Baseline studies North Sea wind farms: fluxes, flight paths and altitudes of flying birds 2003-2004

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photo cover page: M. Poot; vertical and horizontal radar at Meetpost Noordwijk. Vertical radar turned 90° anti-clock wise in actual situation, measuring north-south.

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Preface

The Dutch government has granted 'Noordzeewind' (Nuon Renewable Energy Projects and Shell Wind Energy) the possibility to build a wind farm consisting of 36 wind turbines off the coast of the Netherlands, near Egmond. This project serves to evaluate the economical, technical, ecological and social effects of offshore wind farms in general. A Monitoring and Evaluation Program (MEP) has been developed for the purpose of this evaluation and to gather the resulting knowledge. The knowledge thus gained by this project will be made available to all parties involved in the realisation of large-scale offshore wind farms. The study on ecological effects is coordinated by the National Institute of Coastal and Marine Management (RIKZ). Bureau Waardenburg and Alterra, in cooperation, have been commissioned by RIKZ to execute the base line study of effects on flight paths, flight altitudes and flux of migratory and non-migratory birds (Lot 6).

The fieldwork was based on three different methods: radar observations, visual observations and a combination of both. Here we present the integrated results of these observations, which have been conducted at observation platform 'Meetpost Noordwijk' between September 2003 and November 2004. In the report at hand, methods are described to such an extent that all methods used can be understood and interpreted by the reader. For an in-depth description of methods we refer to Krijgsveld *et al.* (2003), where all methods used have been explained in detail. In 2004 three preliminary reports presenting preliminary results were written (*i.e.* first results, visual observations, radar observations). Since then, the methods for control and analysis of the data were refined considerably and the data extended. The current report thus presents the full data set as well as up to date analyses of all data, and replaces the three former preliminary reports.

The radar equipment was supplied by DeTect Inc. (Panama City, FL, USA). The fieldwork was carried out by Theo Boudewijn, Sjoerd Dirksen, Karen Krijgsveld, Rob Lensink, Suzan van Lieshout, Martin Poot, Hein Prinsen, Popko Wiersma, Richard Witte (all Bureau Waardenburg), Martin de Jong, Hans Schekkerman, Hans Verdaat (all Alterra), Zak Zakrajsek and Andreas Smith (DeTect Inc.). This report has been conceptualised by Karen Krijgsveld, Rob Lensink, Martin Poot, Popko Wiersma and Sjoerd Dirksen at Bureau Waardenburg and Hans Schekkerman and Erik Meesters at Alterra.

Mariska Harte, Geert Koskamp, Ellen Raadschelders and Saskia Mulder of RIKZ and Walter van den Wittenboer of NOVEM supervised this project. Jaap van den Horn of Directie Noordzee played an important role in the logistics of our stays at the observation platform. Our stay at the platform was made possible by the platform managers Guus Goossens, Roel Mager, Arthur Dias, Ed de Boer and the cook John Sels, thanks to who each stay became an enjoyable stay. The crew of mv Albatros always delivered us safely at the platform. The DeTect team has worked very hard at different stages of the project to get the radar set up, the data collected and ready to be analysed, for which we are grateful. Many thanks to Barbara Trösch, Susanna Komenda-Zehnder, and Dieter Peter of the Schweizerische Vogelwarte, Sempach, Switzerland for introducing us to the

technique of moon watching and for analysing the moon watching data. The authors and both institutes they work for, are deeply grateful to all who made this research possible and to all who participated in some way in the process.

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Summary

Background
To build knowledge and experience with the construction and exploitation of offshore wind farms, a large research program was set up to study the economical, technological, social and ecological effects of a near shore wind farm in the coastal waters of the Dutch North Sea. The report at hand concerns the ecological effects, and deals with effects specifically on flying birds (Lot 6). It describes the 'reference situation', *i.e.* the situation prior to construction of the wind farm, and serves as a reference to which the situation during and after construction of the wind farm can be compared in the subsequent effect study. Effects of the future wind farm may range from avoidance behaviour to collision of birds with turbines. Only by determining the undisturbed flight patterns in the reference situation, can we assess the effects resulting from the presence of the wind farm in the future.

Study aims
We quantified flight patterns of flying birds in the undisturbed situation before construction of the wind farm, to be able to assess collision risks and disturbance of flight patterns of the future wind farm. Flight patterns studied were:

- fluxes; *i.e.* intensity of flying birds
- flight paths, *i.e*. flight directions
- flight altitudes

All three aspects were studied in relation to seasonal and diurnal variation, as well as weather conditions. Birds studied included migrating marine and non-marine birds as well as local marine birds.

Methods used
Flight patterns were studied by using two radars and various visual observation techniques. The radars operated both in the horizontal and in the vertical plane, and allowed automatic and continuous registration of signals in a database using Merlin software supplied by DeTect Inc. (Panama City, FL, USA). Observations covered the period from October 2003 through November 2004. Visual observations ended June 2004.

Fluxes
The majority of flying birds were *gulls*. They comprised ca. 90% of all flight movements in the study area. Gull occurrence was highly correlated with occurrence of fishing vessels. Gulls were most abundant in October–December and in May–June (no obervations July-August). Abundance of *seabirds* varied between species. Abundance of alcids, divers, Gannets and skuas was high in late autumn–winter. In April–June, Gannets again and tubenoses had a high abundance. *Migratory non-marine birds* were most abundant in October–December and in March–May, conform migratory patterns. Bird abundance decreased with increasing wind speeds. This was true in general (MTR vertical radar) and for Gannets, gulls and landbirds specifically.

Fluxes, expressed as mean traffic rate (MTR, nr of birds/hr/km, *i.e.* flight intensity), were highest in late autumn-early winter, with a lower peak in April through June. Fluxes at *lower altitudes* up to 250 m were higher during day than at night, reflecting high activity of gulls mostly but not exclusively during day time. At *higher altitudes*, fluxes were higher at night, especially during migration periods in October and April-June.

Fluxes did not show a consistent *pattern throughout the day*. Some species such as gulls were more active in the middle of the day, whereas others were mostly active at dawn and dusk or at night. Fluxes of migratory birds were considerable both at night and during day, but in general showed higher levels at night. During autumn migration in September-October, a strong peak in MTR occurred around sunset, of thrushes and other nocturnally migrating passerines that started migration simultaneously at dusk from the nearby coast. Such concentrations were also observed visually at dawn, from diurnal migrant passerines.

Fluxes recorded by the vertical radar were of low magnitudes compared to the levels recorded by moon watching in autumn. This is mainly due to the fact that during peak nights of autumn migration the radar was not working. Most observations with the vertical radar were gathered in spring. The fluxes obtained by moon watching were of the same magnitude as found in other studies. They reflect peak MTR's as they were collected during nights with intense autumn migration. Possibly, the vertical radar may also have missed small birds due to a large range setting.

Possible differences in flight patterns between the observation platform and the actual NSW site 40 km to the north where the wind farm will be constructed, were evaluated based on observations over sea conducted from the shore at both sites. The following differences in flight patterns of bird groups are presumed: Smaller numbers of geese and swans, grebes, ducks during frost-flights, landbirds (passerines) migrating parallel to the coastline, and foraging flights of gulls during the breeding season. Larger numbers of pelagic seabirds (tubenoses, alcids, Gannet; unknown to what extent) and possibly of Brent Goose, divers, seaducks and Little Gull. Similar numbers of other groups like terns, skuas, waders, and landbirds migrating in directions perpendicular to the coastline.

Flight paths

Flight paths of the majority of birds, *gulls* flying to and from fishing vessels, were oriented in all directions, determined by the position of these fishing vessels. At dawn and dusk, flight paths of gulls included (Herring and) Black-backed Gulls flying from and to the breeding colonies at Voornes Duin and the Maasvlakte.

Flight paths of *local marine birds* such as divers, Gannets and alcids were mostly oriented parallel to the coastline.

Migratory non-marine birds flew in southwesterly directions in autumn, cutting off to the Maasvlakte and Belgium semi-parallel to the coast. Some waterbirds, mainly geese and swans, followed a west-southwesterly direction towards England. In spring, flight paths of migrating birds were oriented east-northeast.

Flight altitudes

Flight altitudes during *daytime* were mostly low, up to 100 m, reflecting flight altitudes of gulls, as well as of seabirds, geese, swans, ducks and waders. At *night*, flight altitudes were much higher, at altitudes of 150 m and more. Flight activities at night were mostly of migrating waders and larger passerines. The vertical radar did not operate in autumn, during fall migration. It is likely that under favourable tailwind conditions crossings during the day also occurred, but at higher altitudes, similar to the night.

Gulls flew mostly below 50m, occasionally higher up to 200m. *Seabirds* (alcids, divers, sea ducks, skuas and tubenoses) flew mostly low above the sea, at altitudes up to 50 m, and mostly below 15 m. Most cormorants, geese and swans flew up to 100 m, occasionally higher. *Migrant birds* flew at altitudes up to 50 m during daytime, but higher at night (over 150 m).

Flight altitudes *varied largely* in especially cormorants, geese & swans, gulls, ducks other than sea ducks, and waders. In these species, flight altitudes commonly varied between 0 and 200 m. In migrating birds such as geese & swans and waders, this variation may be caused by differences in wind direction and wind speed.

Sea ducks

Flight patterns of scoters, which were studied in a separate study within the program, are reported in Dirksen *et al* (2005). The NSW site is situated relatively close to a known major sea duck wintering area, and sea ducks may therefore be an important impacted group. Research was carried out north of the Wadden Islands. Especially after disturbance, e.g. by ships, birds fly away from the original feeding area. At night, these distances may be smaller than during the day. Flight altitudes in part lay below rotor height. However, a smaller but substantial part flew at rotor level, in conditions without turbines present. How presence of turbines will affect flight patterns is as yet unclear.

Radar issues

Currently, radar is by far the best method available to obtain information on flight patterns of birds that needs to be obtained around the clock and throughout the year. Especially at night and at higher altitudes, only radar allows such data to be obtained. Thus, the radar measurements performed at Meetpost Noordwijk, with the resulting data on fluxes and flight altitudes, have contributed importantly to our knowledge of flight patterns of birds flying near shore over the North Sea.

To allow continuous registration of flight patterns, 24 hours a day, throughout the year, radar signals were recorded by an automated hard- and software system. Signals detected by the radar were stored into a database, after filtering out signals generated by waves based on characteristics of these signals. Clutter from waves is a serious problem when operating radars that are fine-tuned to detect birds over sea. Although we were able to remove a high percentage of clutter from the *horizontal radar* data (over 90%), data remained highly polluted with clutter. Resulting horizontal data, used to determine flight directions, showed high correlations with wave height and wave directions. In addition, tracks of birds were split up into many different ID's in the record, thus reducing total track length of bird-signals and therewith the main characteristic that set birds apart from sea clutter. As a consequence, patterns of flight paths based on horizontal radar data were masked to a high extent by clutter. The problems of both clutter removal and track recognition need to be improved significantly for future measurements. The visual observations that were performed largely to back up observations by horizontal radar, proved essential to attain conclusions regarding flight paths of birds.

The *vertical radar* also generated large amounts of records from waves. Because these were restricted to levels below 1,8 m above sea level, clutter could be removed relatively easily from the data. Because many birds, especially local marine birds, fly at very low altitudes above sea, deleting records below 1,8 m implies that many of these flight movements were lost for analysis. The resulting data were still polluted with an unknown percentage of records of objects other than birds. Despite this pollution, the vertical data did reflect fluxes patterns in the right order of magnitude, and could therefore be used successfully to quantify flight altitudes and to determine fluxes.

Severe technical difficulties were experienced with both radars. The hardware repeatedly broke down as a result of strong winds out at sea. Especially the vertical radar proved to be sensitive to strong winds, probably as a consequence of the manner in which it was attached to the platform.

Results and recommendations in light of the effect study

To be able to assess collision risks and barrier effects of flying birds resulting from the presence of the future wind farm, we established fluxes, flight paths and flight altitudes of birds in the ‘undisturbed’ situation. By means of vertical radar and additional visual observations, fluxes and flight altitudes of the various species were determined adequately. During and after construction of the wind farm, these data will be indispensable to gain insight not only in the level of barrier effects of the wind farm, but also in collision risks. The data will allow us to relate the fluxes measured in the reference situation with the collision rate measured in the effect study. Information on species level is largely limited to daylight, and nocturnal migrating birds. Nocturnal activity of the various species of local marine birds deserves further attention in the effect study.

Behaviour of the birds in response to the wind farm, such as avoidance of the turbines or the entire farm either by changing flight altitude and/or changing flight paths, will be established in the effect study. Occurrence of barrier effects can then be determined by comparing the results of the effect study with the findings in the reference study. Flight paths however have been difficult to obtain, as the horizontal radar has largely failed to result in quantifiable data, and visual observations of flight paths are restricted to daylight hours. To be able to accurately measure occurrence of barrier effects, clutter removal and track recognition in the horizontal radar needs to be improved.

To prevent interruptions in data recording and high costs of repair, the manner in which the vertical radar is mounted on the platform needs to be improved in the effect study in order to withstand the harsh climatic conditions out at sea.

1 Introduction

1.1 Background

In order to increase the supply of renewable energy in the Netherlands, the Dutch government has decided to support the construction of a near shore wind farm (NSW) of 36 turbines 10-15 km off the coast of Egmond in the Netherlands. The project at hand serves as a pilot study to build up knowledge and experience with the construction and exploitation of large-scale offshore wind farms. The knowledge gained with this project will be made available to those parties that are involved in the realisation of large-scale offshore wind farms. To collect this knowledge, an extensive Monitoring and Evaluation Program (MEP-NSW) has been designed in which the economical, technical, ecological and social effects of the NSW are gathered. Carrying out this MEP serves 'learning goals' for future wind farms further offshore as well as 'effect assessment goals' for the NSW itself.

In order to assess the effects of the wind farm, it is necessary to establish the 'reference situation', *i.e.* the situation without wind turbines, prior to construction of the wind farm. Research to describe this reference situation has been carried out since 2003 and is currently in its final stage. As far as ecological topics are concerned, the National Institute for Coastal and Marine Management (RIKZ) commissions and supervises the project. The project consists of six topics (Lots 1-6), of which Lots 5 and 6 are dealing with birds. Lot 5 (carried out by a consortium of Alterra and Bureau Waardenburg with CSR Consultancy as subcontractor; Leopold *et al.* 2004) focuses on distribution and densities of birds at sea (swimming or flying at low altitude). Lot 6 (carried out in a cooperation between Bureau Waardenburg and Alterra; this report) focuses exclusively on flying birds. Both Lot 5 and Lot 6 are needed to make a full assessment of potential disturbance, barrier effects and collision risks of wind turbines in the coastal waters of the Dutch North Sea.

1.2 Outline of the study

Derived from land-based studies, the MEP requires bird research to enable an analysis of three types of possible effects of wind farms on birds: collisions of flying birds with turbines or their wake, disturbance of flight paths/barrier effects and disturbance of resting and/or feeding birds. The project described in this report deals with the pre-building study for the first two topics: collision risks and disturbance of flight paths/barrier effects.

To assess the effects that collision risks and disturbance of flight paths may have on birds, it is necessary to gain insight in the flight patterns of birds in the area, in the situation prior to building of the wind farm where flight patterns that are unaffected by the wind farm can be quantified. Flight patterns consist of three aspects: fluxes of birds, flight paths (*e.g.*, flight directions) and flight altitudes. These three aspects are the subject of the present study.

The reference study thus serves to establish what species are flying where (e.g., in relation to the coast), when, at what altitude and in what numbers. In the effect study, this information then serves to determine whether and on what scale barrier effects occur, as well as to calculate collision risks under varying conditions. The reference study will be used to be able to register behavioural changes in relation to the wind farm. It does not serve *sec* as a quantification of bird numbers, to which bird numbers, necessary to determine significance of effects in the effect study.

In short, the present reference study entails the quantification of flight and behaviour patterns before construction of the NSW has started, and serves as a reference to which the situation during and after construction of the wind farm can be compared in the subsequent effect study.

Flight patterns were quantified by using a combination of automated and visual observation techniques. All birds flying through the study area were registered by means of an automated system using two radars that processed and stored bird signals in two databases. The first radar rotated horizontally and registered all flight paths of birds. Thus, flight directions and flight speeds of birds flying through the study area could be quantified. The second radar rotated vertically and registered all birds flying through an imaginary 'detection net' suspended in the sky in the study area. Thus fluxes and flight altitudes could be quantified. This automated system was designed to operate continuously, thus collecting flight movements of birds each day of the year, both day and night. In addition, visual observations were used to obtain detailed observations throughout the year on species composition and behaviour of the various bird species in the area, and to back up and validate the automated measurements. These visual observations were made from an observation platform at sea, and comprised observations of fluxes, flight paths and flight altitudes of birds during the day and to a lesser extent during the night. The study was designed in such a way that it allowed to link visual and radar observations and thus to calibrate the radar observations.

In this report we present the integrated results of radar and visual observations on flight patterns of flying birds in the reference situation, as carried out between September 2003 and October 2004.

1.3 Research goals

To determine what effects the NSW will have on birds, we aim to quantify the following aspects of both marine birds and non-marine migrating birds in the reference situation at the NSW-site:

- fluxes of flying birds (*i.e.* intensity; number of birds per time unit per surface area);
- flight paths of flying birds;
- altitudes of flying birds.

Variation in these flight patterns caused by seasonal patterns, spring or autumn migration, day or night, and variation in weather conditions will also be evaluated. To cover this variation, the study of the reference situation was conducted during a full year.

The research questions for the reference study can be summarised as:

- what are fluxes, flight paths and flight altitudes of the species of birds that occur in the NSW area, 10-15 km off the Dutch coast?
- how do fluxes, flight altitudes and flight paths vary between seasons, spring and autumn migration, day and night, and under varying weather conditions?

1.4 Outline of chapters

This report is built up as follows, where numbers refer to chapter numbers:

1 Introduction;
2 Study aims in detail;
3 Study area & overview of research periods;
4 Overview and explanation of the various methods used;
5 Description of handling and analyses of data. Emphasis in this chapter lies on the process of extraction of bird echoes from the collected radar data. Listed in this chapter also is the amount of data that was collected with each of the observation methods. A brief summary of the first paragraphs is given at the start of each paragraph;
6-8 Presentation of results, grouped per subject:
  6 - fluxes
  7 - flight paths
  8 - flight altitudes
  Each of these chapters is summarised in the final paragraph of the chapter;
9 Discussion of results;
10 Conclusions: main findings and evaluation of used techniques;
11 Literature.

2 Study aims

In the light of the potential effects of wind farms on flying birds, which have been outlined in chapter 1, three aspects of bird movements are important: fluxes, flight paths and flight altitudes. To be able to analyse the effects of the Near Shore Wind Farm on flying birds when it will be in place, we have established the three aspects of flight patterns in the undisturbed reference situation, both for migrating marine and non-marine birds and for local marine birds. Based on this information, changes resulting from the presence of the Near Shore Wind Farm can be detected in the effect study which will be conducted at a later stage. In the following paragraphs we describe the three aspects of flight patterns (§2.1-2.3), as well as the species that are of interest in this study (§2.4).

2.1 Fluxes

Collision risk is the division of the actual number of victims by the potential number of victims. The latter is the flux, or the number of flying birds passing a given surface area in a given unit of time. Measuring the flux of birds is therefore an important task. In relation to wind farms, not only fluxes are important, but also the altitudes at which these birds fly and the flight paths they use (see below). Furthermore, with detailed information from visual observations of the underlying species composition, the behaviour of the birds, and observations of factors affecting the number of birds passing, the ecological context of the flight patterns will be described. Behaviour of local and migrating birds for instance, will affect mortality risks, as migrating birds pass the location once or twice yearly, whereas locally foraging birds such as herring gulls may pass the location more or less regularly while foraging in the area. Such differences will be reflected in the calculation of mortality risks.

The main variation in flux comes from migrating birds. Under influence of environmental conditions like wind or precipitation, the densities of birds passing an area during a period of time can vary immensely. The measurements need to cover this variation.

2.2 Flight altitudes

The flight altitude of a bird largely determines the extent to which it potentially can be affected by a wind turbine (or a wind farm). Birds generally fly at altitudes that lie within species-specific ranges. For many species however, these altitudes are not known. Flight altitudes of foraging marine species can be such that it puts them at risk from collision with the windmills.

Migrating birds that are flying over 300 m high may not be directly affected by the wind turbines at the NSW, but birds migrating at high levels occasionally come down under influence of adverse weather or strong winds (Lensink *et al.* 1999). To evaluate the effects of the wind farm it is important to analyse the frequency with which this occurs.

2.3 Flight paths

Many birds fly to and from their nesting, resting or feeding areas on a daily basis, for which they follow more or less constant flight paths. At sea however, apart from birds breeding on shore, daily flight paths are very much the result of drift by wind and tide, in combination with the (generally highly variable) locations of areas that are rich in food.

Wind also largely determines flight paths of migrating birds. The flight paths to be described in this study are therefore very much related to wind. In addition, the effects of a wind farm at sea are not limited to birds flying to and from their feeding grounds, but also include birds during their foraging activities.

2.4 Species of interest

To be able to evaluate whether significant effects on bird flight patterns will result from the construction and presence of the wind farm, we need to gather information on those species of birds that are relevant to the ecosystem of the North Sea. Marine birds are those bird species that are entirely or partially reliant upon the sea. They include local breeding birds that forage at sea, as well as migrating seabirds. Non-marine migrating birds include all other species flying over the study area mainly during the migration periods in spring and autumn, towards and from their breeding and wintering grounds. For the purpose of this study, all birds passing the study area in the North Sea and its immediate surroundings are included.

Both with visual and radar observations, all flying birds are registered and therefore all species and all individuals that fly within a few kilometres of the observation post. With the radars however, different species cannot be distinguished from each other without a detailed calibration of signal characteristics. Because of this, it is not known beforehand to what level species groups or species can be identified from the radar data. Analysis of the ‘flagging’ data collected during the fieldwork in this study will answer the question to what extent species groups or species can be identified by radar.

Because some species groups or species have a higher ecological relevance than other, based on for instance abundance in the area and in respect to population size, the study of the reference situation will pay close attention to the species listed in table 2.1. Those species are more or less abundant in the area of the wind farm during at least part of the year, or may suffer a higher risk from the wind farm due to their behaviour. For similar reasons, priorities in the discrimination of species are to distinguish terns from gulls, divers from sea ducks and grebes, distinguish groups of migrating birds as swans, geese, diving or dabbling ducks, shorebirds, thrushes, or small songbirds, and to be able to positively identify cormorants, gannets, gulls (as a group), common scoters, and alcids.

At the end of the base line study we hope to be able to determine actual abundance of the various species (-groups).

Table 2.1 Overview of the species and groups of birds that will be studied, including the level to which identification is desired (whether this level is feasible, will be established in the course of the project). The list is based on numerousness in the area and high-risk behaviour of species. See also Appendix 1.

species or group	level
Local and migrating marine birds	
cormorant	species
grebes	group
divers	group
alcids –guillemot, razorbill, puffin	group
gannet	species
sea ducks – scoter & eider	species
other ducks	group
shelduck	species
terns	group
large gulls & skuas	group
small gulls	group
fulmar & shearwaters	group
storm petrels	group
Migrating birds	
swans	group
geese	group
sea ducks	group
other ducks	group
waders	group
swift	species
larks	group
thrushes	group
crows	group
starling	species
small songbirds	group

3 Study area and observation periods

3.1 Study area

The Near Shore Wind Farm will be situated 10-15 km off the coast of Egmond and cover an area of approximately 100 km^2. Observations on flight patterns of birds were carried out from the observation platform Meetpost Noordwijk (MpN), 9 km off the coast of Noordwijk, approximately 40 km south of the NSW-location (52,310N 4,359E; figures 3.1 and 3.2).

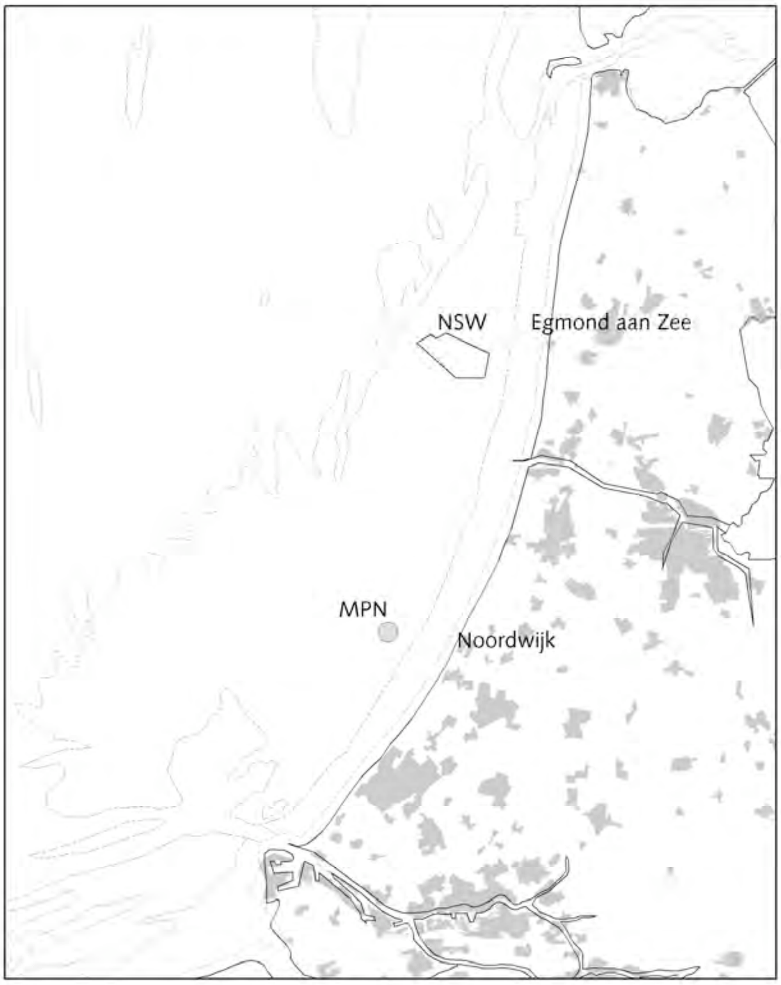


Figure 3.1 Location of the Near Shore Wind Farm (NSW) and of the observation platform 'Meetpost Noordwijk' (MpN) where observations were carried out.

Observation platform 'Meetpost Noordwijk' is situated at approximately the same distance from the coast as the NSW area. It counts three decks, the highest of which is 19 m above sea level, offering a good altitude to observe birds, as well as observation locations that are sheltered from strong winds.

Figure 3.2 Research and observation platform Meetpost Noordwijk, which was used as observation site in this study (photo: R. Lensink).

3.2 Periods of observation on the platform

In table 3.1 below, an overview is given of the periods during which visual observations were carried out at the observation platform, as well as an overview of the visual observations that were carried out at these times. In September 2003 various methods were tested.

Intervals between observation periods vary largely, due to two reasons. First, during the first months of fieldwork the platform was scheduled to shut down at the end of December 2003. With this prospect, in order to obtain a substantial amount of measurements, it was necessary to increase the observation frequency from the scheduled once a month to twice a month or more if possible. When it became evident by January 2004 that the platform would remain available for our measurements, observation frequency was reduced to once a month. Second, for reasons of safety, weather conditions at times did allow the observers to be dropped off at the platform by ship. When wave heights exceeded 1 m, safety regulations at the observation platform did not allow a drop-off by ship. In the winter season this often was the case.

Table 3.1 Overview of types of visual observations on the observation platform MpN; the fieldwork started at 10 October 2003; in September 2003 different methods were tested. 0 = no measurements, 1= measurements were performed.

visit	date	flagging horiz.	flagging vert.	panorama scans	fixed point counts	moon-watching	nocturnal calls	sound-recording
0	26-29 Sept 03	0	0	0	0	0	0	0
1	10-17 Oct 03	0	0	1	1	1	1	1
2	28-31 Oct 03	0	1	1	1	0	1	0
3	5-7 Nov 03	1	0	1	1	1	1	0
4	25-28 Nov 03	1	0	1	1	0	0	0
5	1-4 Dec 03	1	0	1	1	1	1	0
6	21-23 Jan 04	1	0	1	1	0	0	0
7	16-19 Feb 04	1	1	1	1	0	1	0
8	8-11 Mar 04	1	1	1	1	0	1	0
9	13-16 Apr 04	1	1	1	1	1	1	0
10	3-6 May 04	1	1	1	1	1	1	1
11	1-4 June 04	1	1	1	1	1	1	1
12	6-9 Sept 04	0	0	1	1	0	1	1

4 Overview of observation techniques

In this chapter we describe the techniques that were used to gather data on flight patterns of flying birds. In the first paragraph we describe which techniques were used for the various research aspects. Here we also give a general overview of the methods used and how they relate to each other in order to tackle the main questions of this study (see also Krijgsveld *et al.* 2003). Each of the methods is then described in further detail in the subsequent paragraphs.

4.1 Schematic overview of methods used to record flight patterns

Seven different methods were used in this study to assess flight patterns of local marine birds and migrating birds. A flow diagram (fig. 4.1) gives an overview of how these seven methods together yield the required data. The flight patterns studied consist of the aspects fluxes, altitudes and flight paths. Different methods were employed to tackle these three aspects. Of these methods, observations with horizontal and vertical radar, panorama scans and flagging can be considered as core observations. The other three methods, *i.e.* ship-based observations of sea ducks, sea watches, and observations of nocturnal movements and sounds, are complementary methods.

