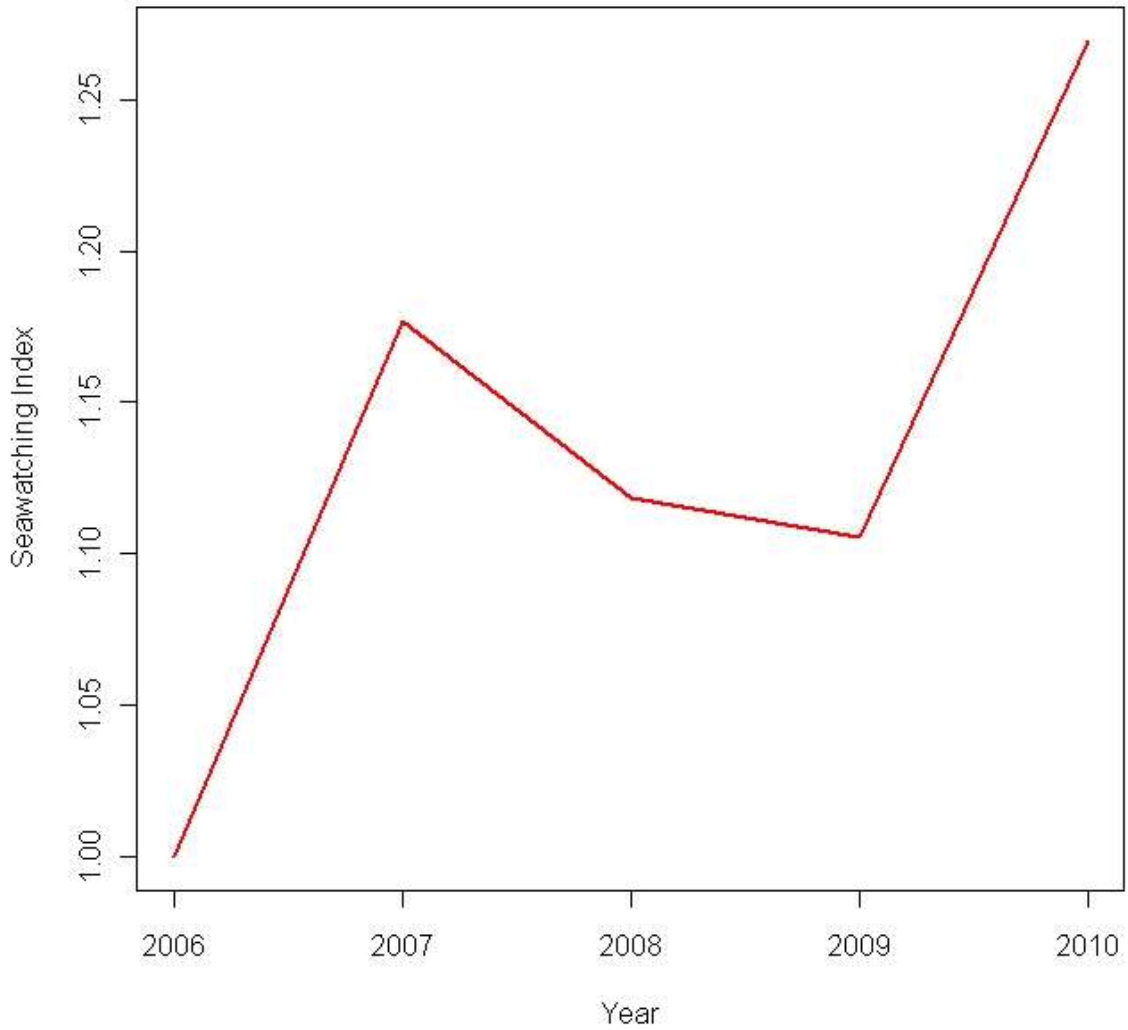


Figure 62 Annual index of the rate at which birds of all species were recorded passing Holme Bird Observatory.