The seven methods in short

- The *vertical radar* measured fluxes and flight altitudes by scanning the area in the vertical plane.
- The *horizontal radar* measured flight paths (*i.e.*, flight direction and flight speed) and to some extent fluxes as well, by scanning the area in the horizontal plane.
- With *panorama scans*, altitudes and flight paths were measured, and as it supplied a detailed species composition, it also served to back up and interpret radar observations. The panorama scan is in its essence comparable to a radar; by slowly moving the binoculars in one direction the observer scans the air in view on flying birds and birds floating on the water surface. If the density is expressed as density per scan, the data obtained with the panorama scans become comparable with that of the horizontal radar.
- *Ship based observations* on scoters and other sea ducks used different methods (radar - and visual observations), which were needed to establish all three aspects of flight patterns of sea ducks.
- *Flagging* was done to assign information about species to the bird echoes that were recorded by radar.
- *Sea watches* served to pick up additional species that were flying by at larger distances and with lower frequencies, and that were not adequately recorded in panorama scans. Secondly, together with *sea watches made from the shore* (data from the Dutch Seabird Group NSG), these counts serve to quantify the gradient in bird density with increasing distance from the coast. In that sense, they serve directly to establish flight paths.

- All visual methods were restricted to daylight periods. Therefore, nocturnal observations by means of *moon watching and recording of nocturnal calls* were the only way to back up radar observations made during the night.

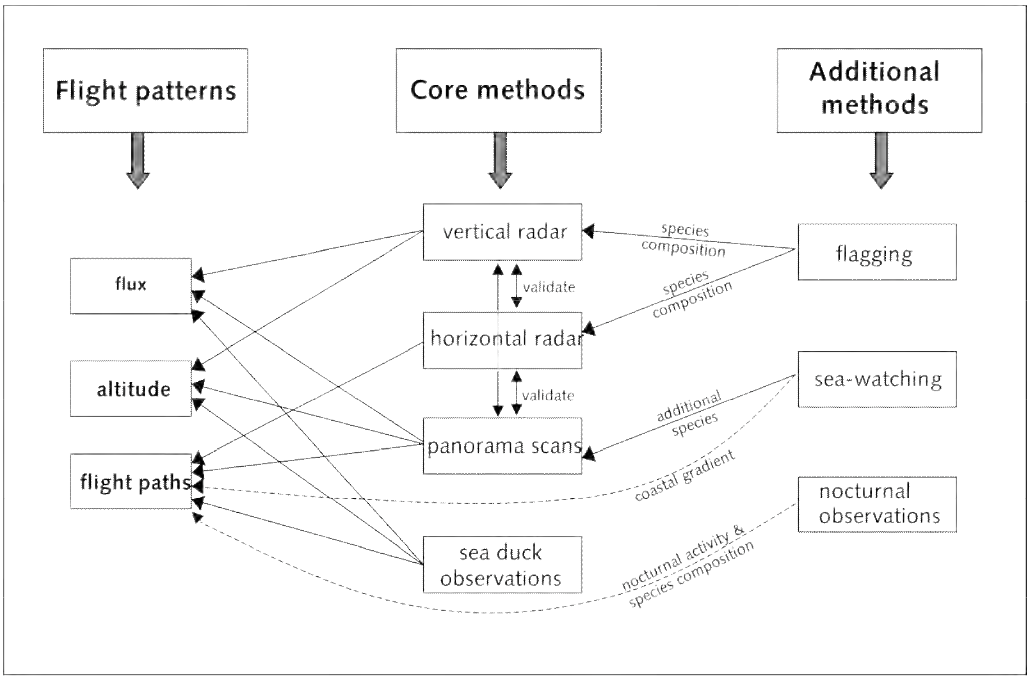


Figure 4.1 Flow chart showing the primary aims of this study (left) and the methods used to study them (middle and right). Arrows indicate which questions the methods answer.

4.2 Radar observations

To obtain information on flight patterns on a larger scale, for an extended period of time, and on diurnal as well as nocturnal flight movements, radar was the best available option. The choice for radar, and more specifically, marine surveillance radar, for bird flight observations has been motivated in the project proposal (Krijgsveld *et al.* 2003).

Two types of radar observations were combined (see fig. 4.2). The first is the observation of flight paths, which was done using a horizontal surveillance radar. This is a standard radar as used on ships, which scans the area in the horizontal plane around the radar. With this radar, flight paths of birds flying through the radar beam were tracked and flight speeds and directions were recorded. The second type of radar-observation is the observation of fluxes and flight altitudes. This was done using a comparable type of radar (X-band), which was tilted to rotate vertically, and thus scanned the air vertically rather than horizontally. In this way, bird flux could be quantified by counting the number of birds that crossed the radar beam during a fixed amount of time, and flight altitude of birds could be measured by recording the vertical distance of the bird to the sea surface.

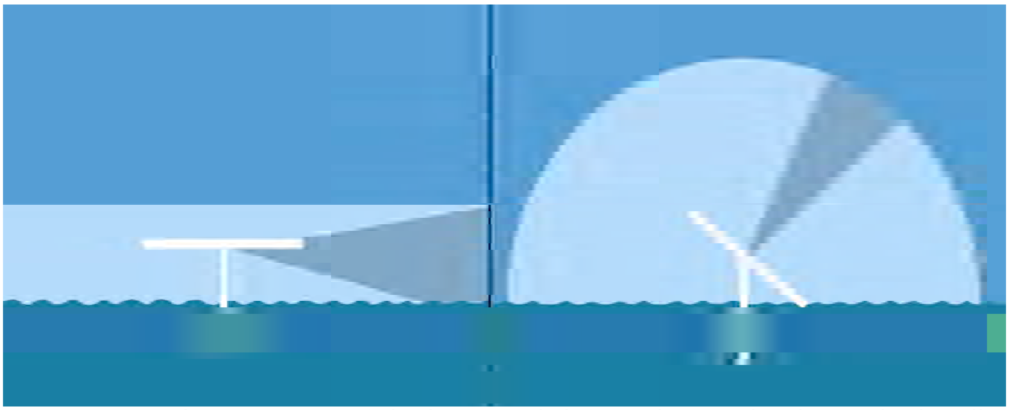


Figure 4.2 Schematic view of the horizontal (left) and vertical radar. Radar bundle is shaded in the image. See front cover for a picture of the systems in operation on the observation platform; vertical radar was turned 90° anti-clockwise in actual measurement situation however.

To process and record echoes detected by the radars, Merlin, a system developed and supplied by DeTect Inc. (Panama City, FL, USA), was used. This system entailed not only the radars, but also computer-radar interfaces and software. With this system the radar signal could be processed and recorded, yielding a database in which echoes belonging to birds were stored along with information on flight direction, speed, altitude and more.

These radars scanned an area of up to 11 km around and up to 2,5 km above the observation platform. They automatically recorded echoes continuously throughout the year, every day, both day and night, and thus recorded all bird movements within the area. In this way, the exact location, direction, speed, and altitude was registered of all birds flying within the scanned area. The data recorded by radar provided the principle dataset on flight patterns, which is far more extensive than the visual observations due to the continuous nature of the measurements and its ability to record flight movements at night. In most weather conditions the radar has a superior detection covering larger distances compared to field observers, especially in the vertical plane.

Bird detection

The capabilities of radar to monitor flight movements have been tested in earlier projects, among which are comparable off-shore projects (Tulp *et al.* 1999b, Poot *et al.* 2001), as well as specifically developed field tests (Poot *et al.* 2000). It is clear that detection limitations exist with radars. The Merlin radars used are more powerful (25 and 30 kW) compared to the radars used up to 2002 by Bureau Waardenburg (10 and 12 KW). Because of the higher power, but also because of the software developed by DeTect for echo data processing, they have much better detection capacities and cover a larger range.

Recording echoes: the Merlin system

On the observation platform two surveillance radar systems were installed; a 30 kW Furuno S-band in a horizontal way and a 25 kW Furuno X-band in a vertical way (see figure 4.2). DeTect Inc. has developed a system of hardware and software to automatically store all echoes in a database. This system is called Merlin.

The Merlin system functioned as follows. The radar signal first went through the Furuno system (the black box). Subsequently it was processed in PC 1 with specialised software in order to get rid of as many false echoes (clutter) as possible (signal processor in figure 4.3). Secondly, all remaining tracks were stored in a database in PC 2 (data storage in figure 4.3). Radar echoes could be seen on screen in two ways; both as an unprocessed image by the Furuno radar (screen from the black box) and as a processed image by the Merlin software (screen from the data storage). Each recorded (trail of) echoes had its own ID (identification number), by which it was stored in the database.

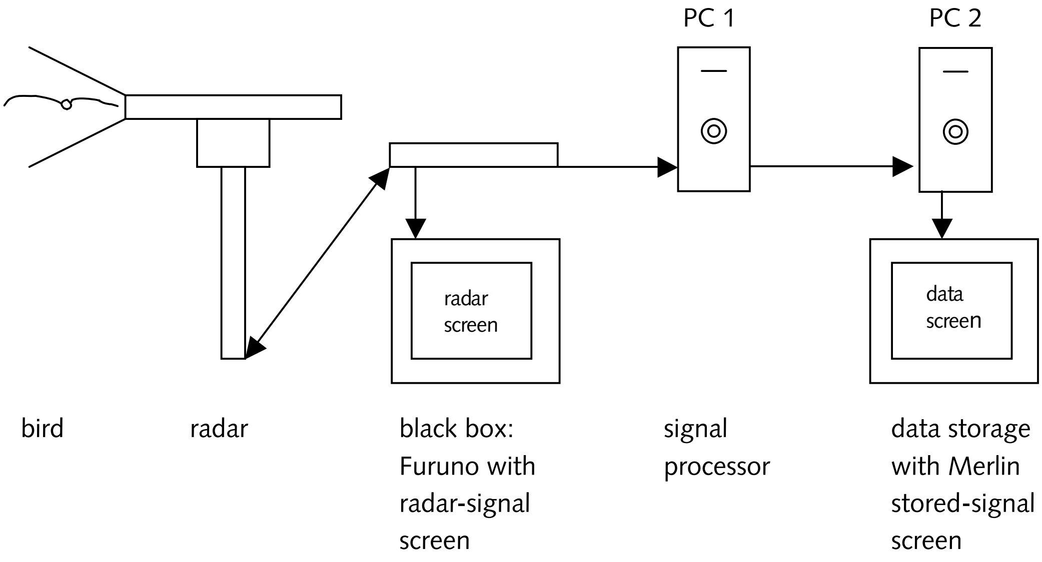


Figure 4.3 Schematic overview of the horizontal radar equipment used. The setup for the vertical radar is identical.

Echo characteristics

The Merlin system records a large quantity of characteristics of each signal that is detected. These characteristics can be used to identify which bird species belonged to the recorded signal (by a method called flagging; see § 4.3). They include, among others, speed (relative to ground surface), size (relative to distance), signal strength and reflectivity. A list of all echo characteristics recorded is given in table 4.1.

Table 4.1 List of the echo characteristics registered and logged by the Merlin system of DeTect Inc for both the horizontal S-band and the vertical X-band radar.

S-band Data	X-band Data	Definitions
DBASE ID	DBASE ID	Unique database identification number for each echo identified in the radar data. These are supposed to be birds, but may also be boats, airplanes, waves, or other clutter.
Period	Period	Link to Session Metadata with this field. This is a Unique ID for the Session
Date	Date	Date and Time - dd/mm/yyyy etc.
Scan Index	Scan Index	How many seconds into the current hour the scan is made (max 3600)
Target Index	Target Index	The number assigned to the target in the current scan, targets in the same scan are numbered from top left to bottom right of the display
Area	Area	Area of the target in pixels
Max Segment	Max Segment	Longest length across the target
Perimeter	Perimeter	Perimeter of the target measured in pixels
Orientation	Orientation	The angle of the longest axis of a target with respect to the horizontal axis. This value is between 0 - 180 degrees.
Ellipse Major	Ellipse Major	Length of the major axis of an ellipse that has the same area and perimeter as the target
Ellipse Minor	Ellipse Minor	Length of the minor axis of an ellipse that has the same area and perimeter as the target
Ellipse Ratio	Ellipse Ratio	Ratio of Ellipse Major to Ellipse Minor
Elongation	Elongation	A measure of the elongation of a target, the higher the value the more elongated the target
Compactness	Compactness	Ratio of the target's area to the area of the smallest rectangle that contains the target
Heywood	Heywood	Ratio of the perimeter of the target to a circle with the same area as the target
Hydro Radius	Hydro Radius	Ratio of target area to it's perimeter
Waddel Disk	Waddel Disk	Diameter of a circle with the same area as the target
Mean Intercept	Mean Intercept	The mean length of segments along the length of a target
Max Intercept	Max Intercept	The length of the longest segment of an echo, in any direction
Type Factor	Type Factor	
Mean Chord X	Mean Chord X	The mean length, in pixels, of the horizontal segments of a target
Mean Chord Y	Mean Chord Y	The mean length, in pixels, of the vertical segments of a target
Av Reflectivity	Av Reflectivity	Average reflectivity over the entire target area (Max 4096)
Max Reflectivity	Max Reflectivity	Maximum reflectivity over the entire target area (Max 4096)
Min Reflectivity	Min Reflectivity	Minimum reflectivity over the entire target area (Max 4096)
Std Dev Reflectivity	StdDev Reflectivity	Standard deviation in reflectivity over the entire target area (Max 4096)
Range Reflectivity	Range Reflectivity	Range in reflectivity over the entire target area (Max 4096)
Range	Range	Distance from the radar to the target in a direct line
Bearing	Bearing	Bearing from the radar to the target
Distance FT		Distance in feet away from the S-band radar location
Track ID	Track ID	Unique identifying number for each track. At least 3 echoes are required to make a track. If a track is broken for two or more scans but then reappears, then a new track is started
Track Type	Track Type	
Target X1	Target X1	X coordinate in pixels of the centre of the current target in a track
Target Y1	Target Y1	Y coordinate in pixels of the centre of the current target in a track
Target X2	Target X2	X coordinate in pixels of the centre of the target from the previous scan in this track

Table 4.1 Continued.

S-band Data	X-band Data	Definitions
Target Y2	Target Y2	Y coordinate in pixels of the centre of the target from the previous scan in this track
Target X3	Target X3	X coordinate in pixels of the centre of the target from the 3rd oldest scan in this track
Target Y3	Target Y3	Y coordinate in pixels of the centre of the target from the 3rd oldest scan in this track
Target X4	Target X4	X coordinate in pixels of the centre of the target from the 4th oldest scan in this track
Target Y4	Target Y4	Y coordinate in pixels of the centre of the target from the 3rd oldest scan in this track
Lat 1		Latitude of the centre of the current target in a track
Long 1		Longitude of the centre of the current target in a track
Lat 2		Latitude of the centre of the target from the previous scan in this track
Long 2		Longitude of the centre of the target from the previous scan in this track
Lat 3		Latitude of the centre of the target from the 3rd oldest scan in this track
Long 3		Longitude of the centre of the target from the 3rd oldest scan in this track
Lat 4		Latitude of the centre of the target from the 4th oldest scan in this track
Long 4		Longitude of the centre of the target from the 4th oldest scan in this track
Heading	Heading	Azimuth heading of a tracked target (0 - 359 degrees)
Speed	Speed	Speed of a tracked target in the units specified in the Metadata Table of the database
Class	Class	
	AGL FT	Altitude Above Ground Level of a target – this is altitude above the X-band radar, which itself is 20 m above the water
	Cross Track Ft	Distance in feet along the surface of the water or ground that a target is away from the radar

4.2.1 Vertical radar

The specifications of the vertical radar are listed in table 4.2.

Table 4.2 Characteristics of the vertical radar.

type:	X-band
power:	25 KW
antenna length:	2,50 m
beam width:	20°
rotation speed, avg:	25 rpm
range:	1,5 NM, *i.e.* 2.778 m
orientation:	north-south
altitude:	axis at ca. 20 m above sea level
data handling:	all echoes with characteristics are stored (see table 4.1).

4.2.2 Horizontal radar

The specifications of the horizontal radar are listed in table 4.3.

Table 4.3 *Characteristics of the horizontal radar*

type:	S-band
power:	30 KW
antenna length:	3.00 m
beam width:	25°
rotation speed, avg:	22 rpm
range:	6 NM; *i.e.* 11.112 m
orientation:	horizontal
altitude:	axis at ca. 20 m above sea level
data handling:	all echoes with characteristics are stored (see table 4.1).

4.3 Flagging: assigning species to radar echoes

Flagging
The data registered by radar and stored in the database are not automatically linked to a bird species. The system only logged the echoes encountered, together with the characteristics of these echoes (see table 4.1), but did not give information on the nature of the echo, *i.e.* whether the echo belonged to a ship, a bird, or perhaps a wave, and if a bird, to what kind of bird. Thus, in order to be able to use the radar data, the echoes need to be identified as belonging to a certain species group or even species. In order to enable this assignment, a dataset was built in which visual and radar observations were combined: Radar signals were flagged and linked to the bird that was seen and identified by observers simultaneously watching the actual bird flying by. This method is called ‘flagging’.

Signal identification was done by one-on-one linking of the visual observations and the radar observations (fig. 4.4). Through direct communication by means of portable radios between a field observer and an observer behind the radar screen, the echo of an object (bird) that was sighted visually could be identified and flagged on the radar screen, *and vice versa* an object generating the radar signal could be located in the sky and identified. These coupled observations were made during all periods of visual observations (Lensink *et al.* 2004). This resulted in a database of radar signals each assigned to a species of bird, as well as to ships or to clutter from waves. In this database the accompanying signal characteristics of that bird or object were stored as well. These signal characteristics were then used to find relations between signal characteristics and different species groups / objects by means of regression techniques and multivariate analysis (see § 5.1).

It is impossible to positively assign species or species group to every signal. However, by combining advanced radar observations and standardised visual observations such as panorama scans and sea watching, registration of the flight movements at sea could be covered adequately to identify main flight patterns and thus assess the risks of the future Near Shore Wind Farm.

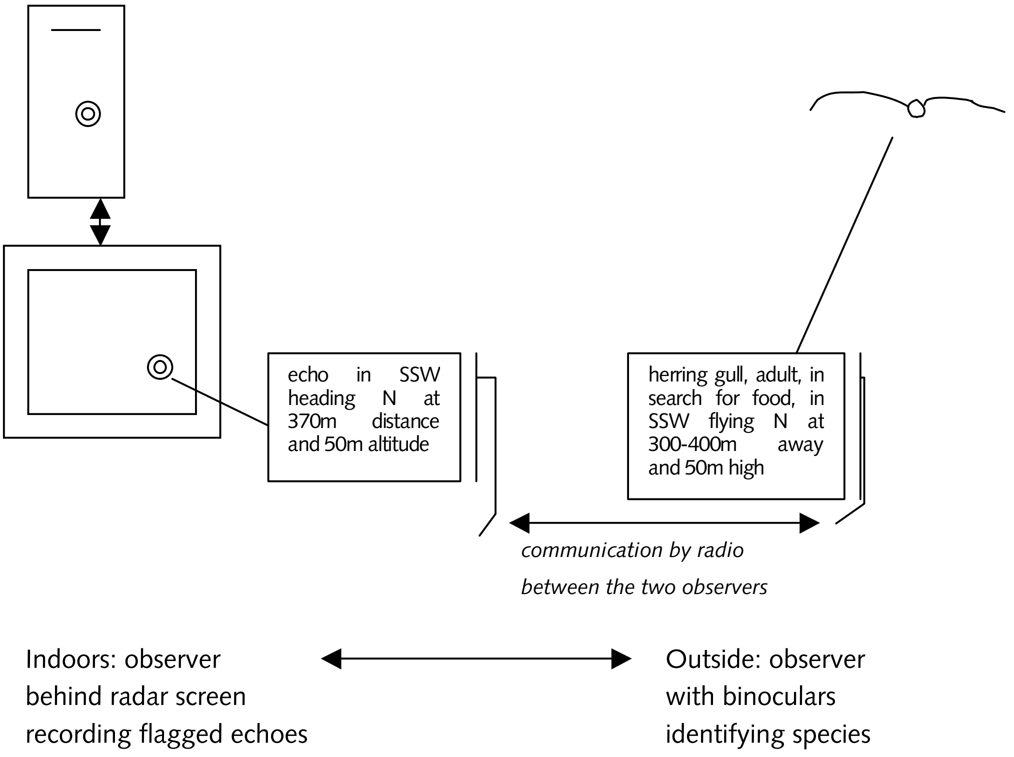


Figure 4.4 Schematic overview of flagging of radar echoes; see also figure 4.3.

4.4 Panorama scans

Field methods

A panorama scan is a visual count of all birds flying within sight of the observation platform (Lensink *et al.* 2000). It serves as a backup and calibration of the radar counts, and supplies us with information on species composition, density, flight altitude and flight direction of birds around the platform. The technique has been calibrated extensively (Lensink *et al.* 1998, Poot *et al*. 2000).

A panorama scan was done by scanning the air and water in a 360° circle around the platform, using a standard pair of 10*42 binoculars fixed on a tripod. The 360° circle was divided into 8 sectors (fig. 4.5) in order to be able to register where the bird was flying (e.g., NW or SE). Each panorama scan consisted of two full circles, one to count birds at or just above sea level (low scan, 1/2; horizon in the middle of the field of view of a pair of binoculars), and a second to count birds at higher altitudes (high scan, 1/8: horizon at an eighth of the field of view). A panorama scan was carried out approximately every hour (during daylight). Of all birds flying through the field of view of the binoculars, species, number, altitude (4 classes), distance (in 4 classes; figure 4.6) and behaviour (following ESAS coding, see appendix 2, Camphuysen & Garthe 2001) was registered. In this report, densities of birds per scan are given (number per unit surface area). Because distance and altitude of each bird was recorded, these numbers could be transformed to number of birds per km^2. Recording was done on preprinted forms (appendix 2).

The panorama scan is in its essence comparable to a radar; by slowly moving the binoculars in one direction the observers scans the air in view for flying birds and birds floating on the sea surface. If the density is expressed as density per scan, the data of the panorama scan are comparable with those of the horizontal radar.

Two observers in the process of making a panorama scan. Low scan of sector 1. Photo: K. Krijgsveld.

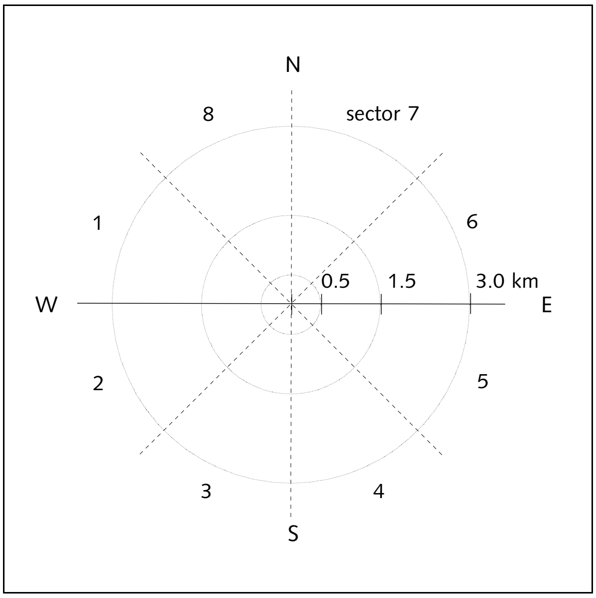


Figure 4.5 *Schematic view of the area covered by panorama scans and the division into sectors and distances. MpN is situated in the centre. Surface area of inner circle = 0,79 km^2, of distance 0,5-1,5 km = 6,28 km^2, of distance 1,5 - 3 km = 21,21 km^2. Scans were performed at two heights: one low scan with the horizon halfway the binocular view and a high scan with the horizon at 1/8 in the lower part of the binocular view (see figure 4.6).*

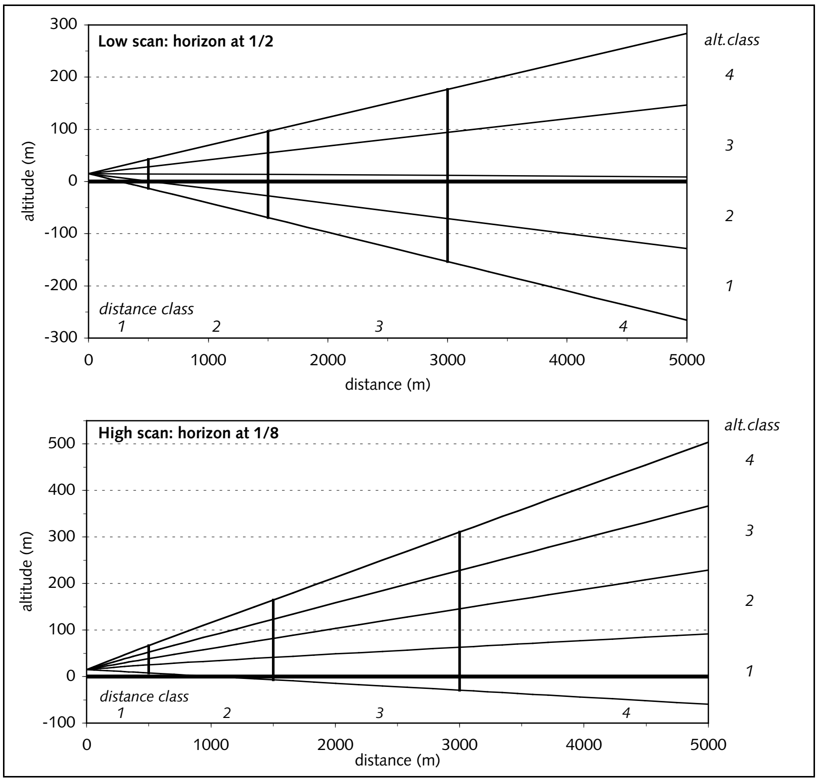


Figure 4.6 *Schematic view of the volume of air covered with a panorama scan using a 10×42 pair of binoculars. With the water surface visible in the bottom part of the view, the maximum altitude at which birds are scanned is 165 m at 1500 m distance.*

4.5 Sea watching

Field methods

Sea watches – counts of birds flying past across the sea, made by looking in a fixed direction from a fixed location – are made primarily to gather data that are additional to those obtained by the panorama scan. Differences between the two methods are that (1) the panorama scan quantifies flights in all directions while by using a constant view direction, sea watches mainly register flights more or less perpendicular to this direction, (2) by using a smaller-magnification binocular and scanning at two elevations, panorama scans cover a larger altitude range. The panorama scan therefore covers a greater proportion of all flight movements than the sea watches. However, (3) the panorama scan is basically a 'snapshot' technique, in which low-altitude flights in each compass section are recorded for only about one minute per hour, while sea watching is done much more continuously in the direction perpendicular to the main axis of low altitude seasonal migration flights. Also (4), by using a larger magnification and a fixed position, more birds will be detected and identified at larger distances. Hence, sea watching will produce more observations of less numerous species, especially those with directed (migratory) flights.

Sea watching was done in bouts between other activities. Panorama scans, and 'radar flagging' had priority over sea watching when observers were limiting. All sea watching data presented in this report were collected from the Western side of the platform, looking in a W to NW direction, depending on wind and light conditions. Watches were made by 1-3 observers, sitting behind a tripod-mounted telescope with 20x magnification (binoculars with 10x magnification were used in a minority of watches with limited visibility). When more than one observer was involved, one looked through the scope all the time while the other acted as a secretary. When watching alone, the observer was his own secretary.

Observer in the process of sea watching. Photo: H. Schekkerman

Recording was done on pre-printed forms in 5-minute bouts. (Flocks of) birds were recorded separately and species, number, age and sex if possible, distance zone (0-500 (1), 500-1500 (2), 1500-3000 (3) and >3000 m (4)) and flight direction were recorded. Flight direction was usually recorded in broad categories. Birds were observed when crossing an imaginary East-West (SE-NW) line. The predominant flight direction of birds other than gulls was parallel to the SW-NE coastline. In addition, birds flying roughly perpendicular to the line of view are more likely to cross it and be seen than birds flying parallel to it (the latter are only seen if they fly out along the line of view, not if they fly out in other directions). Because most birds seen thus flew broadly in these directions, observers usually defined flight directions as either S-SW (crossing the line of view to the left) or N-NE (crossing to the right), and recorded other directions only if they clearly deviated from this usual pattern (notably, flying out to sea or in towards the land).

4.6 Flight patterns of sea ducks

This study is reported separately in Dirksen *et al.* (2005). For details regarding the sea duck observations we refer to this report. Below we give a brief description of the methods.

Fieldwork
Observations on nocturnal flight movements and flight altitudes of sea ducks, especially of common scoter *Melanitta nigra*, have been made in the winter of 2003/2004. Since this species does not occur in the area of Meetpost Noordwijk, fieldwork was carried out in an area with a large number of wintering sea ducks, *i.e.* north of the Wadden Sea islands Ameland and Terschelling. During ship-based surveys in this area, nocturnal flight movements were recorded using a 10 kW surveillance radar in a horizontal plane and a 12 kW surveillance radar in a vertical plane. Observations of movements were recorded in pre-printed forms on a 15 minute base. In addition a video camera was mounted in front of the radar screen, and the most important movements of sea ducks were recorded as well. During daylight, movements of sea ducks were registered using binoculars and a standard protocol for recording the observations.

Data available
Fieldwork to study flight patterns and behaviour of scoters and other sea ducks was carried out from aboard a ship, which sailed to locations with large concentrations of common scoters (north of Terschelling and Ameland). Two series of observations were done: the first from January 30 to February 2 2004, and the second from February 12 to February 15 2004 (see also Dirksen *et al.* 2005). During the first survey no sea ducks were found. In addition, during the trip wind force increased to such an extent that we had to return to harbour. During the second trip, circumstances were much better, and during two nights many data on flight paths, flight altitudes and flight behaviour of sea ducks were obtained.

4.7 Nocturnal bird movements: registration of calls and sound recording

As visual observations are limited to daytime periods, the only observations that are made of nocturnal flight patterns are the radar measurements. We have investigated possibilities, described here and in the following paragraph, to extend nocturnal radar observations with other observations, and these are used in addition to the radar data to interpret nocturnal flight patterns.

Registration of calling birds

Some species (groups) give flight calls during migration, especially thrushes, larks, pipits, *etc*. (Gatter 1976). These calls can be identified to the level of species or at least species group by a trained ear, and thus offer a way to quantify migration during hours of darkness. The number of calls heard is an indication for the intensity of migration. During the night it is generally presumed that songbirds migrate individually and not in flocks, whereas waders and waterfowl show the same behaviour as during daylight hours. Counts of calls were conducted from the platform in the beginning of the evening, lasting at least one hour. Numbers of calls were registered per 5-minute time interval.

Automated sound recording

Within the framework of the baseline study, a cooperative project has been set up between the Behavioural Biology Department of the University of Leiden (EEW, drs. T. Schrama & dr. H. Slabbekoorn) and Bureau Waardenburg (M.J.M. Poot). The goal was to develop an automatic bird call recording system which could be used to gather more information on species composition of nocturnal migrants within the baseline and effect studies in relation to the Near Shore Windfarm. The Behavioural Biology Department of the University of Leiden is a group specialised in studying acoustic communication in birds. Between Bureau Waardenburg and this group a communal interest exists in developing an automatic bird call recording system. Bureau Waardenburg facilitated the necessary hardware (computer, microphones and assistance time), while the University of Leiden brought in the necessary expertise (software development, technical knowledge in relation to acoustic recordings).

Using MatLab, a program was written that could analyse continuous sound recordings of several hours (Schrama & Slabbekoorn 2005). The program detected bird calls and isolated them from ambient/background noise at the research platform. From June 2004 continuous recording was possible during the periods when observers were present at the platform and from September to December 2004 every night from 17:00 pm up to 11:00 am the next day. The analysis of data was still in progress at the time this report was produced.

Microphone for automated sound recording on the platform. Photo: K. Krijgsveld

4.8 Nocturnal bird movements: moon watching

The moon gives opportunities to register nocturnal migration (Lowery 1966). Between four days before and four days after full moon, the moon is big enough to see silhouettes of birds passing the moon when using a telescope. Most birds have characteristic silhouettes, which allows a trained observer to identify them to the level of species group or even species. By means of calibrated calculations, developed by the Schweizerische Vogelwarte (1996), densities, flight altitudes and flight directions can be calculated based on the observed passages (number, size, direction) of birds across the moon. Using the position of the moon in the sky, the intensity of migration can be calculated based on the number of birds passing the moon disk. Flight altitude was calculated by classifying the size of the bird in relation to Tycho, a large moon crater visible in the southern section of the moon. Migration heading was calculated by registering in which sector of the moon the bird 'entered' and 'left' the moon-disk (by allocating clock-hours to the different sectors of the moon). Thus, a reliable estimate of migration at night could be, although restricted to clear nights around full moon.

Counts were made using a 20x telescope, which was aimed at the moon. Moon watching started 1 hour after moonrise. In observation bouts of 5 minutes, all birds passing the disk of the moon were registered. All observations were sent to the Schweizerische Vogelwarte, for analysis and calculation of flight density, altitude and direction.

4.9 Environmental data

Weather conditions may not only affect the numbers of birds present and their flight patterns, but also the probability with which the birds are spotted by observers or radar. Therefore, during observation periods on MpN, several aspects of weather conditions were recorded (table 4.4).

Table 4.4 Description of weather variables recorded hourly at MpN.

variable	description
cloud cover	average coverage in x/8
sunshine	percentage of time visible
visibility	in km, in four directions
precipitation	intensity and duration
wind	wind speed and direction
sea state	wave height and direction

The latter two characteristics were derived from the automated data gathering system of the KNMI on MpN; the first four were recorded during visual observations every hour, when observers were present on the platform. These characteristics have a direct influence on the circumstances under which birds are observed. Especially wind, precipitation and sea state have an effect on the capability of the radar to record data. During strong winds, high seas or heavy precipitation, data sampling by the radar systems was interrupted automatically.

5 Data handling, analytical techniques and data availability

In this chapter we describe how data were processed and analysed to yield information on flight patterns. For example, here we describe what filters were used to reduce radar data to quantifiable bird records, and what distance and altitude limits were maintained in the panorama scans and sea watches. We also list, at the end of each paragraph, the quantity of data that was collected with each method. Each observation method is dealt with in a separate paragraph. We start with the analysis of flagged data and the possibilities to assign species ID's to the recorded radar data in §5.1. In §5.2 and §5.3 we describe how vertical and horizontal radar data were processed and analysed. The analyses of the various visual observation methods (panorama scans, sea watches, etc.) are dealt with in §5.4 through §5.7. In §5.8 we describe how and why the species that were observed around the platform were clustered in different groups, for analysis.

5.1 Flagged radar data: assigning echoes to birds and species

Summary of the paragraph
Recorded echoes were identified in a flagged subset of the main database to allow assignment of species name or type of object (ship, bird, clutter) to recorded objects in the main database. Regression trees were used to find differences between different types of echoes recorded (§5.1.1-5.1.3). Large amounts of clutter made it necessary to focus on differences in echo characteristics between clutter and birds. In both vertical and horizontal radar, differences between species or species groups could not be established. Flagged echoes of the vertical radar differed in altitude, distance from radar and reflectivity, but did not provide reliable rules to differentiate between birds and clutter (§5.1.4). Instead, clutter was removed from the vertical database through analysis of the entire databasee (§5.2.2). Flagged echoes of the horizontal radar differed in length of the track and quality of the track (consistency with which an object is seen in each scan) and size of the echoes. Of the flagged echoes, 98,8% was classified correctly as birds on the basis of one variable, namely the number of echoes per track (5.1.5).

General
To continuously collect data on quantities, altitudes, flight directions etc. of birds flying in the study area, a horizontal and a vertical radar were used from which echoes were. Echoes received by these radars were stored in a database. The radars were equipped with software that was designed to distinguish bird echoes from other types of echoes, such as ships and sea clutter (echoes resulting from radar energy reflected by waves), but this filtering is not 100% foolproof. The database therefore still may contain an unknown proportion of echoes that do not pertain to birds, but to sea clutter or objects other than birds. It is of importance to be able to distinguish these echoes from those of real birds, to get a clear picture of bird movements at sea.

The radar equipment records and stores bird echoes, not data of identified birds, and thus provides information of overall bird flight activity without partitioning this into flight activity of different species or species groups. To be able to do this, echoes of different species must have differing characteristics, which enable them to be separated *a posteriori* in the echo database. In each record in the echo database, a fairly large number of characteristics of each echo are stored. In theory, these may allow species or group recognition, but if they really do in practice will depend on how much within-species variation and between-species overlap in echo characteristics there is.

Determining the characteristics of different bird species' radar echoes and those of non-bird echoes (ships, clutter) requires a training set, a dataset of stored echoes of which the bird (or other object) to which they pertain has been identified with certainty. These training sets have been assembled during fieldwork at Meetpost Noordwijk. During 'flagging' sessions (see §4.3), bird observers outside and radar operators inside the Meetpost were in radio contact, so that the position of echoes could be explained to the observers and the relevant birds picked up visually and identified.

The resulting 'flagged' data were analysed to see how much echoes of different species differed from each other and if they could be used for *a posteriori* species identification. In this chapter we present the result of the analysis of the flagging data for the horizontal and vertical radar.

Occurence of sea clutter in the database

The flagging method was designed to differentiate between echoes of the various species and/or species groups of birds, which means that observations were aimed at collecting data on as many different species of birds under different weather conditions and spread out over the entire research period. Although other objects were seen by the radar, such as ships and waves ('clutter'), the Merlin software was designed such that these objects would be filtered out from the database. This would make flagging of ships and clutter unnecessary. However, in the course of the study it became evident that large amounts of clutter and also ships were stored in the database. Thus, the flagged data had to be used not only to differentiate between echoes of various bird species, but mainly to differentiate between records of birds versus those of clutter and ships. This complicated the classification analysis, because the flagging-database contained only low numbers of flags of clutter and ships, unevenly distributed over weather conditions.

5.1.1 Preliminary analyses

In a previous report (Wiersma *et al.* 2005) we tested several statistical methods to explore the data and to extract classification rules from the flagging data set. The methods tested were nonmetric multidimensional scaling (nMDS), discriminant analysis (DA) and classification trees (CT). On the basis of the results the tree method appeared to be most successful in distinguishing between the different groups of echoes. In this paragraph we will report on the use of classification trees to extract limits or rules with which the recorded echoes can be classified into relevant species groups or into birds versus clutter from waves and ships.

To be able to distinguish between different groups of birds in the data, the characteristics of each echo image that were recorded by the two radars need to be different to a certain degree. Most preferable, the groups do not overlap at all, since this would make it easy to classify the echoes (eg., fig. 5.1). However, in practice variables do overlap, making it difficult to assess whether a certain observation concerns a bird or a wave, for example. Therefore we can use observations on multiple variables to a) give us the most important variables that b) give us the most optimal separation into the groups that we have defined a priori.

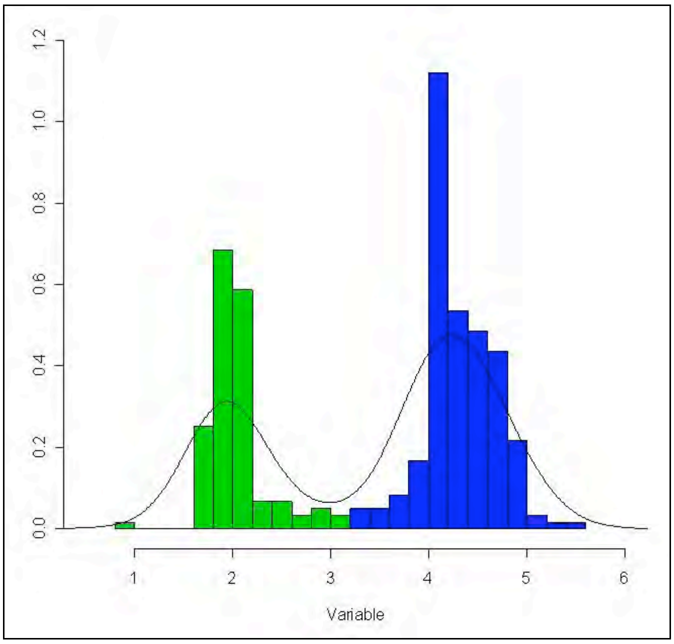


Figure 5.1 The preferable condition in which 2 groups do not overlap for a certain variable. The figure shows a density distribution for two groups with number of observations as density shown on the y-axis.

To be able to use echo characteristics to identify species, the variables need to give a good resolution over their range. Contrary to the example given in figure 5.1, many variables had distributions that were not symmetrical around the mean (fig. 5.2). This was undesirable in view of some of the analyses which should be performed on data that have reasonably normal distributions (eg. Correlation analysis). Consequently, the variables needed to be transformed to reduce this skewness and make the data approximately normal (fig. 5.2). Most variables showed more symmetrical distributions when $\log_e$ or square root–transformed. In the remainder of this chapter variables that had to be transformed are preceded by ln or sqrt to indicate whether they had been log or square root transformed in the analyses.

We used classification tree analysis on the flagged data set that was collected using radar signals while the birds or other objects creating these signals were simultaneously identified by observers on the platform. In this way a set of data was collected of which for each image was known exactly if the echo belonged to a certain bird species or whether it was just noise, ships, helicopters or planes. Using classification trees we investigated what echo characteristics were most important in distinguishing groups and with what settings (limits) of the variables the optimal separation could be obtained.

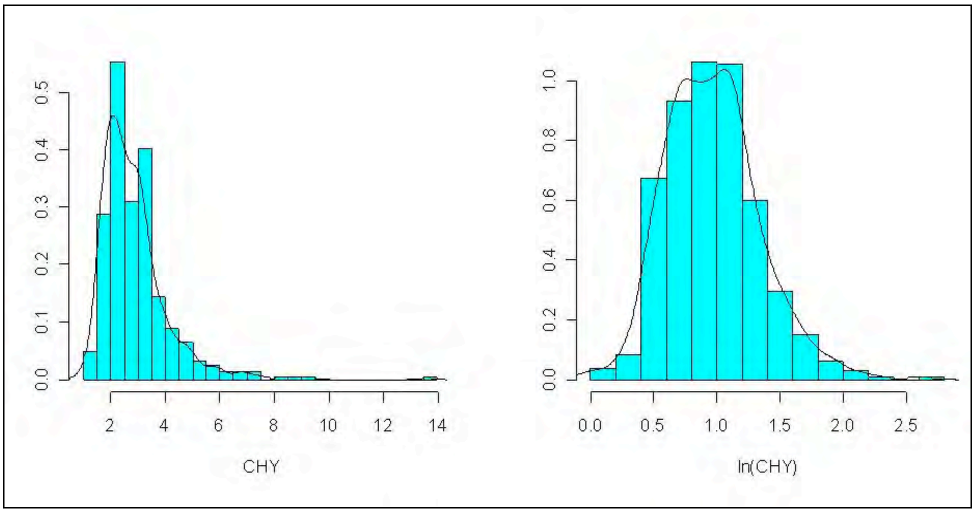


Figure 5.2 Result of transformation (natural log) of the variable CHY. Clearly the resulting density histogram is much more symmetrical around the median value.

5.1.2 Classification tree analysis: theory

Classification trees are part of 'classification and regression trees' (CART). They are used to explore the relationship between one response variable and multiple explanatory variables (De'Ath and Fabricius 2000). Tree models often appear to deal better with non-linearity and interaction between explanatory variables than regression, GLM and GAM models. Hence, they can be used to find interactions that were not discovered by other methods. They also indicate which explanatory variables are more important and are not influenced by correlated variables (they simply choose the one that gives the best separation of the data). Classification trees are used for the analysis of a nominal response variable, and regression trees for a non-nominal/numeric response variable. With classification trees no transformation of the data is necessary (this in contrast with Discriminant Analysis).

Consider a matrix with echoes as rows and variables (*i.e.* echo characteristics) as columns, so each row consists of the characteristics that are measured for one track or echo. The classification tree tries to assign each case (*i.e.* row) to one of the predefined groups (for example birds, clutter and ships) based on a certain value from one of the variables that maximizes variation between the groups while minimizing the variation within each group. This splitting of the data into groups continues until all data are assigned to the predefined groups or a certain value for the splitting criterium has been reached.

A classification tree can continue splitting the data till in theory only one observation remains in each leg/leaf of the tree. How does one obtain the best number of leaves (and therewith the best set of variables)? This is called pruning the tree, which is accomplished by cross-validation. The tree algorithm applies cross-validation by splitting up the data in k (typically k=10) subsets. Each of these k subsets is left out in turn, and a tree is calculated for the remaining 90% (if k=10) of the data. Once the optimal tree size and tree is calculated for a given complexity parameter (cp) value using the 90% subset, it is easy to determine in which leaves the samples of the remaining 10% belong; just use the tree structure and the values of the explanatory variables. We can calculate a residual (observed value minus group mean) and prediction errors (sum of all squared difference between observed values and mean values) for each sample in the 10% group. This process is applied for each of the k=10 cross-validations, giving 10 replicate values for the prediction error. Using those 10 error values, we can calculate an average and standard deviation. This entire process is then repeated for different tree sizes (and cp values) in a "back-wards selection type" approach. The average and the standard deviation are plotted versus the complexity parameter (cp) and the tree size (e.g., fig. 5.3). Along the lower x-axis, the complexity parameter (cp) is printed, and along the upper x-axis the size of the tree. The y-axis is the relative error in the predictions, obtained by cross-validation. The vertical lines represent the variation within the cross-validations (standard deviation). This graph is used to select the most optimal cp value. A good choice of cp is the leftmost value for which the mean (dots in fig. 5.3)) of the cross-validations lies below the horizontal line. This rule is called the one standard deviation rule (1-SE). The dotted line is obtained by the mean value of the errors (x-error) of the cross-validations plus the standard deviation (X-std) of the cross-validations upon convergence. However, tree sizes one larger or smaller should always be investigated to see if these give better distinction of the data as the one-standard-deviation-rule is only an aid and should be used with caution.

After the optimal size of the tree has been determined, the final tree is constructed by running the analysis one more time but now with the correct cp value.

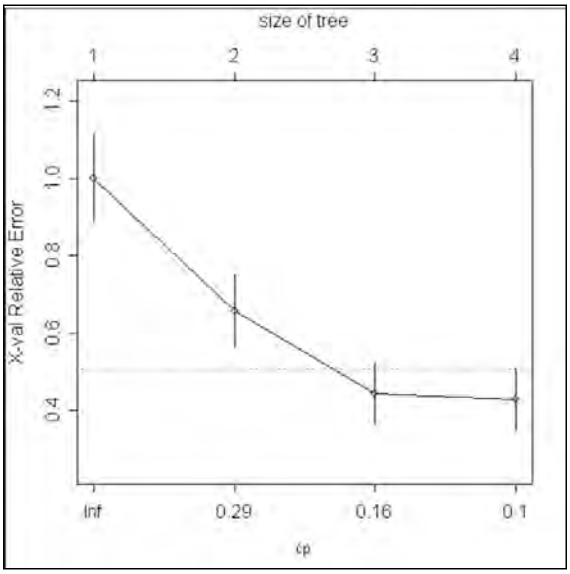


Figure 5.3 Cross-validation plot for vertical radar data. Plot suggests a tree of size 3, but size 4 gave a more optimal classification, so a complexity parameter of 0.09 was used in the construction of the final tree shown in fig. 5.4.

5.1.3 Variables and groups used

The variables and encodings from table 5.1 are used throughout §5.1.

Table 5.1 Variables (abbreviations) recorded for each echo and used in the analyses.

Variable	Description
EPT	Echoes per track
TKQ	Track quality: defined as STT/EPT
TKT	Track type: measure for the consistency with which the track was seen by the radar (see table 4.1 §4.2))
STT	Sum track type: sum of all TKT within 1 track
AVV	Average velocity of object based on all echoes of one track
VEL	Velocity of object
MXA	Maximum echo surface area (in pixels) of all echoes belonging to one track (only for data from horizontal radar)
AREA	Surface area of the actual target in pixels
MAXREF	Maximum reflectivity of the maximum reflectivities of all echoes in a track
MINDIST	Minimum distance (m) from the radar to the target in a direct line
DIST	Distance (m) from the radar to the target in a direct line
BEAR	Bearing from the radar to the target
HEAD	Azimuth heading of a tracked target (0 - 359 degrees)
TRKDIS	Distance covered by the whole track
MAXSEG	Longest length across the target in pixels
PERI	Perimeter of the target measured in pixels
ORIENT	The angle of the longest axis of a target with respect to the horizontal axis. This value is between 0 - 180 degrees.
ELLMAJ	Length of the major axis of an ellipse that has the same area and perimeter as the target
ELLMIN	Length of the minor axis of an ellipse that has the same area and perimeter as the target
ELLRATIO	Ratio of Ellipse Major to Ellipse Minor
ELONG	A measure of the elongation of a target, the higher the value the more elongated the target
COMPACT	Ratio of the target's area to the area of the smallest rectangle
HEYW	Ratio of the perimeter of the target to a circle with the same
HYDROR	Ratio of target area to it's perimeter
WADDEL	Diameter of a circle with the same area as the target
AVINT	The mean length of segments along the length of a target
MAXINT	The length of the longest segment of an echo, in any direction
CHX	The mean length, in pixels, of the horizontal segments of a target
CHY	The mean length, in pixels, of the vertical segments of a target
AVREF	Average reflectivity over the entire target area
MAXREF	Maximum reflectivity over the entire target area
MINREF	Minimum reflectivity over the entire target area
SDREF	Standard deviation in reflectivity over the entire target area
RREF	Range in reflectivity over the entire target area
CTM	Cross-track distance in meters. Distance in meters along the surface of the water or ground that a target is away from the radar.
ASLm	Altitude of echo in m above the sea surface.

Variables that are highly correlated do not add much additional information because the information that is presented by one variable is paralleled by the values of the other variable. In appendix 3, a table with correlations between variables is given.

The conclusion from this table is that variable AREA is higly correlated with many other variables (PERI, ELLMAJ, ELLMIN, HYDROR, WADDEL, AVINT, MAXINT) and these variables are obviously also more or less correlated with eachother. Another apparent high correlation is between variables that are related to the reflectivity of the echo image (AVREF, MAXREF, RREF). For Discriminant analysis highly correlated variables should not be used, but for tree analysis this is of minor importance because the analysis chooses the variable that best classifies the data into the different groups.

5.1.4 Vertical flags

Data available

In table 3.1 an overview is given of the periods during which flagging observations were carried out at the observation platform MpN. These flagging observations were continued until June 2004. The number of recorded flags available for analysis is presented in table 5.2. Due to malfunctioning of the vertical X-band radar or extreme cluttering of echo signals by high seas, no vertical flags could be obtained during the first observation periods. Since the horizontal radar was functioning most of the time, more horizontal than vertical flags were obtained.

The vertical flagged data consisted of 478 cases of birds, clutter and ships (for the tree in which we tried to classify more species we had 498 cases).

Table 5.2 List of birds and other objects flagged on the vertical radar.

species group	total
Black-backed Gull	186
Common Gull	23
clutter	51
Cormorant	15
divers	20
helicopter	4
Herring Gull	35
passerines	5
ships	39
terns	45
unidentified large gulls	66

With the data of the vertical radar, pre-analysis filtering was carried out which removed all the clutter at sea level (see 5.2.1 and 5.2.2). The tree analysis gave a cross-validation result as shown in figure 5.3. The minimal tree size resulting from the cross validations was given as a tree with three terminal nodes at a cp-value of 0.16. However, several analyses at lower cp-values gave a better score of correctly classified cases with the best classification at a tree size of 4 leaves (fig. 5.4).

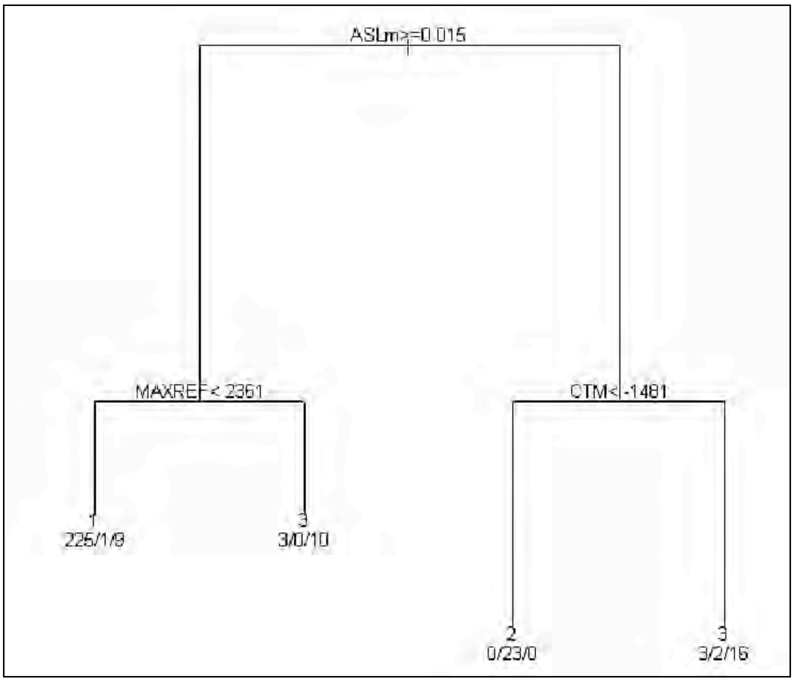


Figure 5.4 Tree for vertical flagged data using a cp-value of 0.03 resulting in 6 end nodes. If condition is true, follow the left branch. Classes used in the tree are: 1= birds, 2=clutter, 3=ships. ASLm, altitude in meters; CTM, distance in meters along the surface of the water that a target is away from the radar; MAXREF, Maximum reflectivity over the entire target area.

The tree starts by splitting the values that have an altitude higher or smaller than 0.015. Basically, the right leg of the tree (data with altitudes lower than 0.015m) contains only ships and clutter, and 3 (groups of) swimming birds. The clutter in this leg is distinguished from ships by CTM<-1481 (cross-track distance between radar and object), which might be due to selection by the observers. Other explanatory variables that can be used instead of CTM are MINREF>480 or RREF<810. When RREF (Range in reflectivity) is used the consequences for the birds in the right leg are that there is only one bird left now, but 3 ships are classified elsewhere. Using MINREF no more birds are classified in this node, but there are 4 ships missing.

If we exclude all the echoes with very low altitude and concentrate on the left part of the tree, the next important variable is MAXREF(maximum reflectivity of the entire target area). At values smaller than 2361 most echoes are birds while at larger values most are ships. The tree analysis also indicates other variables that give similar results: Ships can also be classified by EPT (>15), STT (>24) or AREA (>180).

5.1.5 Horizontal flags

In total there were 10,367 observations of 'flagged' radar echoes, but many were on the same object (shorter or longer trails). Because echo characteristics within these trails were strongly correlated, using all echoes would introduce massive pseudoreplication in the analyses and overestimate the potential to distinguish different echo types, we made a selection to obtain one single echo observation for each object (see §5.3.1). This resulted in a file with 1073 object observations (table 5.3). An object consisted of a single echo or a group of echoes.

Table 5.3 List of birds and other objects flagged on the horizontal radar.

group	species	nr flags
alcids	Guillemot	8
	Razorbill	6
	Razorbill/Guillemot	10
divers	diver spec.	26
	Red-throated Diver	4
gannets	Northern Gannet	9
cormorants	Great Cormorant	4
sea ducks	Common Scoter	15
	Eider	9
other ducks	Red-brested Merganser	2
	Common Shelduck	1
	Eurasian Wigeon	3
	duck spec.	1
geese & swans	Bean Goose	6
	Greylag Goose	6
	Pink-footed Goose	1
	Barnacle Goose	2
	Dark-bellied Brent Goose	3
	Greater Canada Goose	1
	goose spec.	14
skuas	Great Skua	1
gulls	Common/Herring Gull	10
	Great Black-backed Gull	112
	Herring Gull	186
	large gull	60
	Lesser Black-backed Gull	29
	Black-headed Gull	8
	Common Gull	75
	Kittiwake	136
	small gull	8
	gull spec.	19
	Little Gull	13
terns	Common/Arctic Tern	16
	Sandwich Tern	5
waders	Eurasian Curlew	2
	Homing Pigeon	1
landbirds	Starling	5
	Meadow Pipit	2
ship	large motor vessels	50
	motor vessels	7
	sailing vessels	12
clutter	clutter	110
	clutter air	75

Group size

Because there were much more data available from the horizontal radar we also investigated whether there was an effect of groupsize and distance on the different echo characteristics. The echoes were assigned to three groups of different size: between 1-10, 11-100, and 101-1000 individuals. For each echo characteristic an analysis of covariance (ANCOVA) was carried out to investigate if a)there is an effect of distance, b) this effect is similar for the three groups and c) if groupsize affects the characteristic under investigation. Figure 5.5 shows the results for lnArea. There is a lot of variation in the data and the three regression lines do not differ significantly (p = 0.45). The ANCOVA indicated that distance has a significant effect (p = 0.004) on lnArea and that the three group sizes differ significantly when corrected for differences in distance (p < 0.001). However, the amount of explained variation is only 0.05 (5%) which is very low. This is likely due to the fact that there are different species used in this regression, but because we do not know before hand which species we are investigating we can not use this information. Table 5.4 gives results for other variables that are either related to size (Perimeter and Maximum number of segments) or to reflectivity. In all cases there is much variation in the data and the slopes for the three group sizes do not differ significantly from each other. The regressions however are in 4 of the 7 cases significant indicating an effect of distance. This effect is mostly small. Group size appears to have a significant effect in the variables that are related to the size of the target but not to those related to reflectivity.

In conclusion, there is proof that distance and group size affect some of the echo characteristics. Further analyses that were aimed at discovering how echo characteristics could be used to predict group size and group membership were inconclusive. Therefore we decided to concentrate on distinguishing different groups from the flagged data set irrespective of group size.

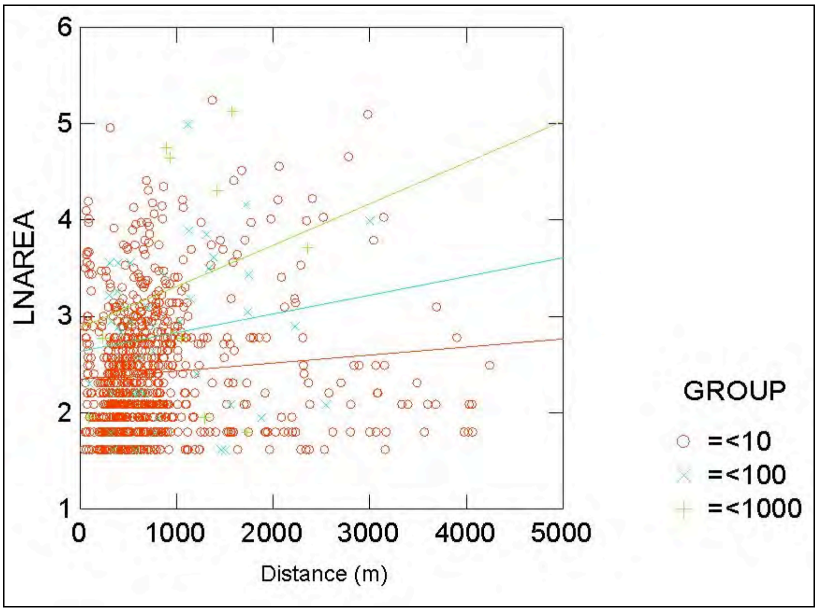


Figure 5.5 Effect of group size and distance on lnArea as measured by the horizontal radar. Results show that lnArea increases with distance and group size.