The annual index for birds passing Holme Bird Observatory shows an increase between 2006 and 2007, a slight decline between 2007 and 2009, before the rate peaked in 2010. However, combining data in this manner hides the natural variation in numbers of the contributing species, which is likely to be influenced by a wide range of factors. As a result, such an index cannot be used to determine the cause(s) of year to year variation in the rate at which birds are observed passing Holme Bird Observatory.

4.4 Discussion

All six study species showed strong seasonal variation in their passage rates at Holme Bird Observatory. Passage rates for Gannet, Kittiwake, Great Skua and Arctic Skua peaked during the autumn as birds were dispersing from their breeding colonies. Sandwich Tern numbers peak during the summer when they breed at the nearby Scolt Head and Blakeney Point colonies, whilst Fulmar numbers peak during the spring. Gannet and Fulmar numbers peaked during the morning whilst Great Skua numbers peaked during the afternoon.

There were also strong relationships with wind, with Gannet, Arctic Skua, Great Skua and Kittiwake peaking during periods of strong winds and Sandwich Terns more prevalent during spells of calmer wind. Arctic Skua, Great Skua and Fulmar all peaked during periods of Northerly winds whilst Gannets peaked during periods of Northerly and Easterly winds.

For all six species, corrected indices were a reasonable match for the observed indices. This indicates that sea-watching would be a useful tool for monitoring the health of the UK's seabird populations. It should be noted that these indices were constructed using data from a single site, which in some cases was hundreds of miles from the species closest breeding colony. Given that data from Holme show such a striking correlation with data from other sources, it is likely that by developing a network of sea-watching sites within the UK, it would be possible to monitor the status of breeding seabird populations with great accuracy.