Table 5.4 Results of ANCOVAS for different echo characteristics.

characteristic	slope	regression	groups	R^2
lnArea	0.454	0.004	<0.001	0.046
lnPeri	0.141	<0.001	<0.001	0.050
lnMaxseg	0.429	0.300	<0.001	0.026
lnMaxRef	0.814	<0.001	0.065	0.107
lnMinRef	0.902	0.570	0.784	0.001
lnAvRef	0.147	<0.001	0.915	0.069
lnSdRef	0.623	0.296	0.224	0.004

Classification tree analyses

Much of the clutter that was flagged, was recorded in only a few days. This bias may have led to a reduced variation in characteristics of clutter-echoes. Also all distance measures were not randomly collected, due to observational restrictions. Meteorological data (e.g., wind direction, wave height) were strongly correlated to different types of echoes. These could however not be used to differentiate between the various groups of echoes, mainly because not all whether conditions were included in the database. Because of these restrictions, we adopted a different procedure to select variables for constructing the tree. First, one-way ANOVAS were calculated to find variables that best distinguished between the four groups (clutter in the air, clutter from the water, ships and birds). The variables that varied most for these four groups were:

- Echoes per track (EPT),
- Minor axis length of ellips (ELLMIN),
- The length of the longest segment of an echo) (MAXINT),
- Maximum of the maximum reflectivities of all echoes in a track (MAXREF),
- The mean length of segments along the length of a target (AVINT),
- Range in reflectivity over the entire target area (RREF)

Using these variables a number of tree analyses was performed (fig. 5.6). The cross-validation plot was unclear, possibly because the Number of Echoes per Track had a very large effect on the amount of variation that could be explained. In fact the cp-plot suggested a tree that would only use this variable in which case all clutter could successfully be removed, but all ships would be classified as birds. The final tree was calculated with a cp-setting of 0.022 and has 9 end nodes (fig. 5.7). The length of the tree branches after the first split indicates that the variable Echoes per Track explains a very large amount of the variation in the data. Below (table 5.5) the percentages of echoes correctly assigned to a group (classification scores) are given.

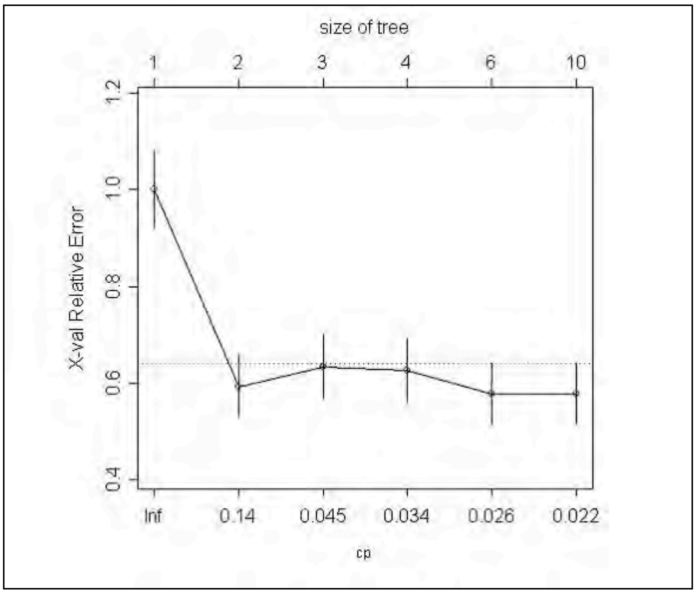


Figure 5.6 *Cross-validation plot for horizontal radar data. Plot suggests a tree of size 2, but the plot is rather inconclusive. Several other cp settings were used resulting in the final tree with a setting of the complexity parameter of 0.019 which was used in the construction of the final tree shown in figure 5.7.*

Table 5.5 *Classification score (percentages of echoes correctly assigned to a group) for tree of horizontal flagged data.*

	sea clutter	air clutter	ships	birds
% correct	88.5	62.2	29.4	99.6
total number	52	37	34	536

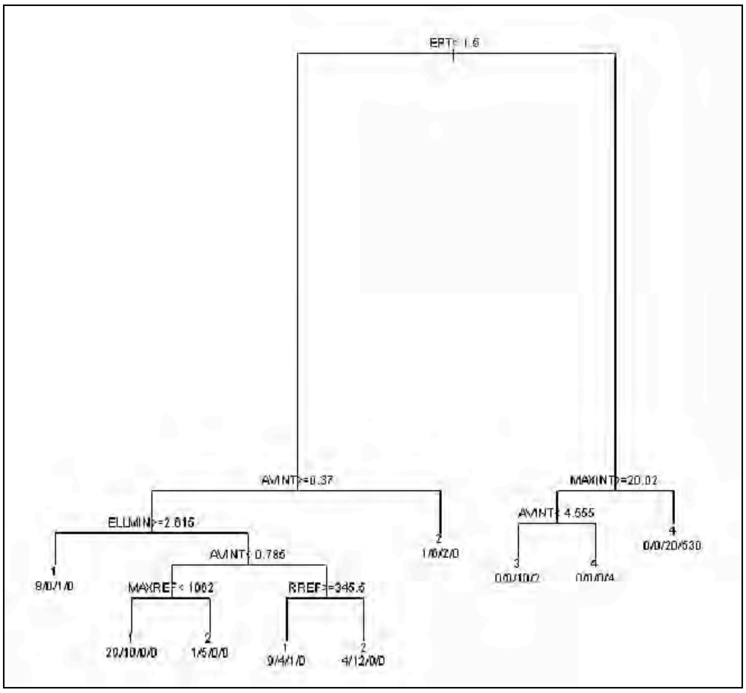


Figure 5.7 Tree for horizontal data using a cp-value of 0.022 resulting in 9 end nodes. If condition is true, follow the left branch. Classes used in the tree are: 1, Birds; 2, Clutter; 3, Ships. For meaning of abbreviations see table 5.1.

The tree indicates that the first split should be to separate clutter from the rest by using the rule EPT<1.5. The result is that 98.8% of all birds are correctly split off. However, Echoes per Track are not recorded in real numbers, but in integers. How many echoes per track should we use as a limit? For the flagged data, all birds had an EPT of 1, but this is not representative and it is probably better to use estimates based on the variation of the data. In figure 5.8 the limits for the echoes per track are given on the basis of estimates for the mean number of tracks and the 95% confidence limits. From this graph it is clear that it is impossible to separate ships and birds on the basis of the Number of echoes per Track, however, on average most clutter can easily be removed by taking a value for echoes per track of 2. This may remove a very small portion of the ships in the sample, but it is certain to retain all birds while excluding most of the clutter. Below other (surrogate) variables are described that can be used to filter clutter, but these are less successful. They are given in order of decreasing accuracy.

Surrogate variables for Echoes per track are STT(<7.88), MXA (<9.41), and a combination of TKT and TKQ (resp. >2.5 and >2.95). For STT, Sum track type, a lower limit of 7.88 (lower 99% confidence limit of ships) below which most data will be clutter with as good as no birds (99.9% estimated range of STT for birds lies between 17 and 21). Another filter that may be used is MXA, the maximum echo area (in pixels) of all echoes belonging to one track. Below a value of 9.41 (upper limit of 99% confidence limit for Clutter Air) most data will be clutter.

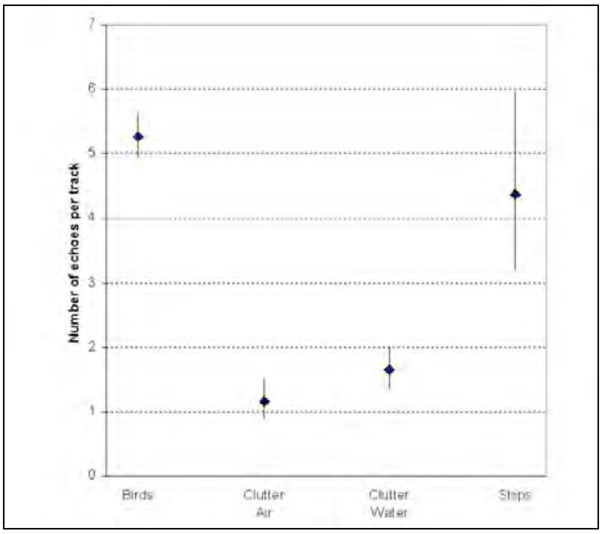


Figure 5.8 Mean (geometric) for Echoes per Track (including 95% confidence limits) for birds, air clutter, sea clutter and ships.

If the number of echoes per track is not used, a combination of track type and track quality can be used with a setting for track quality of larger than 2.95 (95% lower limit for Clutter Sea) almost all clutter and many ships will be removed, especially when combined with track type>2. As we are not interested in distinguishing between different forms of clutter we will focus below on ways to separate the remaining ships from birds.

For the distinction between ships and birds MAXINT (length of the longest segment of an echo, in any direction) and AVINT (mean length of segments along the length of a target) are the main variables (fig. 5.7) to separate ships and birds after all the clutter has been removed. MAXINT<20 results in mostly birds and AVINT>4.55 separates birds for which MAXINT>20 from ships. However, there is some overlap between ship and bird values in the right branch so that it appears impossible to separate all birds and ships. Variables that one might think very different between birds and ships are average velocity (AVV) and maximum area (MXA), however these do overlap considerably and do not provide a satisfying way to separate the remaining ships from birds. On average the maximum area of ships is larger than for birds and the estimated 99.9% confidence limits around the means do not overlap, but in the flagged data set there is considerable overlap between data points (fig. 5.9). The same is true for velocity or any other variables. On average one could use the lower 95% limit of the Maximum Area of ships which is 44.5. Anything above this limit should on average highly unlikely be a bird. However, as can be seen in figure 5.8, there are a considerable number of birds in the flagged data set that have a maximum area larger than ln(44.5) = 3.8. Verifying the estimated height or other variables from the tree analysis of the vertical radar data on the same objects may provide a way to separate birds and ships, but one would need to connect objects from both radars.

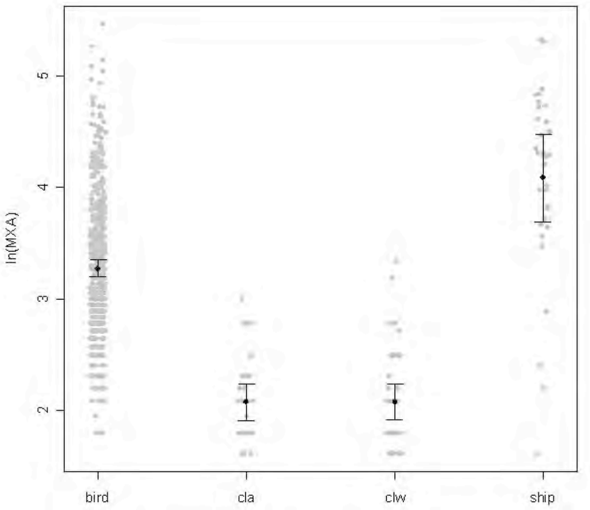


Figure 5.9 Mean maximum area (MXA, ln-transformed), 99%-confidence limits and individual data points.

Can different groups of birds be discerned?
We tried to classify bird and the ship observations by tree analysis using groups with more than 10 observation. The groups used were alcids (11 observations), divers (22), geese & swans (27), gulls (412), sea ducks (18), ships (34), and terns (16). The tree cross-validation did not give a satisfying picture (fig. 5.10) indicating severe overlap of the different groups. Several tree analyses at different cp-values therefore did not render a very satisfying tree and the tree that was finally chosen was only able to distinguish between divers, geese and swans, gulls and ships (fig. 5.11). The percentages of the flagged data that were correctly classified were respectively 18, 52, 100 and 65. However, from the tree no clear picture emerges: ships sometimes split off from gulls by average velocity (AVV), perimeter (PERI) or area (AREA). Within the birds not much distinction is possible. Most birds are thrown together in the upper left branch of the tree (AVV>=26, 412 observations). Velocity is used to separate some divers from geese and swans (VEL<48.5 splits off 18% of the divers and on the other side 40% of the geese and swans). In conclusion it appears impossible to reach satisfying rules for echo characteristics of birds that can be used to classify birds into different groups. Possibly that the effect of groupsize introduces extra variation by which it becomes impossible to distinguish the different groups of birds.

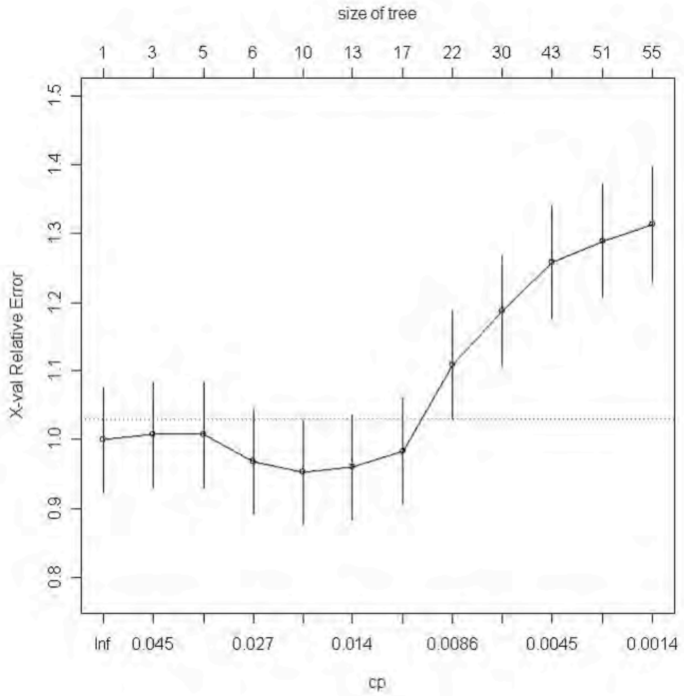


Figure 5.10 *Cross-validation plot for horizontal radar data using different bird groups (alcids, divers, geese & swans, gulls, sea ducks, terns) and ships. The plot is inconclusive since it does not level off. This indicates that no satisfying tree can be reached.*

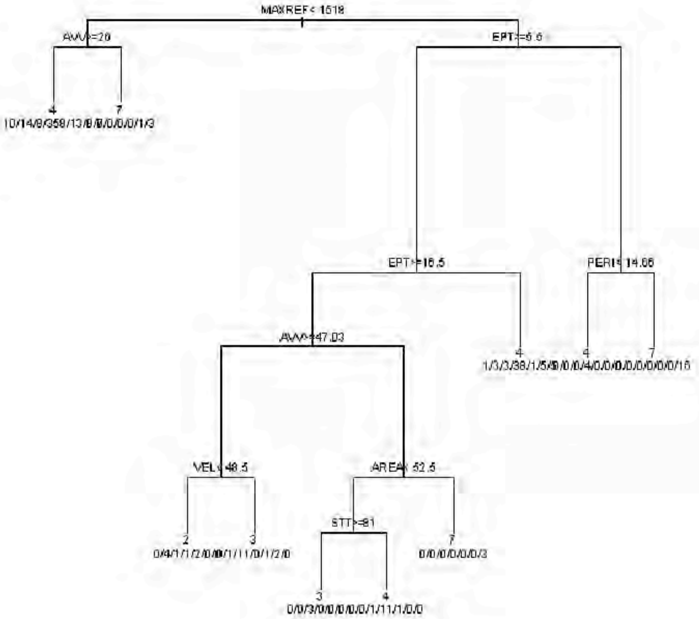


Figure 5.11 *Tree for horizontal data using a cp-value of 0.019 resulting in 10 end nodes. If condition is true, follow the left branch. The numbers in the graph are the number of observations in the 7 subsequent classes being: 1= alcids (11 observations), 2=divers (22), 3=geese & swans (27), 4=gulls (412), 5=sea ducks (18), 6=terns (16), 7=ships (34).*

5.2 Vertical radar

Summary of the paragraph

Data recorded with the vertical radar covered the study period in scattered intervals due to technical problems. For analysis, data were reduced to 1 record per track (§5.2.1). Clutter from waves was recorded in large quantities at the lower altitude ranges, up to 1,7 m above sea level. Above this altitude, 'noise' still made up a significant part of the data. This clutter was removed from the dataset as much as possible through analysis of patterns in the data. This way, 64% of the records were removed from the database (§5.2.2, see also analysis flagged data §5.1.2). Although some clutter will still have occurred in the cleaned dataset, the majority of the remaining data belonged to birds, as became evident in the subsequent data analysis (chapter 8). Data served well to establish flight altitudes and fluxes of birds, both at night and during day.

5.2.1 Processing recorded data

Data selection

Each object is recorded several times, depending on the length of time the track is detected by the radar. Records of the same object are recognisable as they share the same trackID. For purpose of analysis of fluxes and flight altitudes, the radar data were reduced to 1 record per track. Each track is characterised as belonging to the same object. This was achieved by selecting, from each track, the record in which the object had the maximum size (*i.e.* area). Size of an object is maximal when it is closest to the vertical radar. By selecting the record with the maximum size, we selected the record which is in the centre of the beam, and which thus gives the most accurate measures of position.

Sea clutter and flagging

Sea clutter (*i.e.* recorded waves) formed a large percentage of the recorded data. This clutter was confined to the lowest altitudes, at and just above sea level. In addition, a large amount of clutter was recorded at all altitudes, resulting from, among others, interference with other radars. The range at which the radar was measuring was set to 1,5 NM for the majority of the measurements. According to the manufacturer, using this range has led to an increased amount of clutter in the data, because software to remove interference was developed for a setting of 0,75 NM. Due to the large quantity of clutter in the data, flight patterns of birds would become less distinctive and fluxes inaccurate (fig. 5.12). Flagging of birds on the vertical radar yielded unreliable results, and flagged data could not be used to distinguish between birds and clutter (see § 5.1.2). In the basis dataset of the vertical data, a large amount of clutter was recorded above the altitude at which the tree classified data as clutter (see fig. 5.12). The tree based on the flagged data set, thus did not perform well on the actual data. This may have been caused by the flagged data set being not representative. Using this classification tree, there was no means to differentiate between the clutter above 0.015 m and birds. This is due to the fact that initially the flagging data were collected to differentiate between bird species, not between birds and clutter. Consequently, we did not have enough data on clutter to adequately separate birds from ships and clutter.

To remove as much of the clutter as possible, we analysed patterns in echo characteristics and track frequency, as described below.

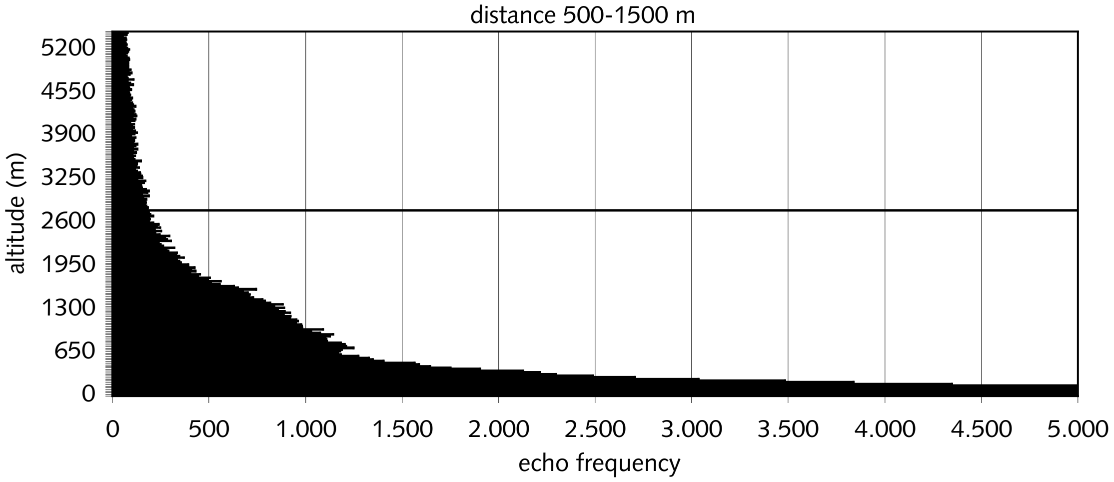


Figure 5.12 Frequency distribution for altitude classes of 25 m, of all echoes recorded by the vertical radar, including those of birds, clutter from waves and rain clouds, and interference.

5.2.2 Rules to remove clutter

Objects which were only recorded once and had a very poor track quality (*i.e.* track type =5) were removed from the data set as clutter. Only data measured at a rangesetting of 1,5 NM were used. All records at or below sea level represent sea clutter and were removed from the data set. The backlobe of the radar beam produced clutter up to 400 m from the radar (increased frequency of tracks). Consequently, all data within a range of 400 m from the radar were removed from the data. As software was set to record data within 1,5 NM, all records beyond this range were removed from the data. They showed clearly different values of echo characteristics such as track quality and - length, reflectivity, and frequency of tracks (fig. 5.13).

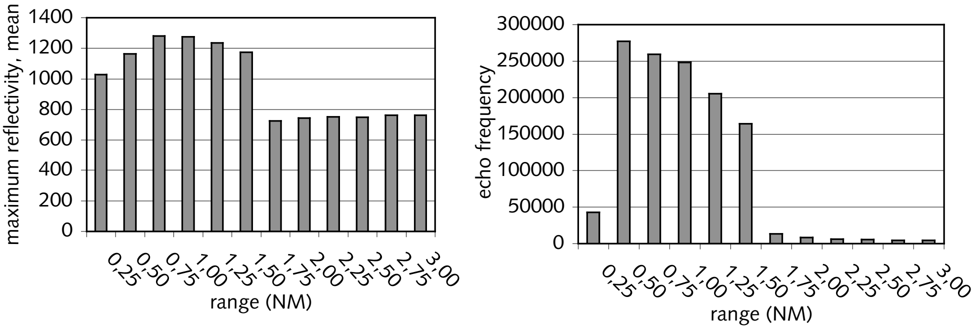


Figure 5.13 Change in characteristic (max. reflectivity) and in frequency of echoes within versus beyond the range of 1,5 NM measured by the vertical radar.

Waves were picked up readily by the vertical radar, creating a large amount of clutter in the database (figs 5.13 and 5.15). These waves were visible in the database as echoes at and just above sea level (fig. 5.14), being much more numerous than echoes at higher altitudes. Above 1,7 m above sea level the echo frequency dropped significantly, indicating that clutter from waves was mainly restricted to altitudes below 1,8 m. We analysed echo characteristics above and below 1,7 m, to differentiate between echoes from birds versus waves. This revealed that maximum reflectivity was higher in echoes from waves and track quality was lower (fig. 5.15). Tracks at or below 1,7 m and with a length of 5 echoes or less, had a lower maximum reflectivity than tracks above 1,7 m with a length of more than 5 echoes (fig 5.16). Tracks with a maximum reflectivity higher than 1500 were removed from the database as clutter. Likewise, tracks with a target quality higher than 2,2 were removed as clutter. Although this procedure did not remove all clutter and removed a percentage of bird-echoes as well, it was the best possible way available. Other characteristics such as range in reflectivity and mean chord length X did vary between echoes of clutter versus those of birds, but these could not be used as tools to remove clutter from the database, because no clear cut-off value could be determined to separate birds and clutter.

After applying the above filtering rules, in total 64% of records were removed: removing tracks with track quality>2,2 and max reflectivity>1500, reduced the database by 44%, removing tracks beyond 1,5 NM and below 1,8 m reduced the database by a further 35%.

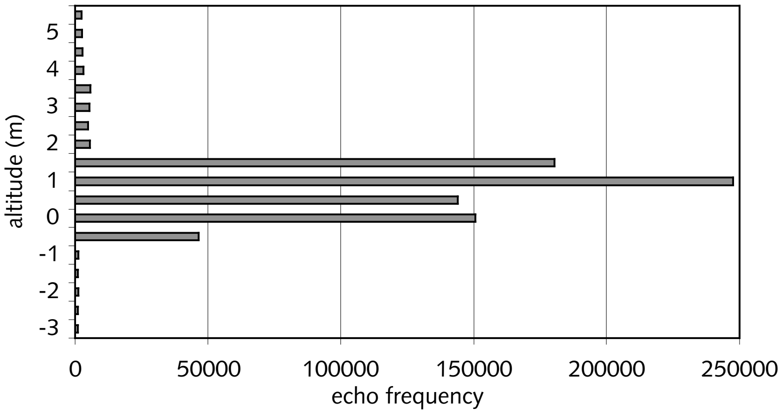


Figure 5.14 Frequency distribution of echoes in altitude classes of 0,5 m, measured by the vertical radar. Above 1,7 m frequency of echoes dropped abruptly, indicating clutter of waves was registered up to that altitude.

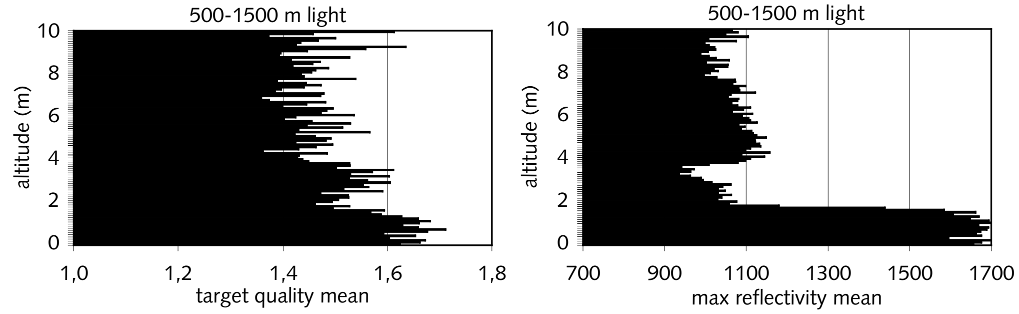


Figure 5.15 Mean target quality and mean maximum reflectivity of echoes at altitude classes up to 10 m. Both target quality and maximum reflectivity have lower values above 1.7 m.

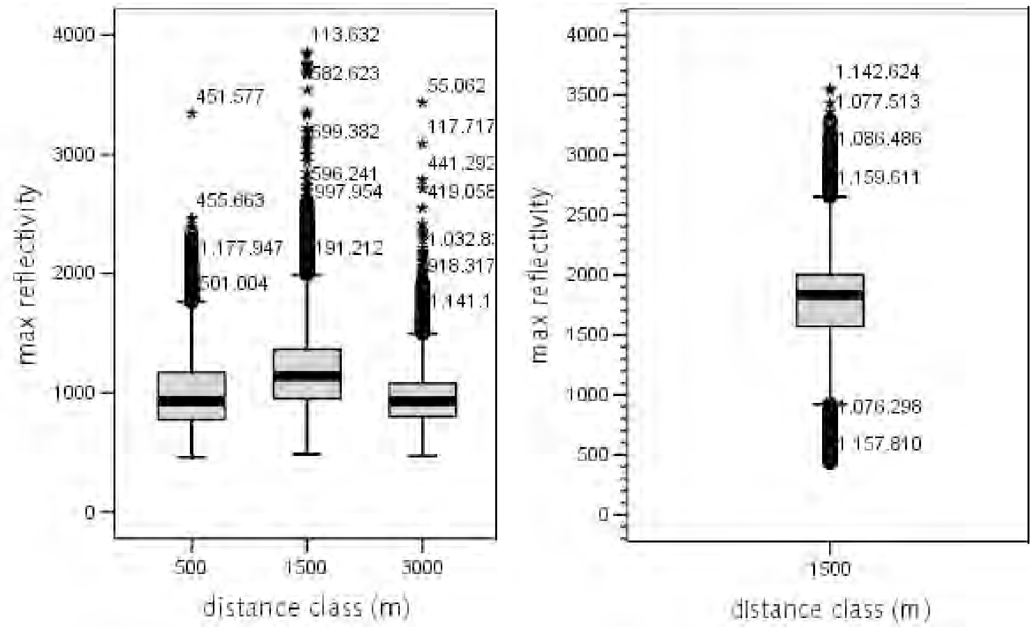


Fig. 5.16 Maximum reflectivity was lower in echoes above 1,7 m and with track sizes > 5, representing birds (left panel), than in echoes below 1,7 m and with track sizes ≤ 5 representing clutter (right panel), recorded with the vertical radar. Shown are median (horizontal line), 50% range (box), highest to lowest values excluding outliers (whiskers) and outliers (dots).

5.2.3 Data properties and availability

General

As radar does not distinguish between individual birds in a flock we use here 'bird flock' as unit of observation. A bird flock can exist of one individual bird, but also up to several tens or even hundreds of birds. Especially during the day and in the edges of the night birds can fly in dense flocks. In the night birds fly in more loose congregations, especially migrant passerines are known for a dramatic shift in flocking behaviour between day and night. The vertical radar was rotating in a perpendicular direction to the sea surface (fig. 4.2). The 'vertical radar', recorded bird flocks that flew through a virtual, vertical half-disc-shaped space. This setup enabled measurements of the altitudes at which bird flocks fly, and of the number of birds per time passing a vertical plane in west-east, and *vice versa*, direction, the so called flux. A bird passing the radar beam will usually be recorded several times, because the radar makes about one turn every 2,5 seconds. The radar system records these successive echoes as belonging to the same bird, and gives them identical track identification numbers. An echo track needs to consist of at least 4 successive echoes before being recorded at all. Only the first record of a track was used for analyses. Therefore, the results are based on single bird flocks and not simply on the amount of echoes recorded. Note that if a bird track was interrupted it was recorded as two (or more) tracks, in that way falsely inflating the data set. However, we do not have indications that this frequently occurred on the vertical radar as the majority of the track lengths were much longer than 4 successive echoes.

The radar was adjusted to record echoes maximally 2,8 km away in both horizontal directions and maximally 2,8 km above sea level. This resulted in records of trails originating from a square-shaped plane. Note that the plane is not really flat, but thin near to the radar and wider further away (see figure 5.17). During October 2003 the range settings of the radar deviated due to testing of the system. These data are not comparable with the other data and are omitted for further analyses.

Clutter

Radar reflections from waves, rain, snow, etc. may cause serious pollution of the dataset. The radar system was able to filter out a large part of this so called clutter, but nevertheless, clutter remained present. Mathematical analyses were used to filter out as much clutter (and ships) as possible. These methods are described elsewhere in this report.

Correction for detection probability

The radar beam shape somewhat resembles a flattened cigar (fig. 5.17). Close to the radar the beam is very narrow and it broadens further away. At the end of the detection range the beam quickly narrows again. Figure 5.17 shows the elliptic shape of the radar beam viewed from above. Because of this shape of the beam, the probability that a bird will fly through the beam is not equal at all distances. A bird that is very close to the radar has a higher chance of being missed by the radar than a bird further away. This effect is even bigger due to the obligation of measuring four consecutive echoes of a bird before being stored. Fortunately, we can to some extent correct for the varying encounter probability. For this we need to know the radar rotation time, the size and shape of the radar beam and the flight speed of the bird flocks (table 5.6). Knowing these parameters, we can calculate the chance that a bird will be caught by the radar beam when flying through its path.

Table 5.6 Parameters needed for correcting the recorded number of bird flocks for the varying encounter probability with distance from the radar.

Input parameters	value
radar rotation time	2,5 s
maximum detection range (Dmax)	2778 m/1,5 NM
beam angle (a, wide)	20°
beam angle (b, narrow)	1,5°
average speed bird	40 km/h

The beam width perpendicular to the rotation direction (diameter; figure 5.17) is calculated as a function of the distance from the radar (following van Gasteren *et al*. 2002). This is done using the formula shown below, incorporating the distance from the radar (D), the maximum detection range (D_{max}) and the beam angle (a) (see table 5.6):

$$beam\ width = 2*D*\tan[SQRT(2)*rad(a)*SQRT(-1*\ln(D/D_{max}))/(2*\ln(2))]$$

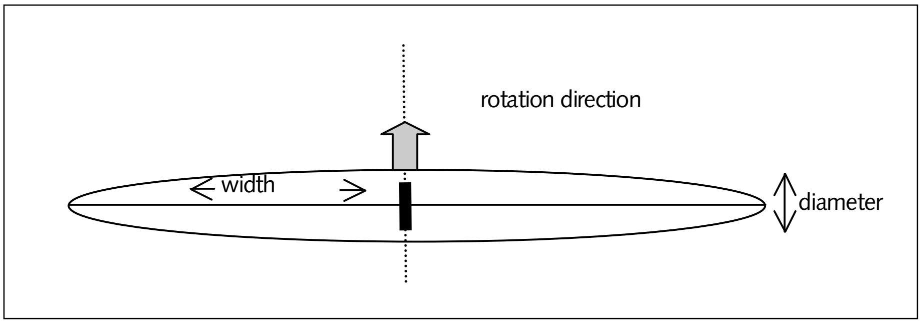


Figure 5.17 View on the radar beam from above with the beam pointing upward. The small black bar represents the turning radar bar/antenna (not the right scale). The width of the beam is defined here as the diameter of the widest part of the beam, and the diameter of the beam is measured perpendicular to the beam width. Beam width and diameter vary with distance from the radar. Ideally, fluxes are measured of bird flocks crossing the dotted line.

Knowing the beam width and the rotation time of the radar, we can assess the probability for a bird to be 'caught' in the vertical radar beam. For this we assumed an average flight speed (v) of 40 km/h and we assumed that bird flocks fly in random directions. This implies that the average speed vector in the direction perpendicular to the rotation direction is 0,5*v.

Because the bird flocks will not always pass the beam at the point where the beam has its maximum width, the average encounter probability will be lower. Assuming that bird flocks will enter the beam at a random point, the effective beam width would be *c*. 0,75 times the actual width, i.e. the average width (for bird flocks flying parallel to the rotation direction of the beam) and the mean width and 0 (for bird flocks flying perpendicular to the beam direction).

From the average flight speed and the effective radar beam width the time bird flocks take to cross the radar beam (CrossTime) at varying distances from the radar can be calculated.

The rotation time of the radar was 2,5 seconds, but because of the diameter of the beam there is a certain time span that the bird can be detected that depends on the diameter of the beam. This reduces the effective rotation time (RotationTime) to:

*((360 – (beam width/radar beam path*360))/360)*RotationTime.*

Radar beam path is the distance the beam travels making a full circle. Beam diameter and radar beam path depend on the distance from the radar. The ratio of the CrossTime and the RotationTime at a certain distance from the radar gives the number of detections by the radar of a bird at that distance.

The range of the radar was set to a maximum of 2778 m and this resulted in bird flocks flying closer than 40 m or further than 2778 m from the radar to be detected less than 4 times. Because only tracks of 4 successive echoes were included, numbers at very close range and far off will therefore be underestimated.

We conclude from this that the beam is at almost every distance wide enough to capture all bird flocks passing by. Therefore, corrections for differences in diameter related to distance to the radar will have only minor effects.

Note that this is an approximation because the maximum detection range, on which the shape of the effective radar beam depends, is dependent on the size and characteristics of the bird. Small birds will have a much smaller maximum detection range than bigger ones, and their numbers will therefore be underestimated at larger distances. In the data this effect was analysed by comparing flight patterns at different distance zones from the radar, and using only those distance zones in which detection did not play a role.

Data available

The vertical radar started functioning properly on October 22 2003. It soon became evident that the system was sensitive to strong winds. In November the radar broke down during a severe storm. Since then a new motor had to be installed on four occasions. The last repair was on October 15 2004 and the last motor crash on October 21 2004. Due to the sensitivity of the system to wind and its consecutive periods of break-down, data are not available consistently throughout the entire research period (table 5.7). Nevertheless, in all seasons, *i.e.* autumn, winter, spring, summer and late summer, data have been collected.

Scan days

Data were recorded during 126 days (excluding October 2003; table 5.7). During the other days the radar did either not function due to hardware problems, or due to strong winds generating too much clutter causing the radar to suspend data processing. The measurement days were divided into 4 seasonal periods, namely spring, late summer, autumn and winter (table 5.8).

Table 5.7 Total number of days on which at least one hour of echo data were recorded by the horizontal and vertical radar. Systems became operational on October 22 2003 and were shut down on December 6 2004.

		radar horizontal	radar vertical
2003	October	8	9
	November	24	8
	December	24	16
2004	January	25	0
	February	29	4
	March	31	0
	April	20	18
	May	28	31
	June	30	23
	July	10	0
	August	30	0
	September	29	10
	October	31	7
	November	30	0
	December	6	0
total number of observation days		355	126
total number of days		411	411

Table 5.8 Days and seasons during which the vertical radar was operational. The radar was not necessarily working during 100% of time on these days.

period	year	period in which operational		
autumn	2003	22 October	–	3 November
winter	2003	26 November	–	10 December
	2003	15 December	–	20 December
	2004	16 February	–	19 February
spring	2004	13 April	–	23 June
late summer	2004	2 September	–	11 September
autumn	2004	15 October	–	21 October

Altitudes

The radar recorded the distance and bearing of the echo, allowing calculations of the echoes height above the sea surface. The maximum detection height was 0,25 – 1,5 NM during October 2003 and 1,5 NM (2778 m) during the other days. Data from October 2003 were not used because of these deviant settings. Because differences in height could be expected during the day and the night, these periods are shown separately.

5.2.4 Comparison of bird numbers observed visually and by vertical radar

The most direct test of the performance of the radar system in detecting birds that was possible within this project, is a comparison between numbers of tracks observed by radar with numbers of (groups of) birds recorded during the panorama scans at (roughly) the same times.

When a field observer records a bird during the panorama scans it is certain that the bird was present, but the observer may miss birds that were present within the scanned area e.g. due to the distance (especially in the highest altitude band). The number of birds recorded in the panorama scan is thus a minimum estimate of the number present. The radar system may also miss birds that are actually present within the radar range (e.g. due to distance), but it may also 'generate' birds that are not present, e.g., when clutter is erroneously identified as a bird. The number of tracks recorded may therefore in practice be both an under- and an overestimate of the true number of birds present.

Method

If the radar works well, we expect a positive correlation between number of tracks recorded and number of birds (groups) seen in the scans. The relation does not have to have a slope of 1 (it is likely that the radar can detect small far-off birds better than the human eye), but it is expected that a linear relationship exists. Data from panorama scans reflect the number of birds at any moment, whereas data from the vertical radar give nr of birds passing in an entire hour. Thus, numbers from X-band will be far higher than numbers from panorama scans. Correlations however will not be affected by this difference.

To test the existence of a positive linear relationship, we selected all panorama scans for which tracking data from the X-band (vertical) radar were available from the same date and clock hour. This was the case for 219 panorama scans on 26 different dates scattered through the year. Data were selected from distances between 500 and 3000 m from the radar (the radar did not see closer birds well due to the abundance of sea clutter; observers do not see many of the birds further away than 3 km) and altitudes that fell within the altitude range covered by the panorama scans (the radar image extends much further upward but tracks recorded there were discarded). For the comparisons the radar data needed to be partitioned into matching distance and height classes. Height classes were calculated from the radar data using the distance and altitude according to the boundary values shown in table 5.9. For the panorama scans, we used both the total numbers observed in all (8) sectors of the scan, and the numbers restricted to the south- and north-looking segments that make up 4/8 of the scan area; these sectors extend in the same directions from Meetpost Noordwijk as the vertical radar disc, and should thus yield 'the same' birds. Both the total number of birds and the number of groups recorded in the panorama scans was used for comparisons; radar echoes may consist of either single birds or flocks.

Table 5.9 *Boundary values of altitudes measured by the vertical radar for classification into height and distance classes as used in the panorama scans.*

horizon	height class	upper altitude boundary (m)		
		distance class 1	distance class 2	distance class 3
1/2	1	7.8	10.8	6.7
	2	14.7	20.9	24.8
	3	21.5	41.1	73.5
	4	26.7	61.7	119.9
1/8	5 (3)	31.9	82.3	166.4
	6 (4)	38.8	109.8	228.3

Results

Figure 5.18 shows the results graphically; table 5.10 gives correlations between numbers observed visually and recorded by radar. When the data are evaluated at the level of separate scans, numbers of birds observed in the scans and with the radar are significantly and positively correlated (r=0.13-0.22). Correlations for number of groups were slightly higher than for number of birds. This is not surprising as a (tight) group will appear on the radar screen as a single echo, while it may consist of a variable number of birds. More surprisingly, the number of tracks recorded by the radar was slightly better correlated with the total number of birds seen in the whole scan than with the number in the N-S directed sectors. This may be due to random variability playing a larger role in only the N-S sectors than in the entire panorama scans. Overall however, it must be stressed that the correlations, although significant, are far from tight and the variation around any linear relationship is much too large to use the visual observations to correct the radar data for missed or erroneously identified birds (or vice versa).

One potential source of this large variation is severe and variable under-recording of birds by the visual observers. However, the panorama scan method has been extensively tested in the field, e.g. by double observation, and under-recording of birds seems to play a limited role only.

Consequences of flocking

Another potential source of variation is flocking of birds, as discussed above. Birds at sea tend to occur in flocks more often more during the daytime than at night, and thus at night the radar data might be somewhat closer to the true number of birds than in these comparisons which were necessarily all made during the day. However, the difference will be small as can be seen from table 5.10. A special case of flocking is the large concentrations of gulls associating with fishing vessels at sea. If such a concentration is present within the area scanned during the panorama scan but (just) outside the area covered by the vertical radar, a large discrepancy in recorded flight activity will result. Many of the observations of large bird numbers in figure 5.18 will be caused by such gull flocks. If the panorama scans with the largest numbers of birds (>10 flocks or >20 birds in the N-S sectors of the scan) are excluded, the correlations between visual and radar observations become notably stronger (r=0.23-0.28), indicating that this 'associated gull effect' indeed does play a role in our comparisons.

This effect may be particularly prevalent when comparing panorama scans with the vertical radar, in view of its restricted coverage in the horizontal plane. It may be less influential a comparison with the horizontal radar. However, we did not perform a similar comparison using the horizontal data, as it was clear beforehand that the horizontal data do not provide a good estimate of bird traffic rate, due to the fact that long tracks are often cut into several short ones by the tracking software.

Random variability

Although the above issues, detection and flocking, play a role both at the observer- and at the radar side, we believe that random variability is another reason for the lack of correlation of the two data sources. Panorama scans were carried out once every hour. In the study with panorama scans at the Pier van IJmuiden, no correlation could be found between two panorama scans within the same clock hour due to random variability of flight movements. In that study flight movements also mainly consisted of gulls flying back and forth in response to active fishing vessels.

Concluding

In conclusion, direct comparison between (near-) simultaneous visual and radar observations show that variation in the number of echoes recorded by the vertical radar does reflect variation in numbers of flying birds. However, there is large variation around the relationships and thus we cannot conclude that the radar data provide an accurate estimate of bird flight activity. On the other hand, the mean traffic rates estimated with the vertical radar generally are in the same order of magnitude as those observed with other techniques such as the panorama scans, sea watching and moon watching.

Table 5.10 *Correlations (r) and associated probabilities (one-tailed, expected r>0) between number of (groups of) birds observed in panorama scans and number of echo tracks recorded by the vertical radar in the same clock hours and within the same distance and altitude regions. Correlations are calculated for the entire datasets and after discarding scans in which more than 10 groups or 20 birds were observed in the North- and South-directed scan sectors (see text).*

	all data included		data restricted to max. 10 groups / 20 birds in N-S sectors	
	r	P	r	P
by separate scan (N=219)				
N birds in entire scan	0.22	<0.001	0.28	<0.001
N birds in N-S scan sectors	0.14	0.021	0.26	<0.001
N groups in entire scan	0.18	0.003	0.24	<0.001
N groups in N-S scan sectors	0.13	0.027	0.23	0.001

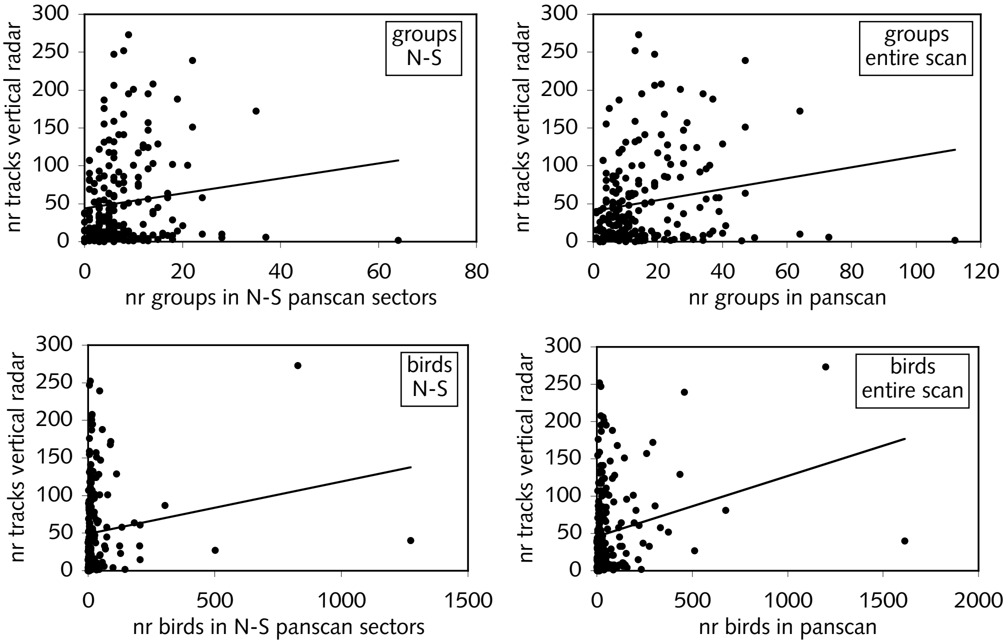


Figure 5.18 Relations between number of (groups of) birds observed in panorama scans (scan totals or numbers in the 4 N-S-directed sectors) and number of echo tracks recorded by the vertical radar in the same clock hours and within the same distance and altitude regions. For correlation coefficients, see table 5.10.

5.3 Horizontal radar

Summary of the paragraph

Data recorded with the horizontal radar covered most of the study period from October 2003 to October 2004. Only during periods with strong winds (several weeks in the winter period), data were not recorded. For analysis, data were reduced to 1 record per track (§5.3.1) Large amounts of clutter from waves were recorded, making up more than 85% of the recorded data. These 85% could be filtered out as clutter after analysis of the echo characteristics (§5.3.2, see also analysis flagged data §5.1.3). However, clutter still occurred in the remaining data, obscuring bird patterns. Data served well to establish mean flight directions and – speeds, both at night and during day. Tracks of birds were consistently split up and assigned to different birds, thus making it impossible to quantify flight movements on the horizontal radar (§5.3.3).

5.3.1 Processing recorded data

A large fraction of the echoes recorded with the S-band radar were echoes of waves (clutter) rather then of bird flocks. This is caused by the fact that water-rich bodies reflect the radar beam very well, and consequently waves moving across the sea surface are often recorded by the radar. Based on echo characteristics, a large part of this clutter could be filtered out of the data set (see $5.1.3).

Data reduction

For analysis of flight paths, data were reduced from several records per track to one record per track (see start of § 5.2.1). For the horizontal radar, this reduction was achieved by selecting, from each track, the records with the best track quality, and of those the record furthest away from the radar. By this procedure we selected the record with echo characteristics most representative for the object. Additionally, as clutter concentrated around the platform, choosing the record furthest away from the platform means selecting a record with values of echo characteristics least affected by background noise. This helps to distinguish between echoes of birds versus those of clutter. To visualise flight paths of objects, we used data of the entire track.

Tracks of flagged echoes

Flags of birds were made for the purpose of echo identification. These flags allowed us to visualise the tracks of these birds, belonging to various species, around the observation platform. This is depicted in the figures below (fig. 5.19). Naturally, these flagged tracks are concentrated around the platform (52,31 N; 4,35 E), as birds could not be observed visually at large distances from the platform.

There is a large difference between species groups in the length of the tracks. The flagged alcids mostly had very short tracks. Gulls also had relatively short tracks. This is probably related to the flight behaviour of these species: alcids generally flew very low above the water, and tracks will have disappeared behind the waves frequently. Foraging gulls have an irregular flight, often changing in direction, which may have caused the track to be lost as belonging to the same bird. Flagged groups of geese on the other hand had very long tracks. These are large birds flying in flocks, resulting in steady signals which could be followed for a long time. Similarly divers and seaducks also had longer tracks. Divers are large birds, flying steadily at ca. 5-15 m above sea level. Seaducks, although not specifically large, flew in large flocks which may have made them conspicuous to the radar. Gannets were usually not recorded by the radar software. In many cases observers would see gannets flying by, either foraging or flying at a steady pace in some direction, with the echo of the gannet showing up on the radar screen, but remaining undetected by the software and thus not registered in the database. The reason for this is unclear.

Tracks of clutter were mostly very short, which is in line with expectation, as echoes from waves are linked randomly, without following a specific direction which would result in a longer track with a consistent heading. Echoes from ships generated either very short or very long tracks. Probably, the ships generally moved too slowly for the Merlin software to identify a series of echoes as belonging to the same object. Only occasionally the speed of the ship was such that echoes could be identified as belonging to the same object, in which case very long tracks were recorded.

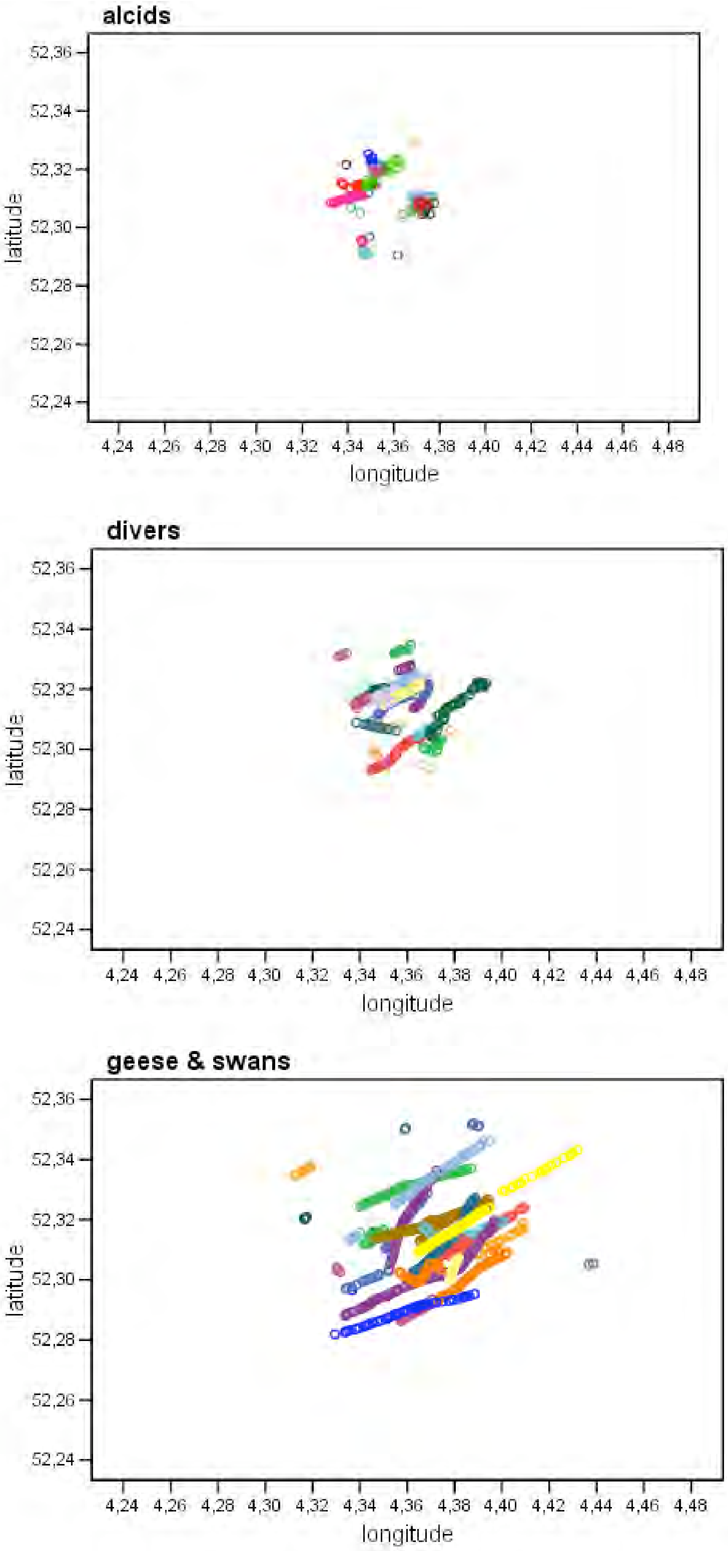
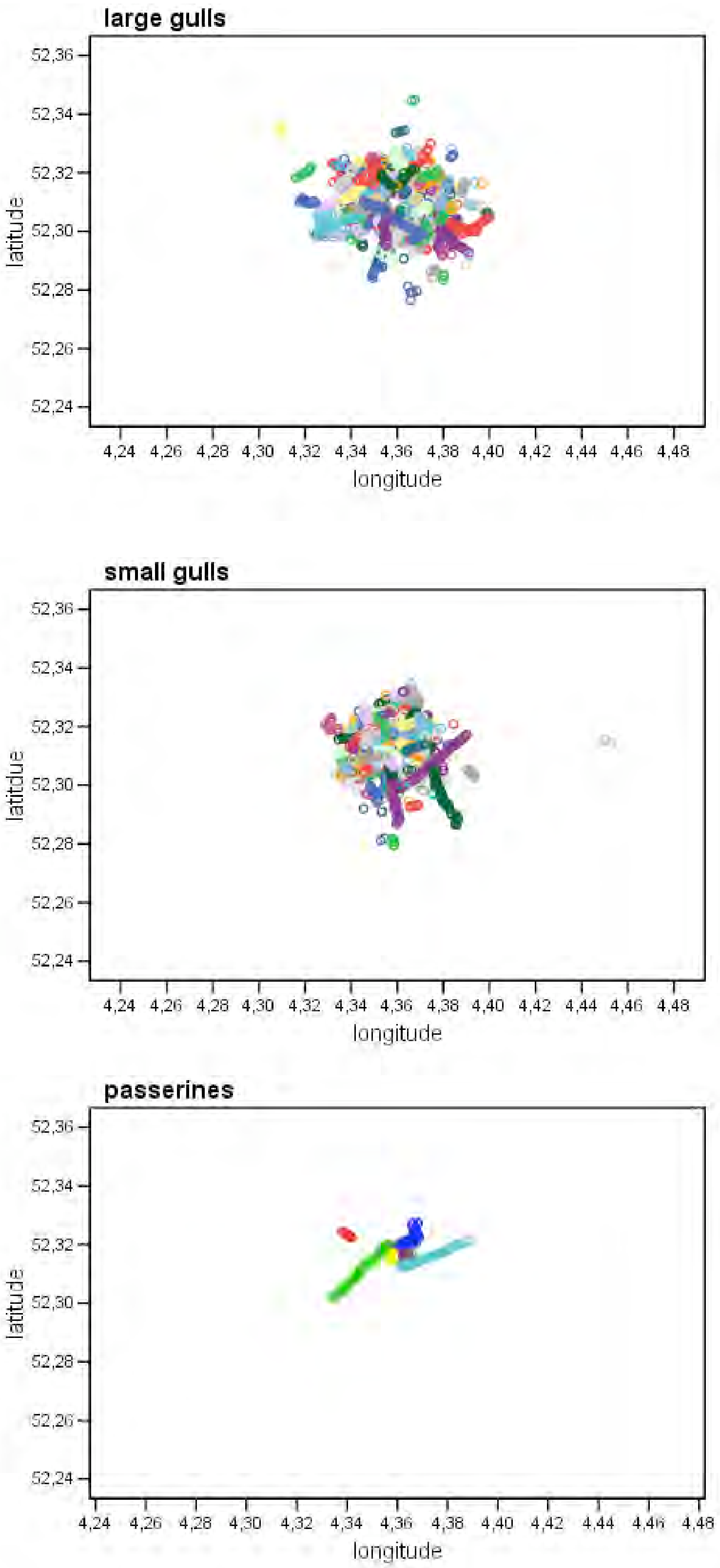


Figure 5.19 Tracks, seen from above, of various species groups flying near the observation platform, in this case alcids, as obtained through flagging. Different birds are depicted by different colours. The platform is located at 52,310 N; 4,359 E.



large gulls

small gulls

passerines

Figure 5.19 Continued.

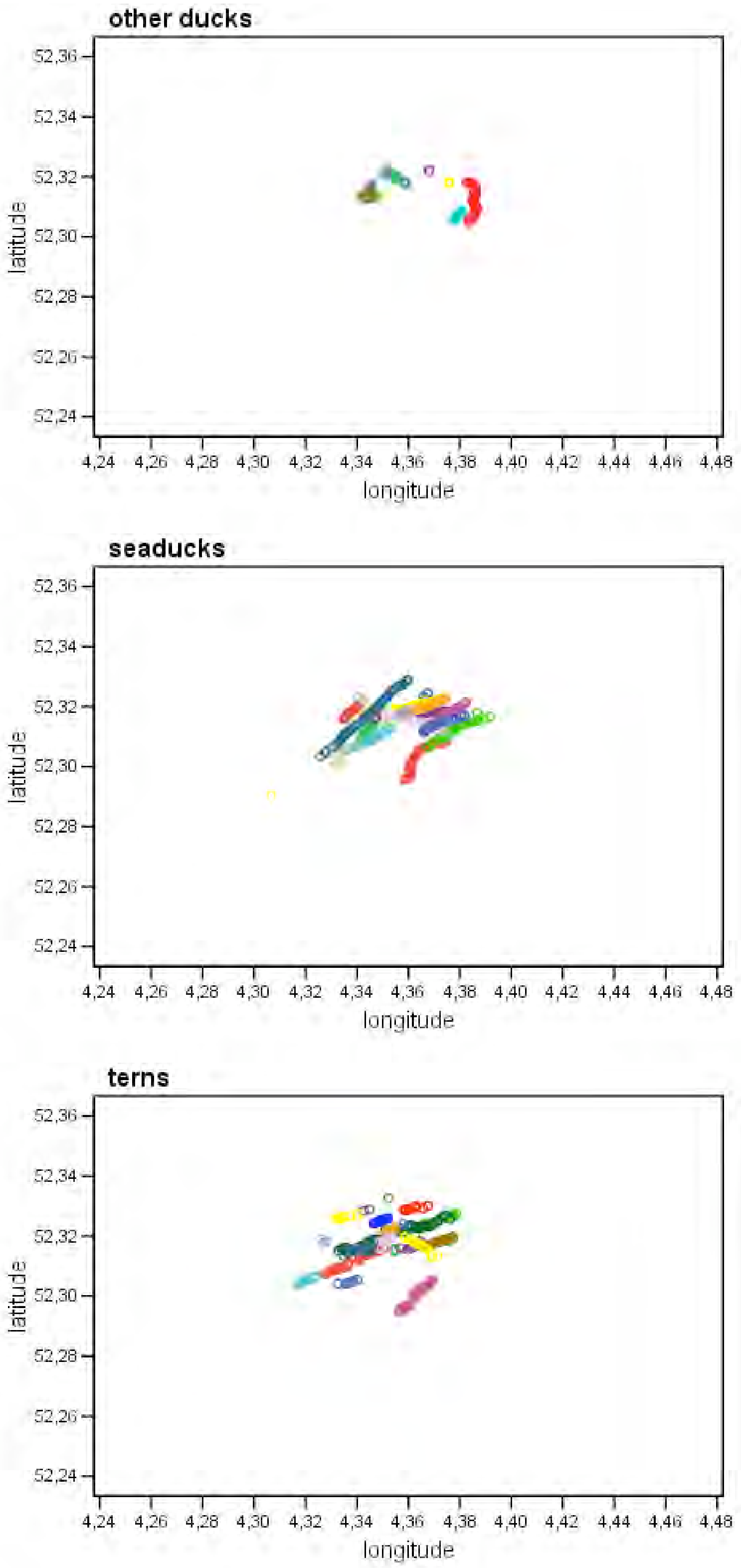


Figure 5.19 Continued.