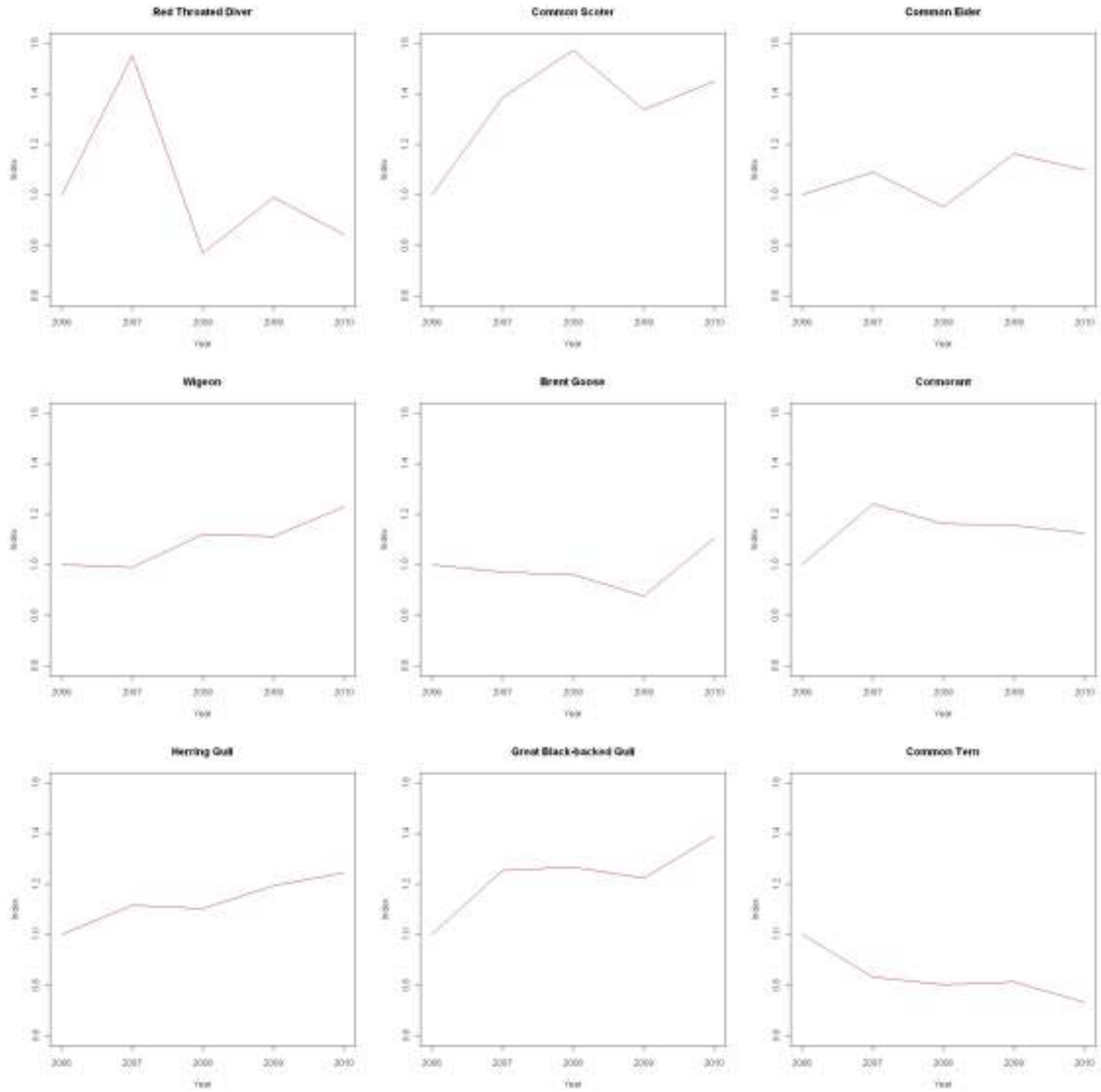
4.5 Benefit of sea-watching data

The marine environment is under increasing pressure from offshore industries including renewable energy developments, fisheries and aggregate extraction. As a result, it is important to ensure that populations of vulnerable species, such as seabirds, are monitored so that any impact of these activities can be fully appreciated.

Many seabirds breed in remote and isolated locations, consequently effective population monitoring can be costly in terms of both time and money. Sea-watching is an increasingly popular past time and by standardising recording it is possible to use this medium to accurately and effectively monitor seabird populations. The power of such a monitoring scheme would be enhanced through the development of a national network of sites which could correct for regional patterns in abundance and distribution.

5. WHAT DO INDICES TELL US ABOUT LOCAL POPULATIONS?

Following the above methodology, population indices were developed for additional species at Holme Bird Observatory, to investigate variation in bird abundance and to consider what link these patterns may have to the completion of the nearby Lynn and Inner Dowsing wind farms. We identified a further 10 species for which sufficient data were available to develop indices using the above methodology – Brent Goose, Common Scoter, Common Eider, Wigeon, Red-throated Diver, Cormorant, Little Tern, Common Tern, Herring Gull and Great Black-backed Gull.



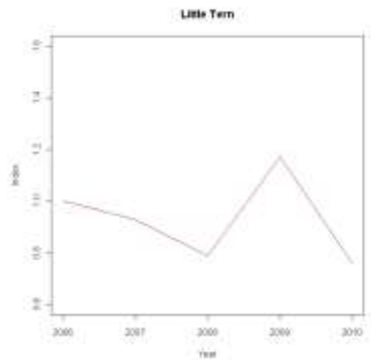


Figure 63 Population indices for 10 species based on sea-watching data collected from Holme Bird Observatory

An unusual feeding event was recorded across a suite of species in January 2007. This has been attributed to an influx of food, attracting birds to the area from elsewhere (Cooke 2007). There is evidence of this peak in the indices for Red-throated Diver, Cormorant and Common Eider (Figure 63), and also in the all-species index (Figure 62). Correcting for this influx, either by excluding the data concerned, or by incorporating it as a fixed effect within the model, had a limited impact on the index. The 2007 peak in the data was still evident, although slightly reduced.