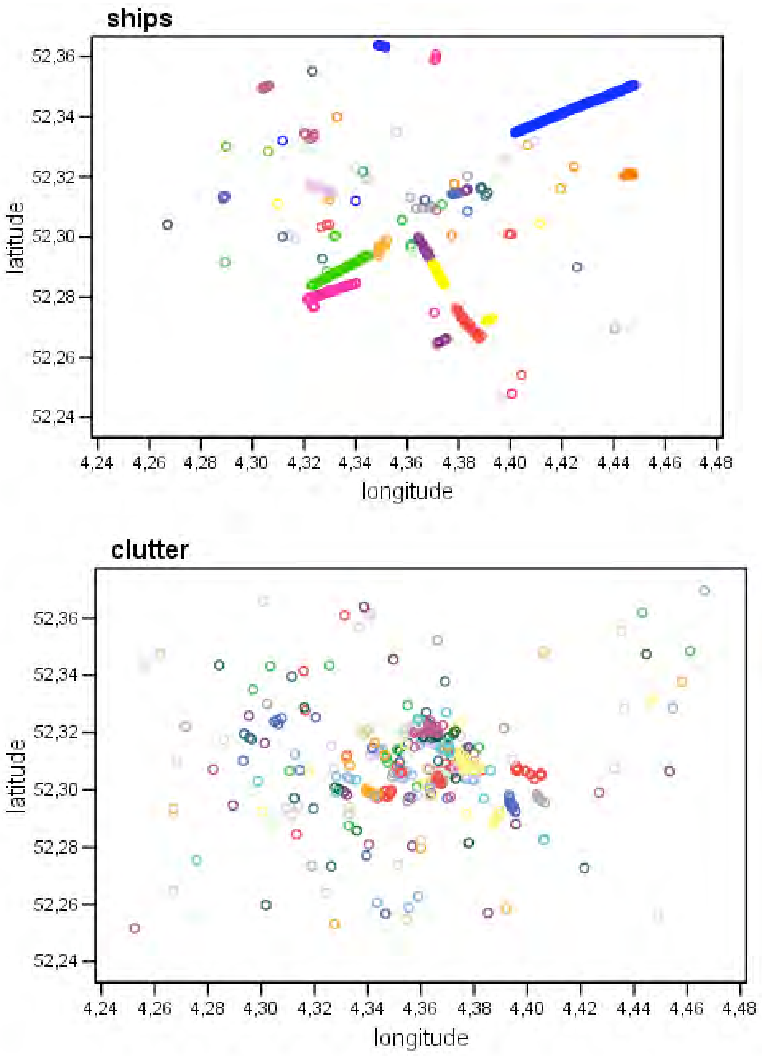


Figure 5.19 Continued.

5.3.2 Rules to remove clutter

Clutter was removed from the horizontal radar data following the rules as found and described in § 5.1. In short, after reducing the data to one record per track of an object (see § 5.3.1) echoes were classified as clutter and removed from the dataset according to the following rules:

1. tracksize <=2 (*i.e.* nr of echoes per track)
2. maxarea<9,41 (*i.e.* maximum recorded area of the track)
3. sumtracktype<7,88 (*i.e.* track types summed for the entire track)
4. tracktype > 2,5 & trackquality > 2,95 (*i.e.* consistency with which object was recorded & tracktype/sumtracksize)

By applying this filter, roughly 85% of the data were removed as clutter. Not all clutter could be removed, as can be seen in fig 5.20 and in the graphs in chapter 7: especially around the platform, large quantities of clutter remain visible. A better distinction between clutter and birds could not be found. It was expected that echoes of birds would yield far larger tracks than echoes of clutter, as birds produce a consistent track across the radar screen. However, tracks of birds were frequently lost during a few rotations of the beam. In these cases, a new trackID was assigned to the track, resulting in many trackID's for a single object crossing the screen. As a consequence, tracks of birds were far shorter than expected, and were less distinguishable from the short tracks of clutter. Other echo characteristics neither yielded differences large or consistent enough to fully separate clutter from birds.

Because single groups of birds passing through the radar beam were recorded not as one but as several different groups, the horizontal radar data could not be used to determine fluxes of birds, and was used solely to determine flight directions. Hence, horizontal radar data were used to analyse flight paths. For this purpose, the radar served well, especially during calm weather with little clutter.

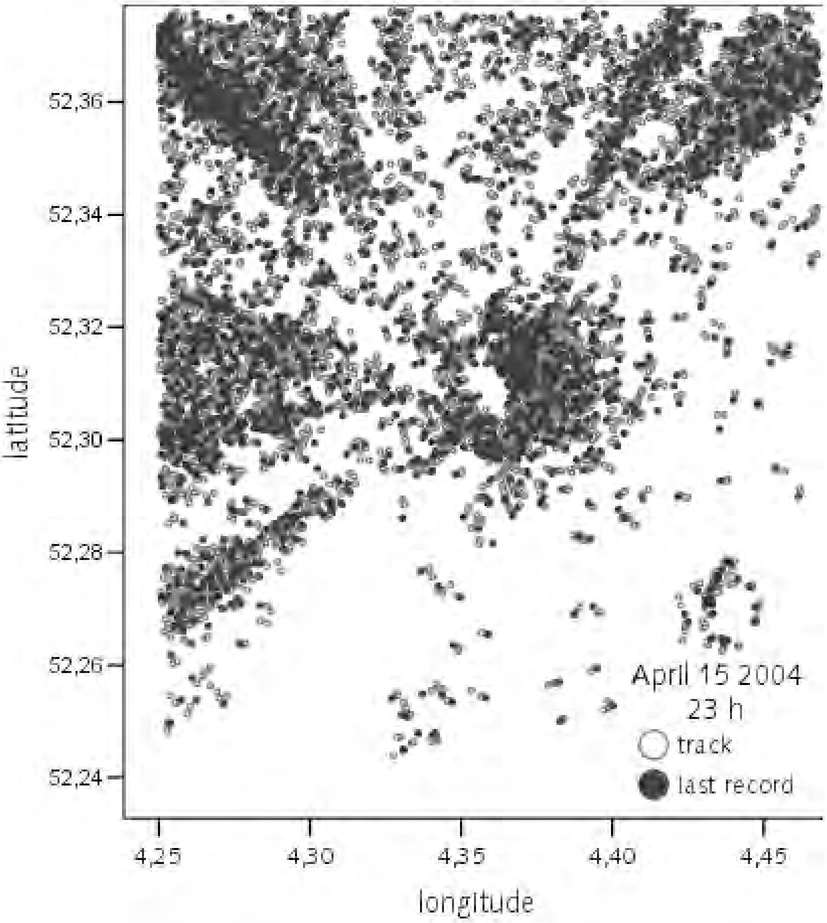


Figure 5.20 Tracks recorded around the platform by horizontal radar, viewed from above. Under conditions with strong winds or high waves moving in certain directions, a large amount of clutter remains in the data set, even after filtering rules are applied.

5.3.3 Data properties and availability

General

With the horizontal radar, flight paths of bird flocks could be recorded, *i.e.* the direction in which bird flocks are flying. In addition, measurements such as flight speeds, bearing of the bird relative to the observation platform, number of birds flying by were recorded. Figure 5.21 is an image of the radar-screen, showing all echoes that are seen by the radar. The way in which data were recorded by the radar is similar to those of the vertical radar. At a rotation-speed of about 22 rpm (once every 2.7 s), a bird usually was recorded at every rotation of the radar, as long as the bird was within radar-range. Successive echoes in one echo-trail were recorded as belonging to the same bird, and were given a similar track identification number. Several of these echo-trails can be seen in figure 5.22, which is an image of the data-screen showing the echoes that are recorded by the radar. An echo-trail needed to consist of at least two successive echoes before being recorded at all, to omit as much as possible recording of objects other than flying bird flocks, such as rolling waves on the sea-surface.

The horizontal radar was adjusted to record echoes up to 11 km (6 NM) away from the platform. Thus, a surface of ca. 390 km^2 was scanned. The maximum altitude at which bird flocks could be recorded, was approximately 5 km (exit angle of radar beam = 25°). This altitude depends on the size of the bird, with somewhat higher maximum altitudes for larger than for smaller birds. On days with strong winds (8 Bft or more), the radar was turned off to prevent damage.

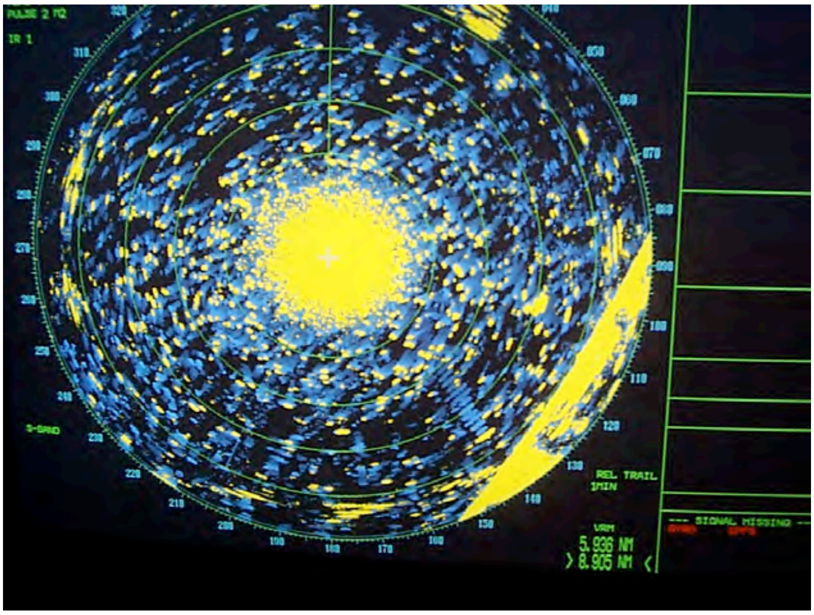


Figure 5.21 Image of the radar screen, showing all echoes that are detected by the radar, without processing, in a view from above. The many trails in south-westerly direction are of meadow pipits on autumn migration in September. The coast shows as a yellow band on the right hand side of the image. A ship is approaching the coast in the lower right corner, coming from the observation platform. A large amount of sea clutter is cluttering up the image in a (yellow) circle around the platform.

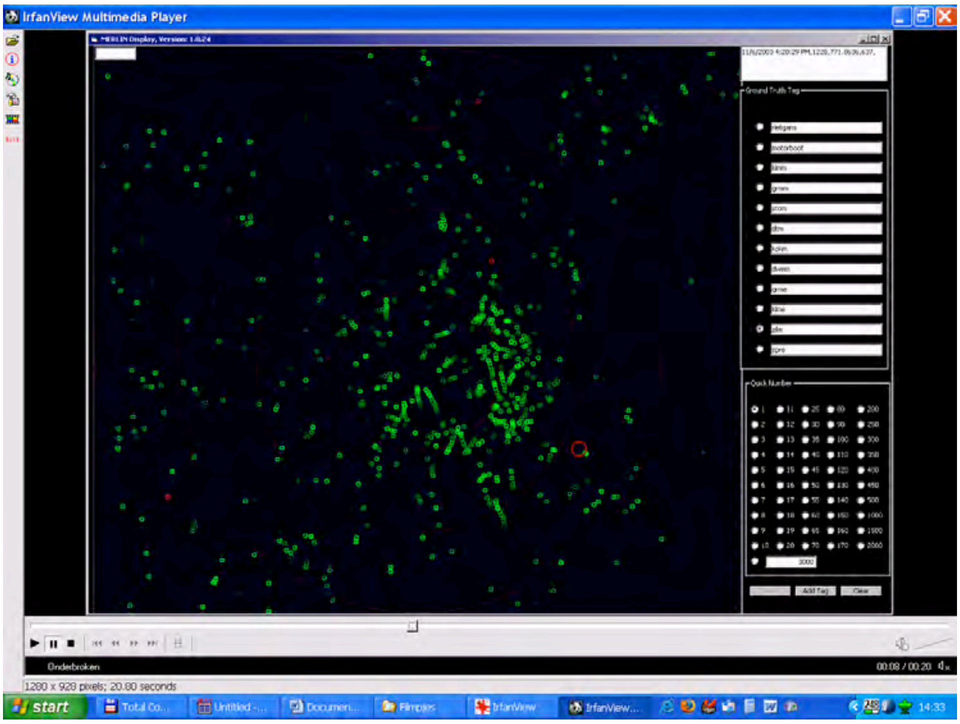


Figure 5.22 Image of the data screen showing echoes recorded by the horizontal radar, after processing. View from above looking down. Several trails of flying bird flocks are visible, mainly in the centre of the screen, as well as clutter.

From tracks to individual birds

A bird flying through the beam of the horizontal radar is in general seen during several consecutive scans, thus creating a track of several echoes. Merlin software assigned an individual number to each series of echoes belonging to the same object. Software settings were such that when in two consecutive scans an object was not detected anymore, the track was ended. When in a following scan the object showed up again, the track was assigned to a new individual. Because of this, a single group of birds could generate a large number of tracks in the database. This can be seen in figure 5.23, which shows the location of the observation platform as viewed from above, with tracks around it. In the south (bottom half of the graph) a clear track moving to the southwest can be seen. This track clearly belongs to the same object, but is recorded by the Merlin software as belonging to many different objects (each black dot signifies the last record of a track). Factors such as wind and wave height and – direction affect how consistently a track can be followed, but also flight behaviour of the bird species. For instance, gannets were visible on the radar screen, but were almost never recorded by the Merlin software. Large flocks of swans flying from England to the Dutch coast were seen passing the platform, but these were not recorded as strong, long tracks by the software despite their size and quantity. In addition, a large amount of clutter still remains in the data, each record contributing to the number of tracks recorded (fig 5.20). The number of objects that was recorded on the horizontal radar consequently varied largely with weather conditions like wave height, wave direction and wind speed (figs 5.24 & 5.25) rather than reflecting the actual number of birds flying by.

Because of these artefacts, it was not possible to quantify the number of birds passing the horizontal radar. Instead, we used the data recorded with the vertical radar to quantify fluxes and analyse temporal and seasonal patterns.

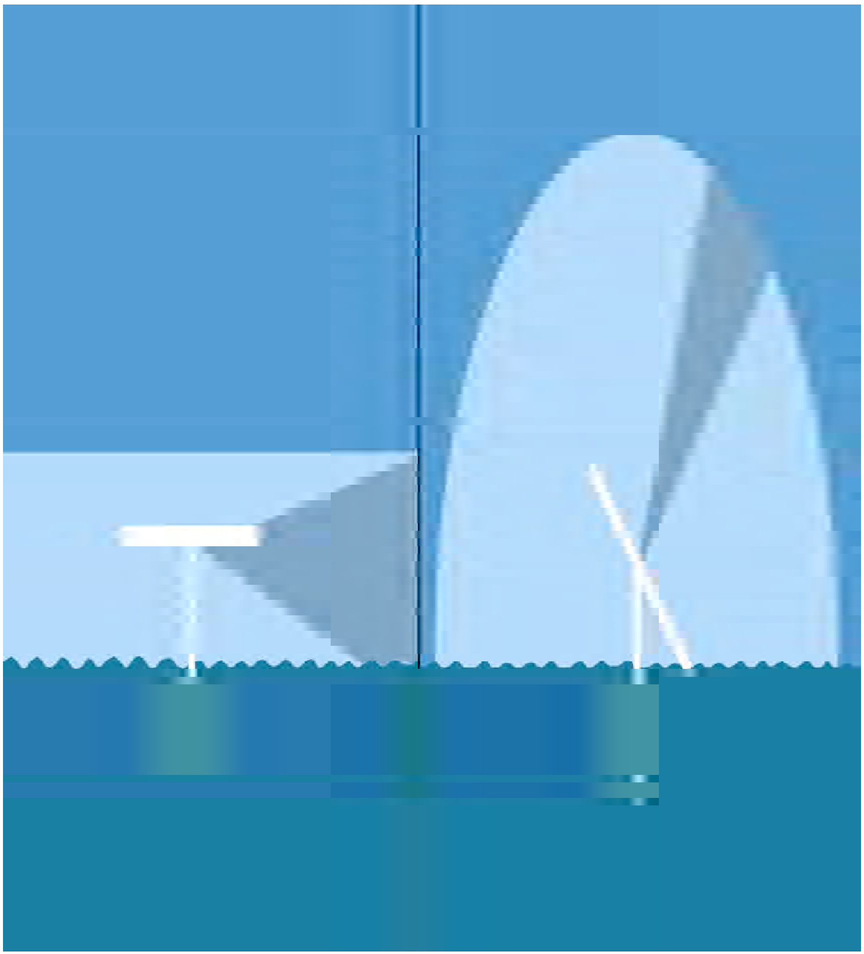


Figure 5.23 Image of tracks around the platform, viewed from above, as recorded with the horizontal radar. The last record of each track is depicted by a black dot. Tracks depict clutter in a circle around the platform, gulls flying mostly northward, and a long but interrupted track of a bird flying southwest.

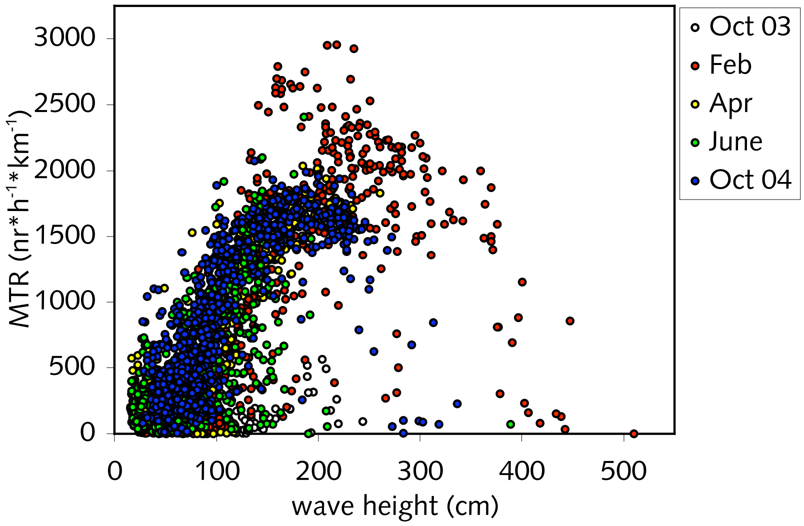


Figure 5.24 Correlation between wave height and the number of tracks recorded with the horizontal radar, at a distance of 0,5-2 km from the radar.

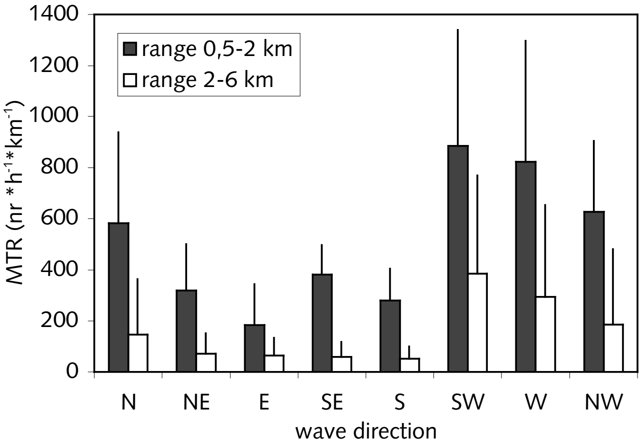


Figure 5.25 Correlation between wave direction and the number of tracks recorded with the horizontal radar, at distances of 0,5-2 km and 2-6 km from the radar.

Correction for detection probability

Similar to the vertical radar, the radar beam was cigar-shaped, which could theoretically result in bird flocks not being detected by the radar when flying at too close proximities to the platform. In $5.2.1 this proportion was calculated for the vertical radar, and was determined to be negligible. Because the exit angle of the horizontal radar is slightly larger than that of the vertical radar (25 vs. 20°), and because bird flocks are flying parallel rather than perpendicular to the horizontal radar beam, the proportion of bird flocks that is missed due to the shape of the radar beam is even smaller with the horizontal radar than with the vertical radar, and therefore is negligible.

The number of recorded echoes decreased with increasing distance from the radar (fig. 5.26). This is due to the fact that detection probability decreases with distance, resulting in a reduced detection especially of the smaller species at larger distances. Also the amount of clutter recorded by the horizontal radar decreased with larger distances. However, this did not affect the fraction of clutter recorded (fig. 5.26 & 5.27). At distances less than 500 m did the number of recorded tracks decrease sharply, due to the reduced surface of the scanned area at close range. By selecting only data within a fixed range of 0,5 to 2 km away from the platform for analysis, we avoided this problem.

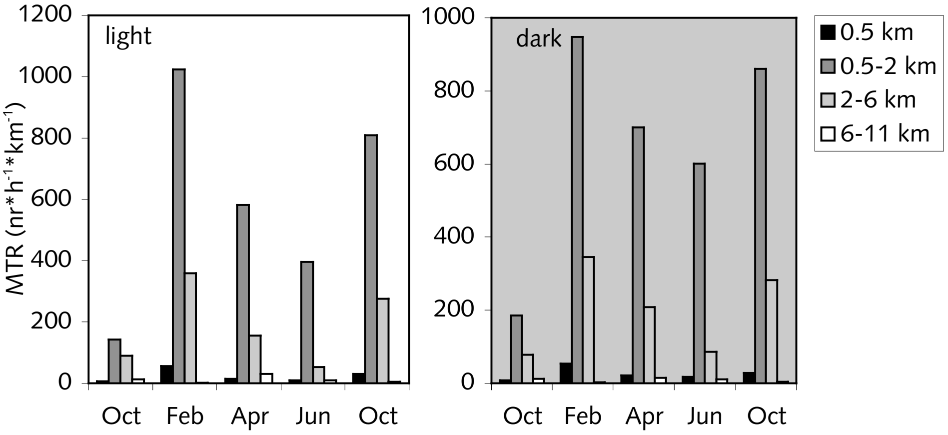


Figure 5.26 Effect of range (differently coloured bars) on MTR as recorded by the horizontal radar, shown for various months and for both light and dark hours. At larger distances, MTR is lower in each of the months, and patterns are similar during day and night.

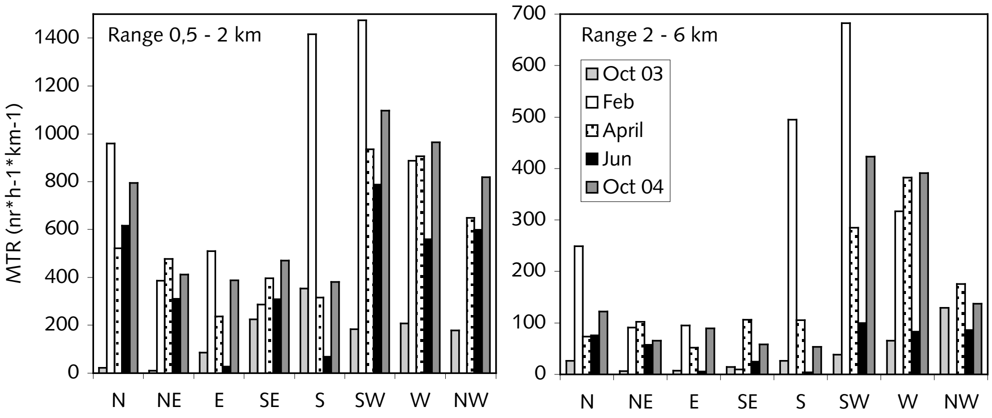


Figure 5.27 Effect of range on MTR as recorded by the horizontal radar. MTR is related to wave direction at both smaller (left panel) and larger (right panel) distances, suggesting high percentage of clutter in data at both ranges.

Effect of range and direction on heading

Other factors possibly affecting the mean heading that was recorded, are the distance of the object from the radar, and at which side of the radar the bird passed. Range had no effect on flight direction. Although at larger distances from the radar the beam reaches higher altitudes and thus may record birds migrating at higher altitudes, similar flight directions were obtained at all ranges around the platform (fig. 5.28). Only at distances closer than 500 m did directional patterns become obscured, possibly due to the larger precentage of clutter and/or of gulls.

Whether birds passed the platform in the north, east, south or west did have effect on the observed flight direction (fig. 5.29). The main flight direction is underrepresented in the data. This is due to the fact that birds are detected better when the beam hits them on the side than at front or rear. As a result, there is always a section of the radar where less signals are recorded. When the majority of birds fly in one direction, as during migration, a comparatively larger number of birds are not detected, as they are flying in an area of the radar where the beam hits them at front or rear. As main flight directions vary during the year, and with species, we chose to calculate flight directions from data recorded in all directions around the platform.

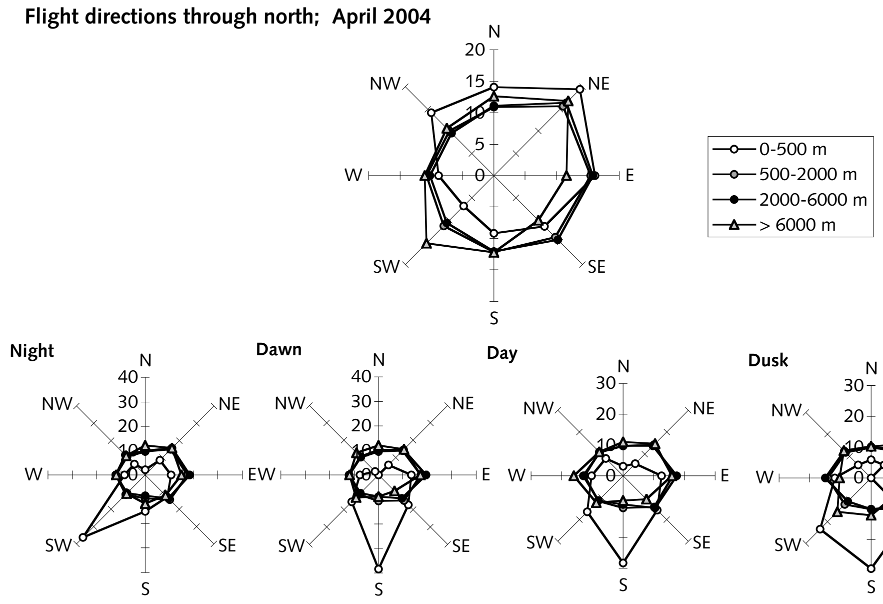


Figure 5.28 *Flight directions are similar at different distances from the platform. Only directions within 500 m deviate. Observed with horizontal radar.*

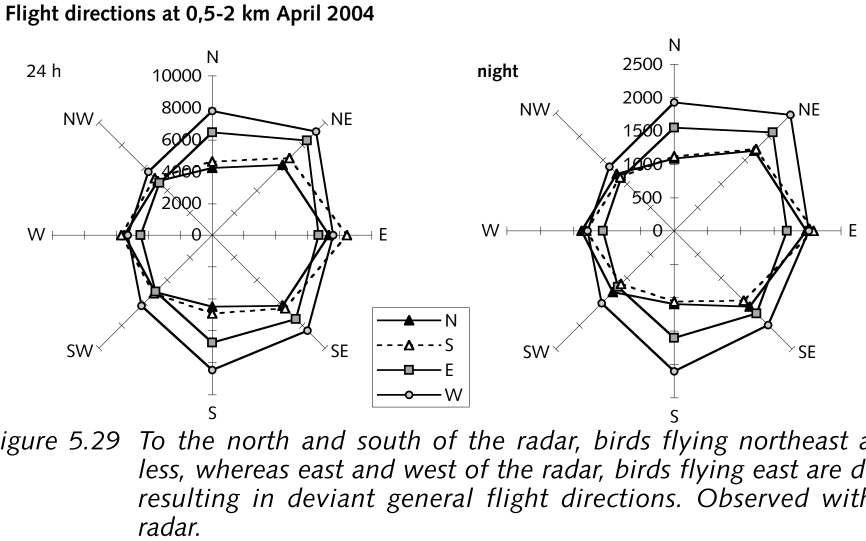


Figure 5.29 *To the north and south of the radar, birds flying northeast are detected less, whereas east and west of the radar, birds flying east are detected less, resulting in deviant general flight directions. Observed with horizontal radar.*

Data available

The horizontal radar started functioning properly on October 22 2003. It appeared that the system was highly reliable. For most days between October 22 2003 and December 6 2004 horizontal data are available (table 5.11). During high waves, the amount of clutter (being the waves) could reach levels too high for the software to process, and the data storage was halted automatically. It started as soon as the weather calmed down and clutter decreased to acceptable levels.

Scan days

The horizontal radar has recorded data for a total of 355 days over a period of 411 days. On the other days, the radar was not functioning due to either strong winds or hardware problems. Days on which horizontal radar data were recorded, were distributed evenly over time (table 5.11, see also table 5.7).

Table 5.11 Overview of days on which data were recorded with the horizontal radar, and division of measurements over the various seasons.

season	year	month	# days recorded
autumn	2003	October	8
		November	24
winter		December	24
	2004	January	25
		February	29
		March	31
spring		April	20
		May	28
		June	30
summer		July	10
		August	30
		September	29
autumn		October	31
		November	30
winter		December	6

Number of echoes recorded

A total of 334 million echoes (actually, database cases) have been recorded. This equals on average close to 1 million echoes on a day that the radar was working. Although the system was designed to filter out non-bird echoes before being stored, many of these data points have originated from waves.

5.3.4 Comparison of bird numbers observed visually and by horizontal radar

Ideally, the horizontal radar would have generated data which represented records of birds flying by the observation platform. However, rather than tracks of individual bird flocks, the data base consists of records of repeated tracks of flocks contaminated with a large fraction of clutter (§5.3.3). Because each track is represented several times in the data base, it is impossible to obtain even a rough an estimate of bird numbers from the horizontal data. Therefore it is useless to compare bird numbers obtained with horizontal radar and panorama scans. Fluxes have been estimated from vertical radar data instead, and these are compared with numbers obtained from panorama scans in § 5.2.4.

5.4 Panorama scans

Data handling densities

Conducted in position 1/2, the maximum height of the view at 1000 m is 55 m and in position 1/8 it is 96 m. The two lower layers of position 1/8 overlap largely with the two upper layers of position 1/2. Data from position 1/2, height class 1, 2, 3, 4 and position 1/8 height class 3 and 4 are used to calculate the density. In theory there is a half height class overlap between position 1/2 height class 3 and position 1/8 height class 1. Due to the somewhat blurred edge of the view of the binoculars the effective overlap is smaller. Therefore no correction was made for overlap.

All panorama scans were conducted from the lower ring at Meetpost Noordwijk (fig. 3.2). Binoculars on the tripod were situated approximately 15 m above sea level. Based on the view of the binoculars (110 m at 1,000 m) and the height of the observer above sea level, for every segment (combination of distance class and height class, an average height could be calculated (table 5.12). It should be noted that in position 1/2 the segments 2.1, 3.1 and 4.1 are below sea level, and therefore no floating or flying birds can be recorded in these segments. For the presentation of average altitudes in chapter 8 on flight altitudes the different segments per distance class in the panorama scan as presented in table 5.12 (combination of altitude and distance class) have been aggregated into altitude bands independent of distance for the first three distance bands. Final altitude bands amount five with for every altitude band the maximum average altitude of the aggregated segments (respectively 11.2, 42.6, 104.4, 135.4 and 197.3 m). E.g. in this way a bird which is recorded in altitude class 4 in distance 1 (with an average altitude of 24.9 m) will be classified as flying in altitude band with the average altitude of 11.3, falling within 27.15 m, the limit with the second altitude band with average 42.6 m). In this way low flying birds are grouped in the same altitude band independent of distance.

Birds flying and birds floating (on sea) were separated because these represent different (behavioural) aspects of birds. Furthermore, flying birds are the main subject of this study and floating birds are the main subject in Lot 5 (see Leopold *et al.* 2004).

In presenting data from the panorama scans the density of birds is the most appropriate format, *i.e.* the number of birds per unit surface or volume, per scan. We chose to use the number of birds per unit surface (km^2). Since most of the birds fly in the lower air layers, using surface area will give a very similar picture as when using volume. Because of its easier interpretation we use surface area for the density calculations.

Table 5.12 Average height (in m) above sea level of segments (combination of distance class and height class, see also fig. 4.6). Correction was made for segments partly below sea level. Binoculars 10x42 Leica, vision 110m on 1000m, angle of the vision field is 6,296 degrees. The average distance for segment 1 is 250m, for segment 2 is 1000m, for segment 3 is 2000m and for segment 4 it is set at 4000 m. x indicates the segment being below sea level.

	distance class			
height class	1	2	3	4
	low scan - binoculars in position 1/2			
1	4,3	x	x	x
2	11,2	7,0	6,3	5,2
3	18,1	27,3	42,6	64,0
4	24,9	54,8	104,4	174,0
	high scan - binoculars in position 1/8			
1	14,6	14,5	39,3	58,0
2	21,5	41,0	73,5	119,0
3	28,4	68,5	135,4	229,0
4	35,3	96,0	197,3	339,0

Data handling distances

Due to the limited capacity of the human eye, an observer will not see every bird at greater distance. Based on field tests on land in Eindhoven and the pier of IJmuiden it has been shown that small birds are observed all up to nearly a 1000 m, medium sized birds up to about 2 km and large birds even at some kilometres (Lensink *et al.* 2000, Poot *et al.* 2001). To handle this aspect, first the observations in distance class 4 were excluded from analysis that is based on density. The main reason is that distance class 1, 2 and 3 are limited in distance and have a known surface. Distance class 4 has no boundary, except for the horizon at a distance of about 15 km under clear visibility. Besides, most birds in this class will be missed by the observers. In this report no further corrections were made for the data from the panorama scans, *i.e.* no corrections for the missed small– and medium–sized birds. This is in contrast with the manner in which the sea watching data were handled (table 5.13). The main reason is the difference in approach of both data sets. The panorama scans are expressed in km^2 and the sea watching data in km.

The visibility and differences between observers do have an effect on the number of birds seen. Since we do not know the relation between visibility and the number of birds seen under circumstances on and above sea, no correction was made for this aspect. We did some tests to explore the difference between observers, especially in estimates of distance (in classes and in meters) of birds passing by. There are large differences between observers, but since we used distance classes, these effects have a minor influence on the data sampled.

Table 5.13 Summary of aspects of data handling within panorama scans and sea watching.

	panorama scan	sea watching
distance >3 km excluded	yes	yes
correction for species size	no	yes
correction for observers	no	no
correction for visibility	no	no
number of observers	not relevant	no

Data handling flight altitudes

To eliminate factors that obscure estimates of flight altitudes, we included observations only under the following circumstances:

- Birds flying at distances in class 1-3 (≤3 km).
  As the upper boundary for distance class 4 is undefined, altitudes cannot be calculated accurately in this class. Also, most variation in visibility conditions occurred within this class, and dropping this class from analyses removes the necessity to correct for weather effects etc.
- Complete panorama scans, in which each altitude and distance class was counted once.
  In a standard scan the airlayers just above sea were counted twice, both in the lower scan and in the high scan. For the analysis, altitude classes 1 and 2 in the high 1/8-scan were excluded, as they overlap with altitude classes 3 and 4 in the low 1/2-scan.
- Flying birds only.
  Birds that were sitting on the water during the scan were excluded from analysis of flight altitudes.
- Ships and aquatic mammals were excluded from analysis.
- Birds not associated with ships
  Often large flocks of gulls were foraging around fishing vessels. The flight altitude of these birds is ca 0-20 m above sea level, and is strongly influenced by the vessel. As these flocks of gulls make up a high percentage of all birds seen, including them in the analysis of flight altitudes would bias the data too much to altitudes of birds associated with ships. Altitudes of birds associated with ships are discussed in § 8.3.2.

For the altitude-distribution of the various species-groups seen in the panorama scans, data were categorised in different altitude-classes. The break-point between the various classes was chosen such that each class contained data from all three distance-categories. Average altitudes of each class were respectively 11.3 m, 43.2 m, 104.4 m, 135.4 m and 197.3 m (results presented in chapter 8) with the break-points of these altitude bands at 30 m, 75 m, 120 m and 165 m respectively.

In a few cases, differences between flight altitudes were tested for significance. As distributions were not normal, distribution-free MWU-tests should be used for this purpose. However, in this paragraph *T*-tests were performed for practical reasons. As significance is harder to prove with *T*-tests than with MWU-tests, differences that were found to be significant would also have been significant using MWU-tests.

Data handling flight directions

Flight directions of birds (and ships, sea mammals) were recorded in 8 directions (45° intervals) or, when circumstances allowed, in 16 directions (22,5° intervals). This discrepancy was resolved by distributing observations in the smaller intervals evenly across the larger interals. For example, 1 % seen in ESE gives 0,5% in E and 0.5% in SE.

Data handling day length

Because the scans were performed during daylight hours, the length of the observational periods varied through the seasons. In the analyses we distinguish 4 periods: autumn (October-November), winter (December-February), spring (March-May) and summer (June). The observation period varied from 10 hours to 17 hours, from winter to spring/summer (fig. 5.30). Due to the fast changing time of sunrise and sunset in spring, the number of observations during the early and late hours is reduced (fig. 5.30). During the winter no scans could be made before 6:00 and after 17:00 (fig. 5.30).

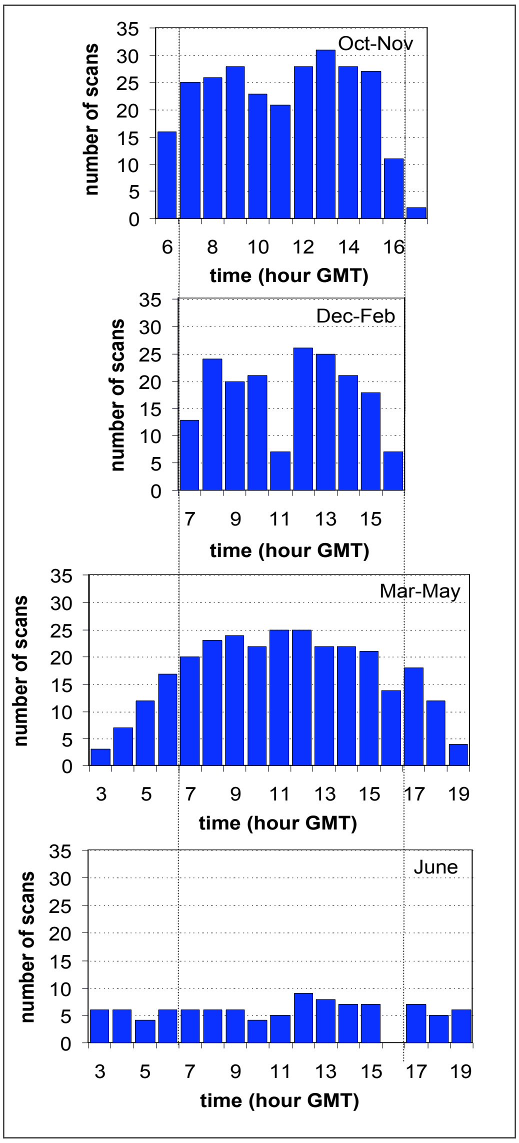


Figure 5.30 *Total number of scans per hour during four seasonal periods. The vertical dotted lines are depicted to aid comparison of the time scales.*

Data available

Between October 2003 and September 2004 935 high and low panorama scans were conducted (table 5.14). The number of scans per day more or less follows the day length; deviations were mainly due to weather.

Table 5.14 Number of panorama scans per day and per month; scans were conducted with the horizon halfway the binocular view (low scan) and at 1/8 of the view (high scan).

month	day	# low	# high	total/month	tot. low	tot. high
October	10	6	6	183	93	90
	11	11	11			
	12	9	9			
	13	10	9			
	14	9	9			
	15	10	10			
	16	10	10			
	17	6	4			
	28	8	8			
	29	7	7			
	30	3	3			
	31	4	4			
November	5	5	5	83	43	40
	6	9	9			
	7	7	7			
	25	3	2			
	26	7	5			
	27	6	6			
	28	6	6			
December	1	9	9	70	35	35
	2	9	9			
	3	9	9			
	4	8	8			
January	21	9	9	48	24	24
	22	8	8			
	23	7	7			
February	16	4	4	64	32	32
	17	10	10			
	18	9	9			
	19	9	9			
March	8	10	10	86	43	43
	9	12	12			
	10	11	11			
	11	10	10			
April	13	12	12	100	50	50
	14	14	14			
	15	14	14			
	16	10	10			
May	3	11	11	105	53	52
	4	15	14			
	5	15	15			
	6	12	12			
June	1	8	8	98	49	49
	2	16	16			
	3	14	14			
	4	11	11			
September	6	11	11	98	49	49
	7	14	14			
	8	13	13			
	9	11	11			
grand total		471	464	935	471	464

5.5 Sea watching

Data handling
Observation periods were grouped into 'sessions' which are uninterrupted runs of 5-minute bouts within a clock hour. Observation effort (in hours) was calculated per session, clock hour, day, visit to the platform, and month. During a minority of sea watches, gulls flying behind and between fishing vessels were not recorded. Effort was therefore expressed separately for this group. Since only 0.2 and 1.3 hours of sea watching were performed in clock hours 03:00 and 05:00 GMT respectively (in June only), both effort and number of birds were pooled for these hours (and presented as clock hour 4). Similarly, data were pooled for the hours between 18:00 and 20:00 GMT (0.8 and 0.7 h respectively). Before analysis, data were corrected for variation in observation effort by dividing observed numbers of birds by the number of observation hours in each relevant period (e.g. month or clock hour).

In the presentation of results, bird numbers are converted to flux, *i.e.* the number of birds passing per hour over 1 km length of view line across the sea surface. Because the view line was oriented (S)E-(N)W, this flux applies only to the flight activity component directed parallel to the coastline. Birds flying towards the coast or out to sea have a probability of crossing the view line (and be seen) that is (much) smaller than 1 km (as opposed to birds flying perpendicularly to the view line), and the flux in these directions is underestimated accordingly by our observations.

For most analyses and presentations, only observations of birds flying in distance zones 1-3 (i.e. ≤3 km from the platform) were selected. Reasons for excluding birds observed at >3 km are: (1) most variation in visibility conditions occurred within distance zone 4 (e.g. on a hazy day there often is still >3 km visibility) and dropping this zone thus removes the necessity to correct for weather effects in the analyses; (2) even in clear weather conditions, the detection of birds varies with their size and coloration and with light conditions, but within 3 km nearly all birds except passerines are visible under most conditions, and (3) because the upper boundary of distance zone 4 is not clearly defined and depends on weather and species characteristics, numbers of birds seen in this zone cannot be expressed as a flux. Additionally, the watched zone is in this way limited to the same distances from the coast as those in which the Near Shore Wind Farm will be erected.

While nearly all waterbirds are large enough to be always visible when flying at <3 km distance, part of the medium-sized (thrushes) and small (finches, pipits, warblers) passerines are missed, and these groups are thus underestimated compared to larger birds. The data were corrected for this by dividing numbers/hour not by 3 km in the calculation of flux, but by 1 km (small passerines) or 2 km (medium passerines) (this is equivalent to multiplying observed numbers by 3 and 1,5). The assumed maximum detection ranges, of 1 and 2 km respectively, are derived from field trials with the panorama scan on land (Lensink *et al.* 1998). Their applicability was checked by comparing the percentage of birds seen in distance zones 1-3 with expectations based on the presumed detection range when assuming equal fluxes in these zones. If the bird density or flux is the same in each distance zone, and all birds are detected up to 3 km distance, 500/3000 m = 17% of the birds are expected to be seen in zone 1, 1000/3000 m = 33% in zone 2, and 1500/3000 m = 50% in zone 3. If however birds are detected only up to 1 km, these percentages become (500/1000 m =) 50%, 50%, and 0% respectively. The observed distribution of small passerines agreed reasonably well with expectations based on 1 km detection range (65%, 34%, and 1% in zones 1-3). The best fit occurred with a detection range of 750-800 m, but the platform probably attracted some small passerines to rest on it, so we used 1 km instead. The distribution of medium-sized passerines agreed best with a 2 km detection range (observed % followed by expected % between brackets): 20% (25%), 64% (50%), 16% (25%).

Prior to the data analyses, we checked whether the number of birds recorded depended on the number of observers. This is imaginable not only because two people may see more than one, but especially because a single observer acting as his own scribe ‘looses’ observation time when writing. We tested whether the average number of birds seen per hour differed between sessions with single or with multiple observers. First, these averages were compared over days on which there were both single- and multiple-observer sessions. On only 46% of 24 days more birds were seen per hour during multiple-observer sessions, and the means were not significantly different between session types (Wilcoxon Matched-pair signed rank test, T=119, P=0.39). This test may not be very sensitive as over a whole day, effects of observer number may be easily masked if there was much variation in flight activity and single- and multiple-observer sessions were made at different times. A more sensitive test compared hourly average bird numbers between pairs of sessions when these were made either in the same or in consecutive clock-hours. Again, multiple observer sessions produced more birds than sigle-observer session in not more than half (52%) of the 41 cases, and there was no significant difference between the means of the two types of sessions (T=413, P=0.83). We conclude that a single observer did not record fewer birds than an observer with a secretary, and no corrections to the data were necessary. We did not test whether there were differences in observation efficiency between individual observers. It is likely that such differences exist but it is also likely that these will be smaller than those expected between single and multiple observers. As the latter were too small to be detectable in our data, we assume that the former will be so as well.

Recorded flight directions were aggregated into five categories. This was done in view of the fact that observers usually defined flight directions as either S-SW or N-NE, and recorded other directions only if they clearly deviated from this usual pattern. Categories used are: N (directions N to ENE, *i.e.* roughly parallel to the coast in northward direction), E (E to SSE, roughly towards the coast), S (S to WSW, parallel to the coast in southward direction), W (W to NNW, flying out to sea), and local flights (either birds making a small scale undirected flight (e.g. circling while scanning the sea for prey), or sitting on the sea surface or on the platform).

Data available

In the period October 2003 through to September 2004, a total of 187 hours of sea watching was done from Meetpost Noordwijk. Sea watching effort varied over the months (fig. 5.31A) due to variation in number and length of visits and in time available for sea watching. Daily patterns are shown separately for October-March and April-September because daily patterns in bird flight activity are likely to differ between the 'wintering' and the 'breeding' season, and because of the substantial difference in day length (fig.5.31B). Sea watching effort was spread rather evenly within the limits of the daylight period. It should be noted that the 'tails' in time of the distribution of effort in figure b are derived from a decreasing range of observation dates; e.g. observations in clock hours 4 and 18 were made in May and June only.

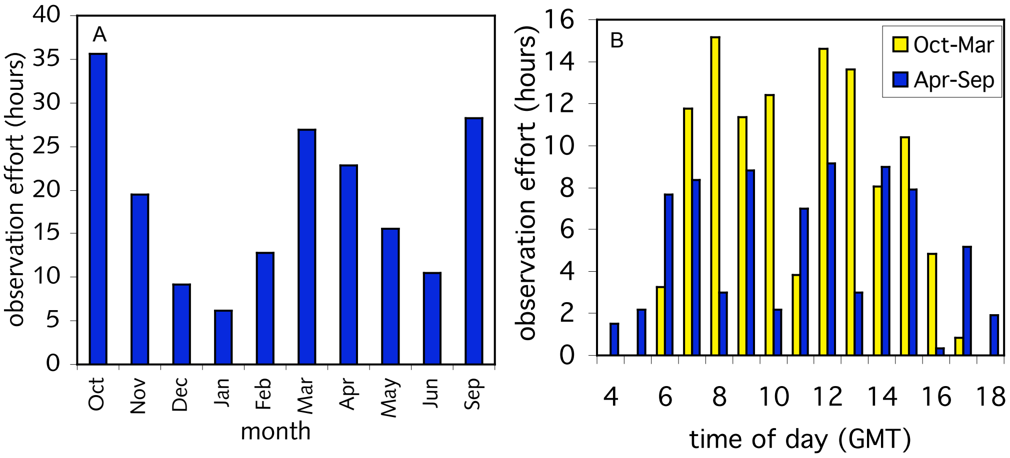


Figure 5.31 *Sea watching effort (hours) at MpN October 2003 – June 2004, by month (A, left) and by time of day (B, right). Note that time is expressed in Greenwich Mean Time, which in winter is 1 hour and in summer 2 hours earlier than Dutch time.*

5.6 Nocturnal calls

Activity of especially nocturnally migrating low flying birds can be evaluated by registering the calls of these birds at night. For this purpose, nocturnal calls were registered on a total of 24 evenings in the period September-April. In January, no recordings of calls were made. Most calls were registered in the autumn of 2003. During the winter period (December through March) hardly any calls were registered. In early spring some migrating waders and swans were registered (see § 6.3.1).

Data available

On 24 evenings data on calling nocturnal migrants were sampled (table 5.15). In most occasions registration started about 1 hour after sun down. In autumn and winter observations differed in duration, depending on the number of birds passing by. In later months 1 hour of observations was considered enough to give an impression on the amount of calling migrants aloft.

Table 5.15 Dates and times of registration of calling nocturnal migrants by field observers, start and stop time in GMT.

date		start time	stop time	total # minutes
Sept	25	18:30	20:10	100
	27	18:50	19:50	60
	29	19:45	21:45	120
Oct	10	19:25	21:35	30
	11	18:00	20:45	50
	12	17:45	21:05	140
	13	18:20	21:10	70
	15	16:50	20:20	130
	16	17:15	19:55	125
	28	17:45	21:35	230
Nov	5	20:00	22:10	130
	6	17:30	20:30	180
Dec	1	17:45	20:00	120
	2	16:00	18:55	125
	3	16:00	17:00	60
Feb	16	21:00	21:30	30
	17	21:45	22:20	35
	18	20:40	21:10	30
Mar	8	18:30	19:30	60
	9	18:30	19:30	60
	10	18:45	19:45	60
Apr	13	19:00	20:00	60
	14	19:30	20:55	90
	15	19:20	20:20	60
Sept	6	19:00	20:15	75
	7	18:55	20:15	80
	8	18:50	20:10	80
total minutes				2.185

5.7 Moon watching

Data available

On 6 evenings nocturnal flight activity and flight paths were observed by means of moon watching (see table 5.16). On December 1 no birds were observed, and this observation period was not included in further analysis.

Table 5.16 Dates and times of moon watching, start and stop time in GMT

date	time
11 Oct 03	*18:30-20:30*
12 Oct 03	*18:30-20:30*
13 Oct 03	*20:00-20:30*
5 Nov 03	*20:00-22:10*
6 Nov 03	*17:35-20:30*
1 Dec 03	*18.15-18.45*

5.8 Grouping of species

Throughout the report, the main level of presentation is that of ‘species groups’, which are aggregations of species with close taxonomic and ecological affinities (and sometimes resembling each other closely). A complete list of species names in English and Dutch is given in appendix 1, together with the categorisation of species groups, and the abbreviations that were used.

Species group names and definitions used in this report are generally straightforward but some require explanation. *Medium passerines* include thrushes and starlings while *small passerines* include all smaller species (e.g., pipits, finches etc.). Together with raptors, owls and pigeons these groups constitute the *landbirds*. Ducks were divided into *sea-ducks* (scoters and Eider) and *other ducks* (Shelduck, dabbling ducks and non-marine diving ducks). Gulls were divided into *large gulls* (Herring, Lesser and Greater Black-backed Gull and unidentified birds belonging to either of these species), *small gulls* (Black-headed Gull, Common Gull, and unidentified small gulls), Black-legged Kittiwake and the Little Gull.

The Little Gull was kept separate from the other gulls because (1) it has a different ecology, feeding on smaller surface plankton than most larger gulls and largely ignoring discards, and its distribution is hardly influenced by presence of fishing vessels, (2) its numbers were always recorded while larger gulls were not recorded during some sessions, resulting in (small) differences in effort, and (3) Little Gull is listed in Annex I of the EC Bird Directive and thus has a conservation status different from other gulls. The Kittiwake likewise is a truly pelagic species that did not feed behind trawlers as much as the more coastal gull species at MpN, and is also treated separately. However, Kittiwakes flying at a distance or feeding in the wake of fishing vessels could not always be separated from other small gulls and this category therefore will contain some kittiwakes as well. The problem is not likely to be large as observations at >3 km distance were omitted before data analysis.

6 Fluxes of flying birds

Outline of the chapter

In this chapter we present data concerning fluxes of flying birds, *i.e.* the number of birds that passes a given line in a given unit of time, expressed as Mean traffic rate (MTR, nr of birds/hour/km). Fluxes are based on observations with the vertical radar, by panorama scans, sea watching and also by nocturnal observations (moon-watching, nocturnal call registration). All these methods together give a complete picture of flux at different times of day and night and throughout the season. In this chapter the temporal variation in these fluxes is described, both over the seasons (§6.1), during the day (§6.2) and at night (§6.3). For spatial variation in fluxes, *i.e.* variation with flight altitude, see chapter 8. In chapter 9, further comparisons of absolute fluxes are made where we discuss the variation in fluxes offshore versus on the coast and inland. results are summarised in §6.4.

6.1 Seasonal patterns

The occurrence of different bird species varies year round above sea under the Dutch coast. Species composition and total number may vary from month to month. These changes are linked to the annual cycle of species, due to which local breeding birds are expected in summer, migrants mainly in autumn, and spring and winter visitors in winter. In addition, environmental conditions affect the occurrence of birds above sea.

6.1.1 Seasonal patterns overall

Radar data

Because each track registered with the horizontal radar was recorded as multiple tracks rather than as one track (see §5.3.3), fluxes could not be calculated based on the horizontal radar data. The vertical radar however does allow calculation of fluxes. MTR was highest in spring and early summer (April – June; fig. 6.1). Flux in October, during autumn migration, was remarkably low at lower altitudes. This was mainly due to the fact that the radar was not operating during days with strong migration (cf. www.trektellen.nl). Another reason may be that detection probability of the radar was reduced for smaller species such as thrushes, starlings, and smaller songbirds, flying at lower altitudes, which is possible given the large range setting of the radar (1,5 NM). Actual fluxes at peak migration could reach much higher values, as was determined visually during daytime in October (see next section). Autumn and spring migration to a large extent took place at altitudes higher than 250 m and mainly during the night, which is shown by MTR at the higher altitudes being relatively high in April and October as compared to the other months (fig. 6.1). For further comparisons of fluxes at different altitudes see chapter 8.

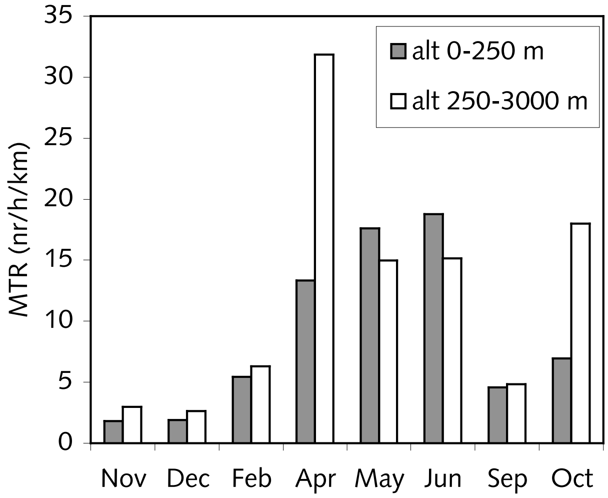


Figure 6.1 Mean traffic rate up to 250 m and above 250 m altitude, day and night, at distances of 500-1500m north of the platform, measured by vertical radar. Note comparatively high MTR's at higher altitudes in April and October.

Panorama scans and sea watches

In the panorama scans, most birds were observed in October. Numbers then decreased during the winter months, and rose again slightly from April on through the spring. In May a low peak in numbers was observed, after which numbers were low again in August through September (fig. 6.2). In January though March and in September MTR's were lowest. The pattern is dominated by gulls, as more than 90% of the birds observed were gulls.

The sea watches revealed a pattern that was highly similar to that of the panorama scans (§6.1.3).

Panorama scans yielded MTR's during daytime which were far higher in the autumn and early winter months (October through December) than was recorded with the vertical radar (fig. 6.2). This difference is to some extent caused by the fact that MTR's of panorama scans were calculated based on individual birds, whereas the vertical radar has recorded groups of birds. Large groups of birds, such as the gulls and also cormorants flying around fishing vessels, may increase MTR of panorama scans considerably while they are not represented in MTR's of the vertical radar. As shown in figure 6.2, gulls and cormorants made up a large part of the counts in October through December. In addition, large numbers of fishing vessels were present at short distances around the platform in October 2003 (fig. 7.12), and the gulls around those fishing vessels have largely inflated the MTR of the panorama scan for that month. This aspect does however not fully explain the discrepancy between MTR's from the vertical radar and the panorama scans. Finally, passerines such as starlings and small songbirds, migrating in October, November and December (fig. 6.3), may have passed undetected by the radar. This issue is discussed in further detail in §5.3.4.

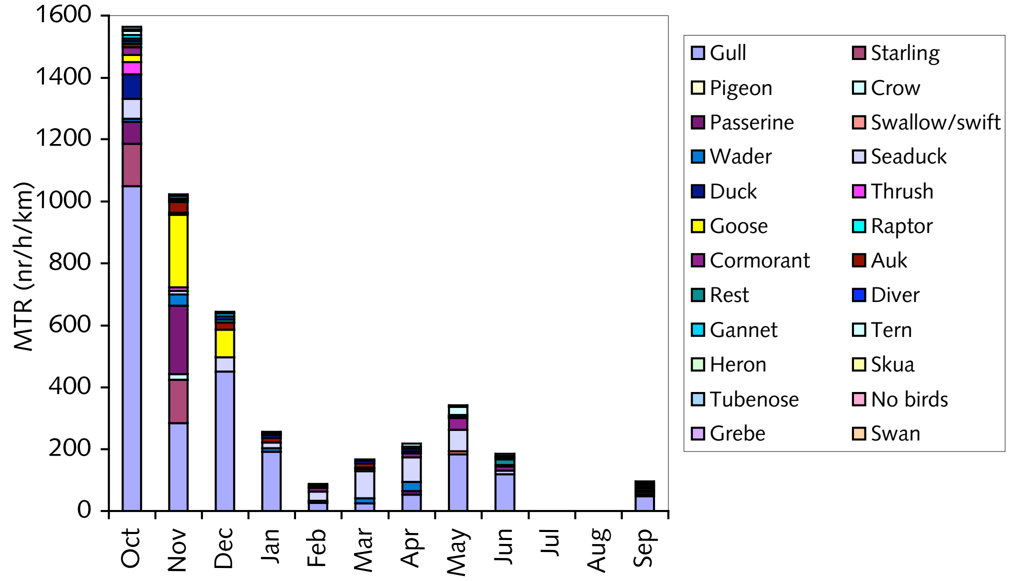


Figure 6.2 Mean traffic rate as calculated from panorama scans.