The construction of Lynn and Inner Dowsing wind farms began in 2007, and both became operational in 2009. As there are no comparable sites from which data are available, it is not possible to assess the impact of these wind farms quantitatively through a BACI (Before-After-Control-Intervention) style analysis. We are therefore restricted to making general inferences about the impact of the wind farm by examining and comparing the population indices based on sea-watching data developed above. If the wind farms are having an impact on species populations, it would be expected that a clear decline would be obvious, either across all 16 indices (the 6 indices described in section 4 and the 10 additional indices developed in this section), or within ecologically meaningful groups of species in 2007 when construction began, or in 2009 when the wind farms became operational.

There were no clear and consistent patterns in the data that would indicate an effect of the Lynn and Inner Dowsing wind farms on the rates at which birds were observed passing Holme Bird Observatory. Indices showed declines in 6 species between 2006 and 2007 - Fulmar, Arctic Skua, Great Skua, Sandwich Tern, Common Tern and Little Tern (Figures 52, 54, 56, 58, 63). The indices for Fulmar, Arctic Skua and Great Skua are a close match for breeding success at a regional level. As any pressure related to the wind farms would be expected to act at a local level, these declines are unlikely to be linked to Lynn and Inner Dowsing. The declines recorded in the three tern species appeared to have been part of longer term declines in these species as they all declined further in 2008. A similar pattern was observed in the index for all species (Figure 62). This may reflect disturbance during the construction phase, although without additional data from further afield it would not be possible to confirm this. However, if this decline were related to disturbance, it might be expected that a greater decline, relative to 2006, would be recorded in 2007, during the installation of foundations, than in 2008 when the turbines were installed, which may be less of a disturbance.

Between 2008 and 2009, indices showed declines in Common Scoter, Great Skua and Sandwich Tern (Figures 52, 56, 61). These are three species with very different ecologies, and had the declines been linked to the turbines becoming operational, it would be expected that they would have been recorded amongst similar species.

Between 2009 and 2010, the all species index (Figure 62) and the indices for nine out of the 15 modelled species showed increases. The markedly different ecologies of the species concerned, and the fact that they occur at different stages in their annual cycles, make it extremely difficult to assign these increases to a single factor. Indeed, it is likely that these increases are the result of several different factors, each acting on the species concerned in a different way.

Based on the evidence presented here, the construction and operation of the Lynn and Inner Dowsing wind farms did not appear to have any impact on the birds recorded passing Holme Bird Observatory. However, this conclusion is based on a general overview of the areas bird populations, as opposed to any detailed analysis. Ideally, a BACI-style approach would have been used, which could control for any impact of the wind farm with the inclusion of data from a similar site(s).

6. GENERAL DISCUSSION

The first step to any long term data collection should be to ensure that it is done in such a fashion that the data are both useful and meaningful. This has been achieved here through the use of hourly passage rates as opposed to raw counts. The value of these data has been demonstrated through the close relationship between passage rates and breeding numbers and success. This raises the potential for the development of a national sea-watching scheme which could be used to monitor vulnerable populations of seabirds up and down the country.

However, the patterns revealed by the data are interesting in themselves. Relationships between passage rates and wind patterns have long been proposed. The data presented here show that species, such as Skuas, which typically feed in offshore environments are seen in greatest numbers during periods of heavy wind, presumably having been blown closer to the shore. In contrast, species such as terns which feed in more nearshore environments are recorded most frequently during calmer periods, presumably in response to the energetic costs associated with foraging in heavy wind.

This sea-watching dataset demonstrates that it is also possible to investigate annual patterns in species abundance, and relate this to their differing ecologies. We can use data to show how species respond to inter-annual variation in climate, and what impact offshore development may have on these species. It is clear from these initial analyses that sea-watching provides a valuable and under-utilised scientific resource.

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