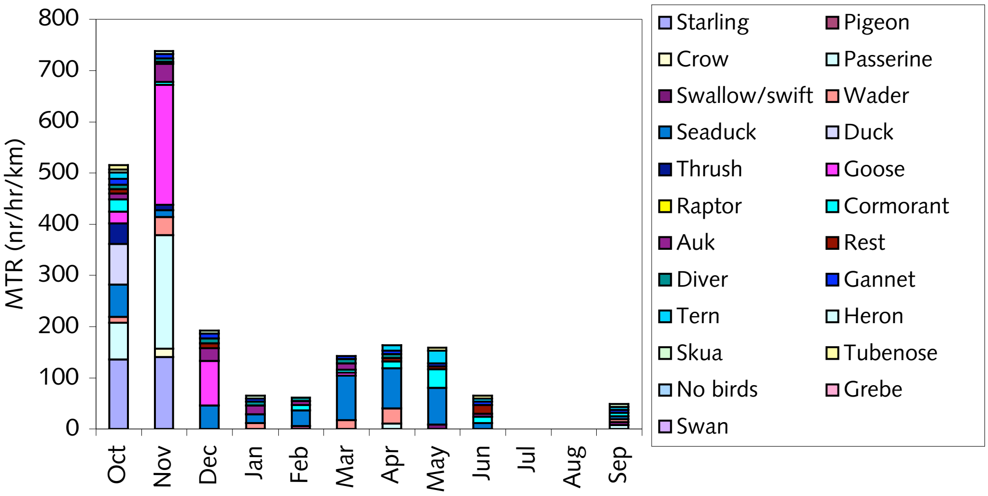


Figure 6.3 Mean traffic rate excluding gulls, as calculated from panorama scans.

6.1.2 Seasonal patterns of the various species groups (panorama scans)

Based on the panorama scans, seasonal variation in the flight intensity of the various species in the area of the platform could be evaluated. Although numbers could only be registered at comparatively low altitudes and short distances from the platform in comparison to vertical radar observations, the consistency with which visual data were recorded throughout the year gives us the possibility to evaluate changes in flight intensities. Below, we give the seasonal patterns in density of each species group, as illustrated in figure 6.4.

- *Alcids* were seen mostly in November with a small peak in March (fig. 6.4). Most alcids that were seen were Razorbills, a minority were Guillemots and a single Little Auk. The peak coincidences with the strongest migration along the Dutch coast. Highest densities of birds floating on sea were also recorded in November. In the other months these two species were hardly seen on the water, except in January.
- *Cormorants* were nearly absent from November to February. In May they were numerous, related to feeding flight from the colonies on the Dutch coast. For birds active in and on the water the same pattern was noted, but with very low densities of feeding cormorants.
- *Divers*, the majority of which were Red-throated Divers, were observed between October en April, with the highest numbers between November en March. The peaks in November and March were related to migration from and to the breeding grounds respectively. Many of those migrants winter in the Dutch coastal zone, which explains the high number observed in the winter month.
- *Gannets* were scarce after new year. The peak in April is probably related to migration to the breeding grounds. In summer mostly sub-adult birds were seen passing by. In autumn adults were dominant in the observations. In September, with no official observation, this species was far more numerous than in the following month.
- *Geese and swans* were most numerous in late autumn and the beginning of the winter. In these period large numbers of Barnacle Goose, Brent Goose and White-fronted Goose migrate to their wintering grounds in West-Europe. The northbound migration was hardly noticed. Among the geese only Barnacle Geese were seen on the water, in April.
- *Grebes* were vary scarce at the observation platform, occasionally they were seen flying by as well as locally on the water.
- *Gulls* were seen in highest numbers in autumn (fig. 6.4). After their numbers had been relatively low in winter, they became more numerous in spring and early summer. In this general 'gull pattern' all gull species were included. Black-headed Gulls were seen mostly in autumn. Common Gulls were present in decreasing numbers from October up to April. Great Black-backed Gulls were seen in autumn and the beginning of the winter. The subsequent peak in April points to migration to the northerly breeding grounds. Herring Gulls were present all months, with low numbers in winter en higher numbers in autumn, spring and summer. Kittiwakes arrived in October and peaked in November and December. Thereafter their numbers were very low. Lesser Black-backed Gulls were nearly absent from December up to February. Their number peaked in summer and decreased in autumn. Little Gulls were mostly seen in October and April, in which periods they migrate southward resp. northward. In winter this species was present but scarce.
- Among the *ducks other than sea ducks*, Wigeon, Merganser, Teal and Shelduck were the most common. The general pattern with peaks in autumn and the beginning of the winter and spring, suggests that birds seen at MpN were migratory birds.
- *Raptors and owls* were only recorded in autumn and spring, suggesting these species occur sporadically above sea during migration.
- Among *sea ducks* Common Scoter and Eider were the most common species. The peak in October indicates the arrival of winter visitors. Movements from January till

May might concern local movements of winter visitors followed by northward migration. On sea both species were scarce. Only in February a flock of Common Scoters was present locally.

- *Skuas* were seen in low numbers between October and January.
- *Terns*, mostly Common Tern and Sandwich Tern, were only observed in low numbers in migration periods. They were recorded in October, coinciding with the southward migration. The northward migration became vivid in April and May.
- *Fulmars* were very scarce in the panorama scans. This species was absent from November till March. Observations of the Fulmar always coincided with strong (north)westerly winds.
- The density of *ships* (mainly fishing vessels) was highest in October and much lower in the following months. From April onwards, their presence increased again. The pattern of fishing vessels showed great similarity with that of gulls. See for a detailed analyses of the relation between gulls and ships § 7.3.
- *Sea mammals* (porpoises and grey seals) were recorded occasionally in all months, with peak numbers in January, February and April. This pattern fits well with that known from the database on marine mammals in the southern North Sea (NZG unpublished). Most porpoises were seen during calm weather. The dip in March does probably not reflect their actual abundance, since it should be a maximum.

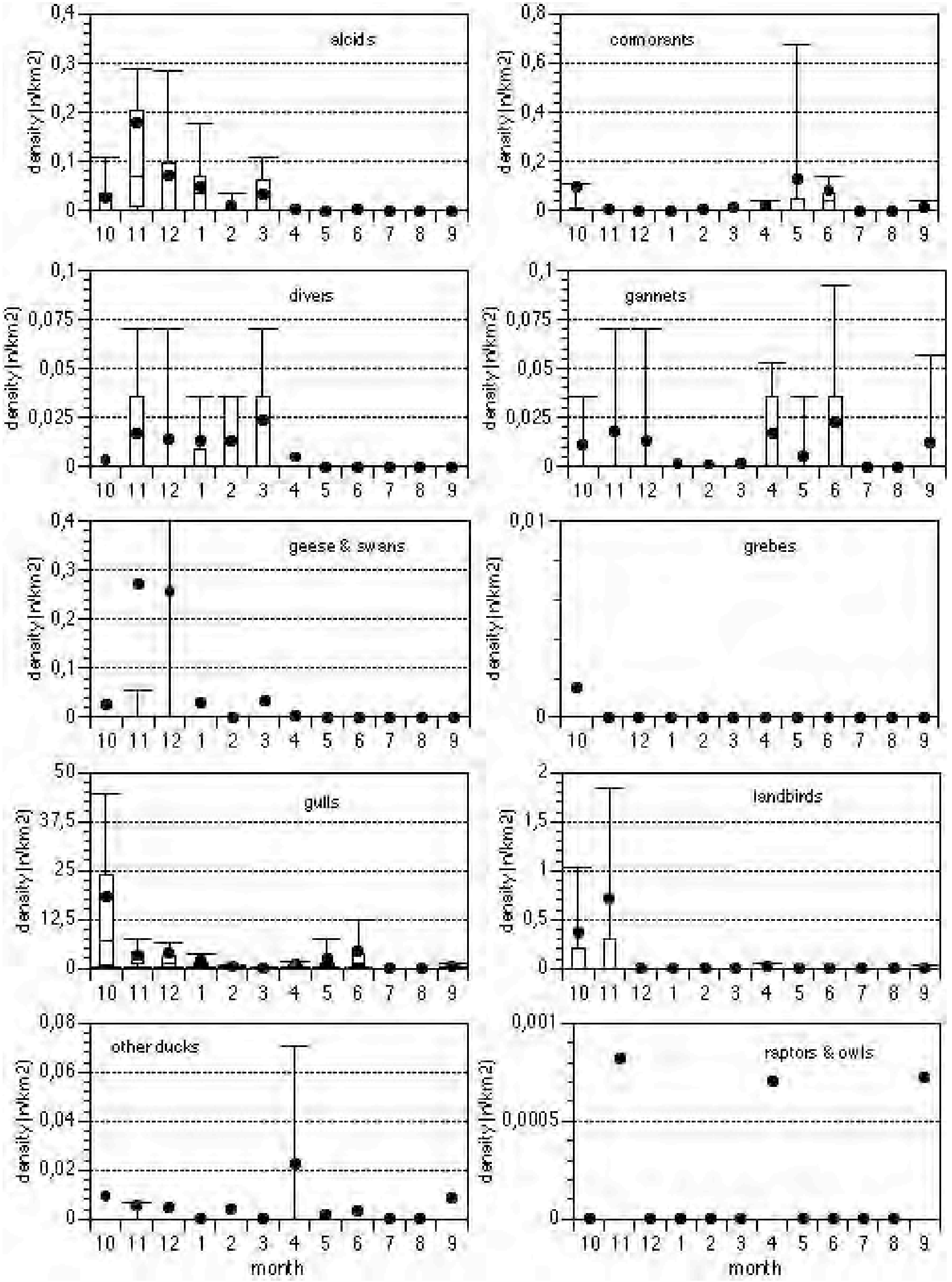


Figure 6.4 Average density of flying birds in the panorama scans per month. Continued on next page.

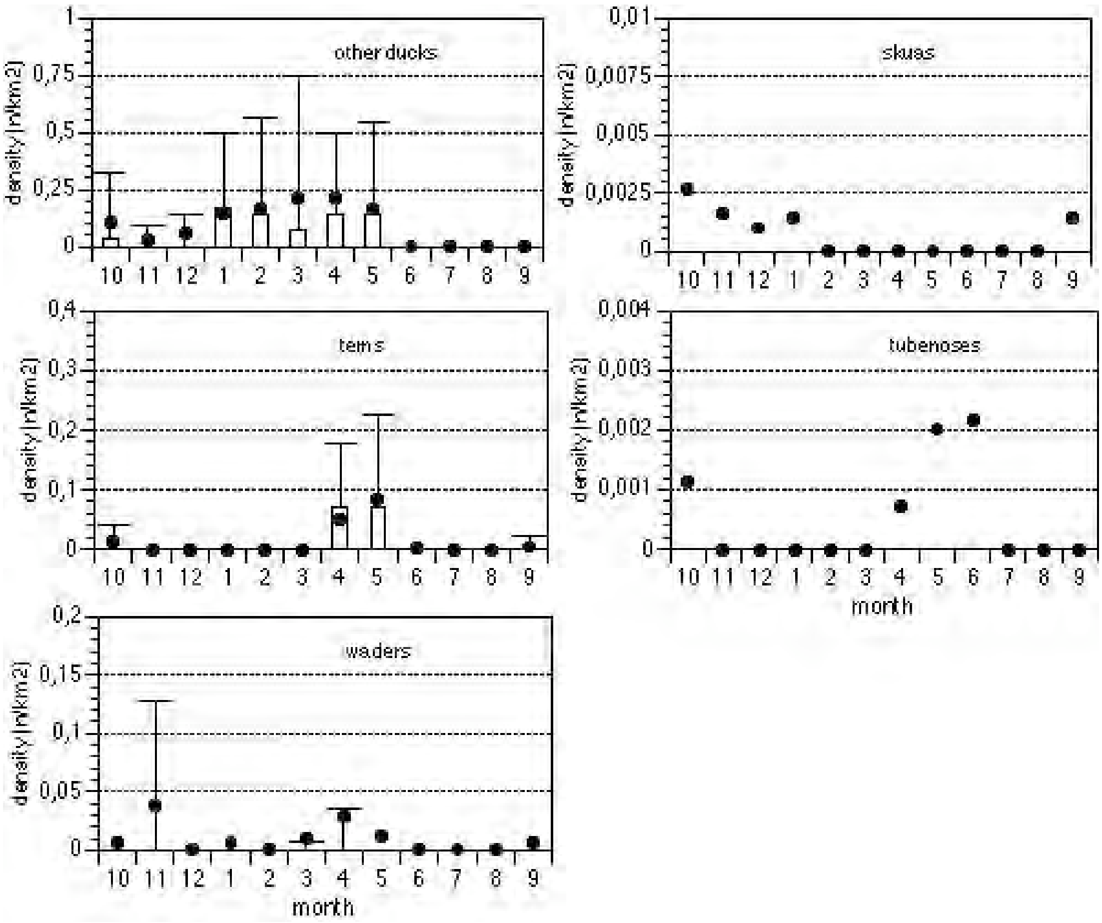


Figure 6.4 Continued.

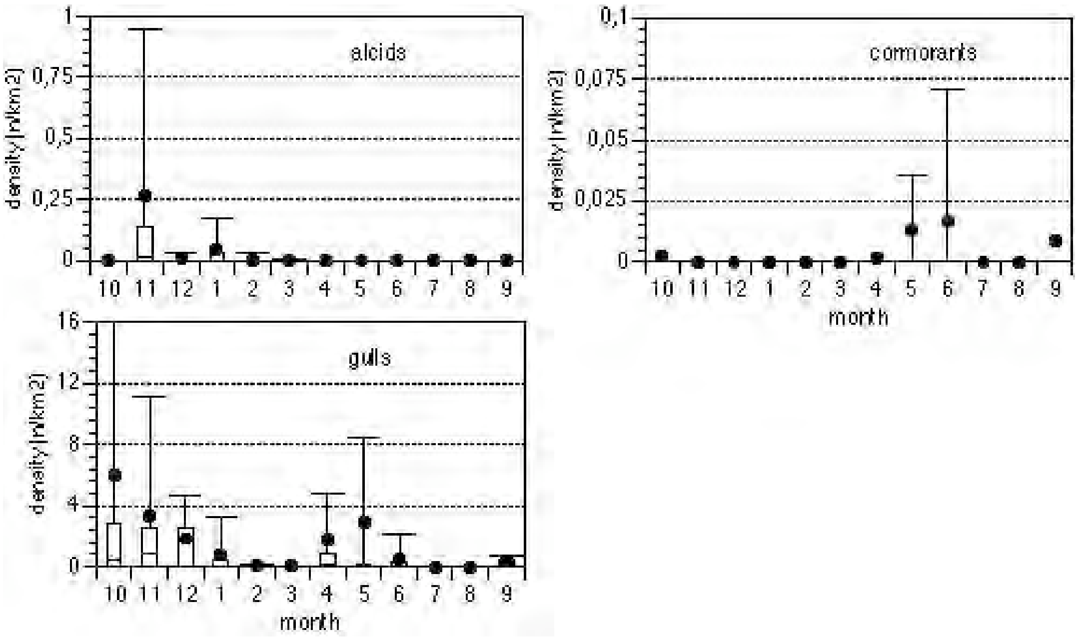
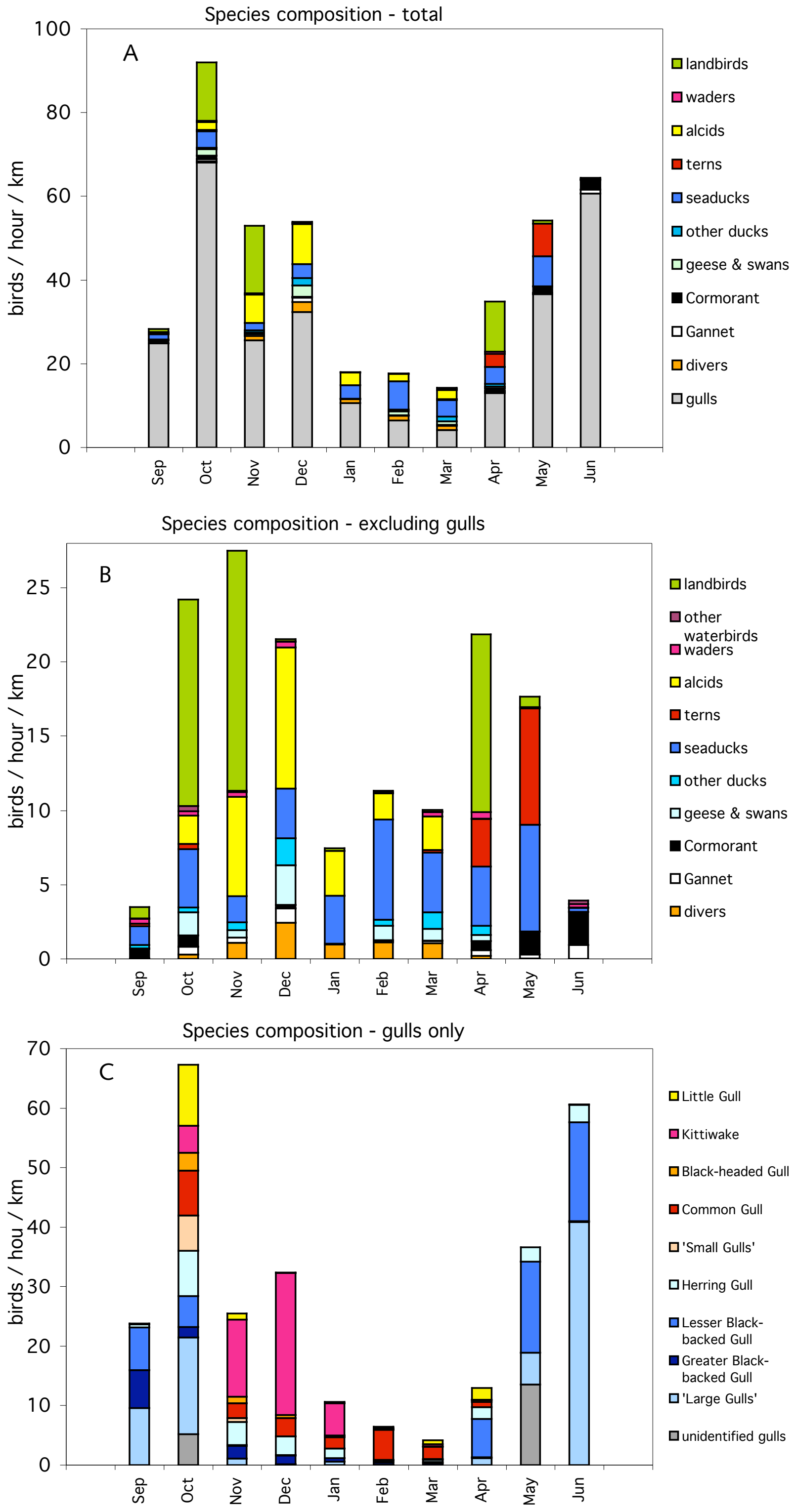


Figure 6.5 Average monthly density of species groups floating on sea in the panorama scans.

6.1.3 Seasonal patterns of birds less frequent and at larger distances (sea watches)

The total flight activity of birds (flux, in birds/h/km) varied substantially in the course of the year, with highest activity in October, decreasing to a minimum in January-March and then rising again until June (fig. 6.6a). There was a roughly sixfold difference in mean flight activity between the busiest and the quietest months. For differences in species groups see table 6.1.

- *Gulls.* The pattern in figure 6.6a mainly reflects the abundance of gulls. Lesser black-backed and herring gulls that dominate this group were abundant in October and then strongly declined to low levels in winter, until foraging flights of birds from breeding colonies increased to peak levels in April-June (fig. 6.6c). Unfortunately there are no data from July-August that show whether this increase continues over summer and when peak flight activity of (large) gulls is reached. Literature data suggest that this may be in September, but this was not confirmed by our counts in that month. During November-January, gull numbers were dominated by Kittiwake and in February-March by Common Gull. Little Gull numbers were highest in October during southward migration, and again in April.
- *Landbirds* (passerines) were seen most commonly during the autumn migration period in October-November, and during spring migration in April (fig. 6.6b, 6.7). In these months, landbirds outnumbered waterbirds other than gulls at MpN (after correcting for detection effects), despite its distance from the shore. In autumn, a variety of species was involved including Starling, thrushes, larks, pipits and finches as well as a few raptors and pigeons. The onset of diurnal songbird migration which starts with pipits in the second half of September, was missed by our observations as these were made in the first week of that month. In April small songbirds predominated, notably Meadow Pipits.
- *Sea ducks and other ducks* occurred relatively evenly throughout the year, except for a near-absence in June, which is known to extend to July-August from other sources.
- *Geese* were seen on southward migration in Oct-Dec, and returning in February-March.
- A single flock of *Bewick's Swans* was seen in February, crossing from English winter quarters to the continent. Divers and auks occurred from October through March, with highest numbers in November-January.
- *Terns* were common in April and May, but absent in June, indicating that all birds seen at MpN were migrating towards distant breeding grounds instead of foraging locally or from breeding colonies like those at the Maasvlakte. The low number of terns observed in (early) September is noteworthy.
- *Cormorants* increased their flight activity through May and June; this reflects foraging trips of birds breeding in the coastal dunes north of The Hague. These foraging flights probably continue at a somewhat lower rate over summer into September-October, but Cormorants were absent at sea during the winter months.
- *Gannets* showed a continuous but somewhat irregular occurrence throughout much of the year, except for a near-absence in January-March.
- *Waders* were observed only in small numbers. Little was seen at MpN of the spring migration wave that normally occurs along the coast during late April and May. It is not clear whether this was caused by unfavourable timing/weather of our visits in these months, or by the birds migrating only close inshore, although the former seems likely.


Species composition - total

Species composition - excluding gulls

Species composition - gulls only

Figure 6.6 *Bird flight activity in distance zones 1-3 (0-3 km) during sea watches from observation platform MpN by month. The upper panel (A) gives the total flight activity, and the middle (B) and lower (C) break this down to species/groups for gulls (lower panel) and other bird groups (centre panel).*

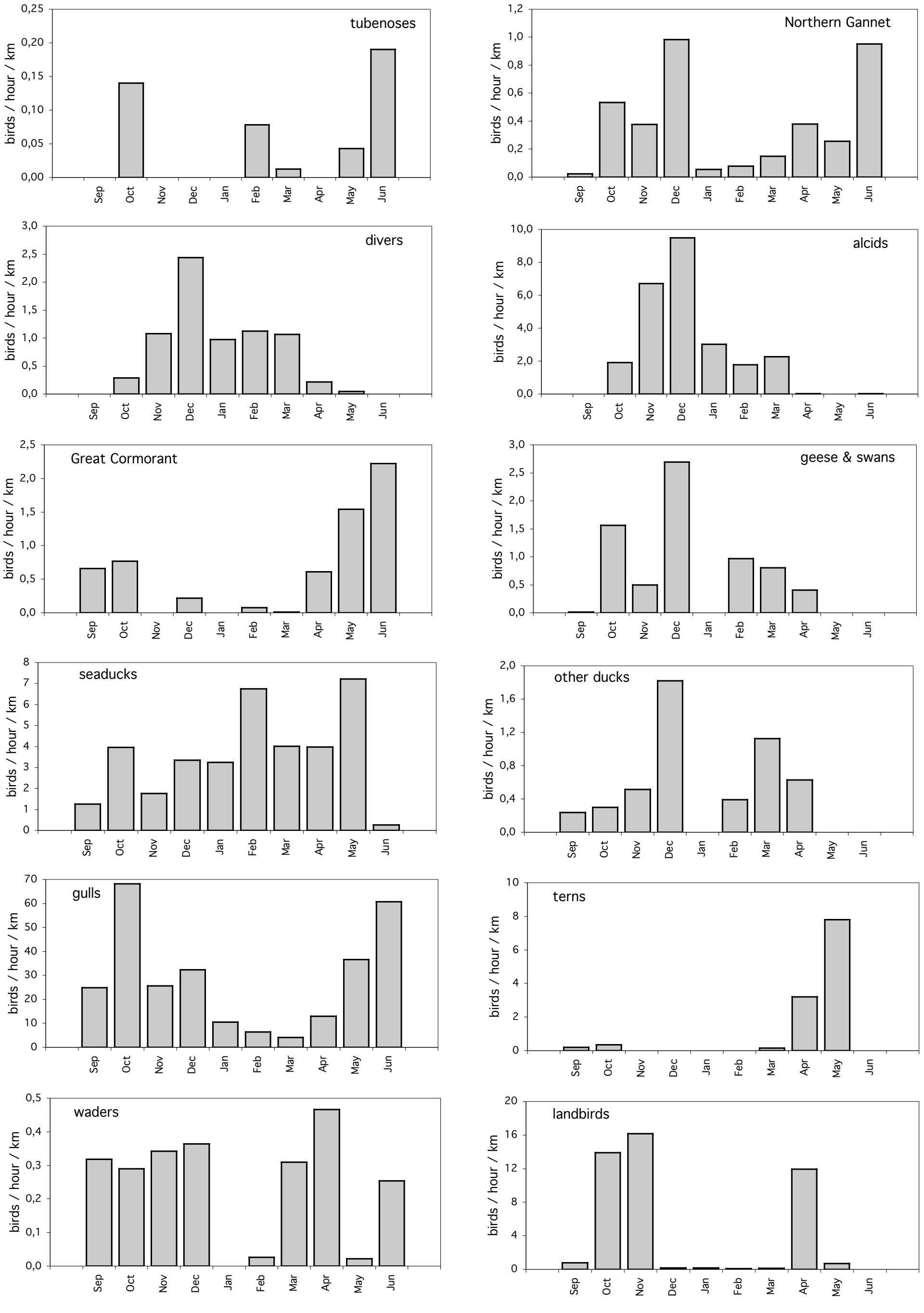


Figure 6.7 Flight activity of the commonest species groups in distance zones 1-3 (0-3 km) during sea watches from observation platform MpN, by month.

Table 6.1 Average flux (birds/hour/km) of species groups by month, during sea watches from observation platform MpN September 2003-June 2004.

species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
grebes	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
divers	0.0	0.3	1.1	2.4	1.0	1.1	1.1	0.2	0.0	0.0
tubenoses	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2
Gannet	0.0	0.5	0.4	1.0	0.1	0.1	0.1	0.4	0.3	1.0
Cormorant	0.7	0.8	0.0	0.2	0.0	0.1	0.0	0.6	1.5	2.2
geese & swans	0.0	1.6	0.5	2.7	0.0	1.0	0.8	0.4	0.0	0.0
other ducks	0.2	0.3	0.5	1.8	0.0	0.4	1.1	0.6	0.0	0.0
seaducks	1.3	4.0	1.8	3.3	3.2	6.8	4.0	4.0	7.2	0.3
skuas	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
gulls (total)	25	68	26	32	11	6	4	13	37	61
unidentified gulls	0.0	5.2	0.0	0.0	0.0	0.1	0.0	0.0	13.6	0.0
large gulls	24.8	31.6	7.3	4.8	2.8	0.7	0.9	9.7	23.0	60.6
small gulls	0.1	16.5	4.2	3.6	2.2	5.2	2.3	1.2	0.0	0.0
Little Gull	0.0	10.2	1.1	0.1	0.2	0.2	0.7	2.0	0.0	0.0
Kittiwake	0.0	4.5	12.9	23.8	5.4	0.3	0.4	0.1	0.0	0.1
terns	0.2	0.3	0.0	0.0	0.0	0.0	0.2	3.2	7.8	0.0
alcids	0.0	1.9	6.7	9.5	3.0	1.8	2.3	0.0	0.0	0.0
waders	0.3	0.3	0.3	0.4	0.0	0.0	0.3	0.5	0.0	0.3
landbirds (total)	0.8	14	16	0.0	0.0	0.0	0.0	12	1	0.0
small passerines	0.7	5.6	6.7	0.1	0.2	0.0	0.0	11.9	0.6	0.0
medium passerines	0.0	8.3	9.4	0.1	0.0	0.1	0.1	0.1	0.1	0.0
total birds	28	92	53	54	18	18	14	35	54	65

6.2 Daily patterns

6.2.1 Daily patterns of the common species groups (panorama scans)

Diurnal patterns in fluxes of the various species groups were analysed using the panorama scans. For many (groups of) species no apparent diurnal patterns existed during most of the seasons. The counts of these species are therefore shown for the entire period (fig. 6.9). For most of these species the densities were very low, except for the gulls. Diurnal patterns in species densities which were overall very low, have to be interpreted with caution, since very low bird numbers can have a strong effect on the emerging patterns.

- Figure 6.9 shows that *gulls* were less active during the early morning and at the end of the day.
- This seems to apply to *skuas* and *sea mammals* too, but their absence during these hours is probably a seasonal effect: during the winter no scans could be done before

6:00 and after 17:00 (fig. 5.30 – in § 5.4-daylength).

- *Divers* were most common during the early hours and numbers steadily decreased in the course of the day.
- *Tubenose* densities were highest at the start and end of the daylight period.
- *Wader* densities seemed to peak at the end of day, corresponding with the timing of migratory movements of many wader species.
- No apparent pattern could be detected in the *ship* densities.

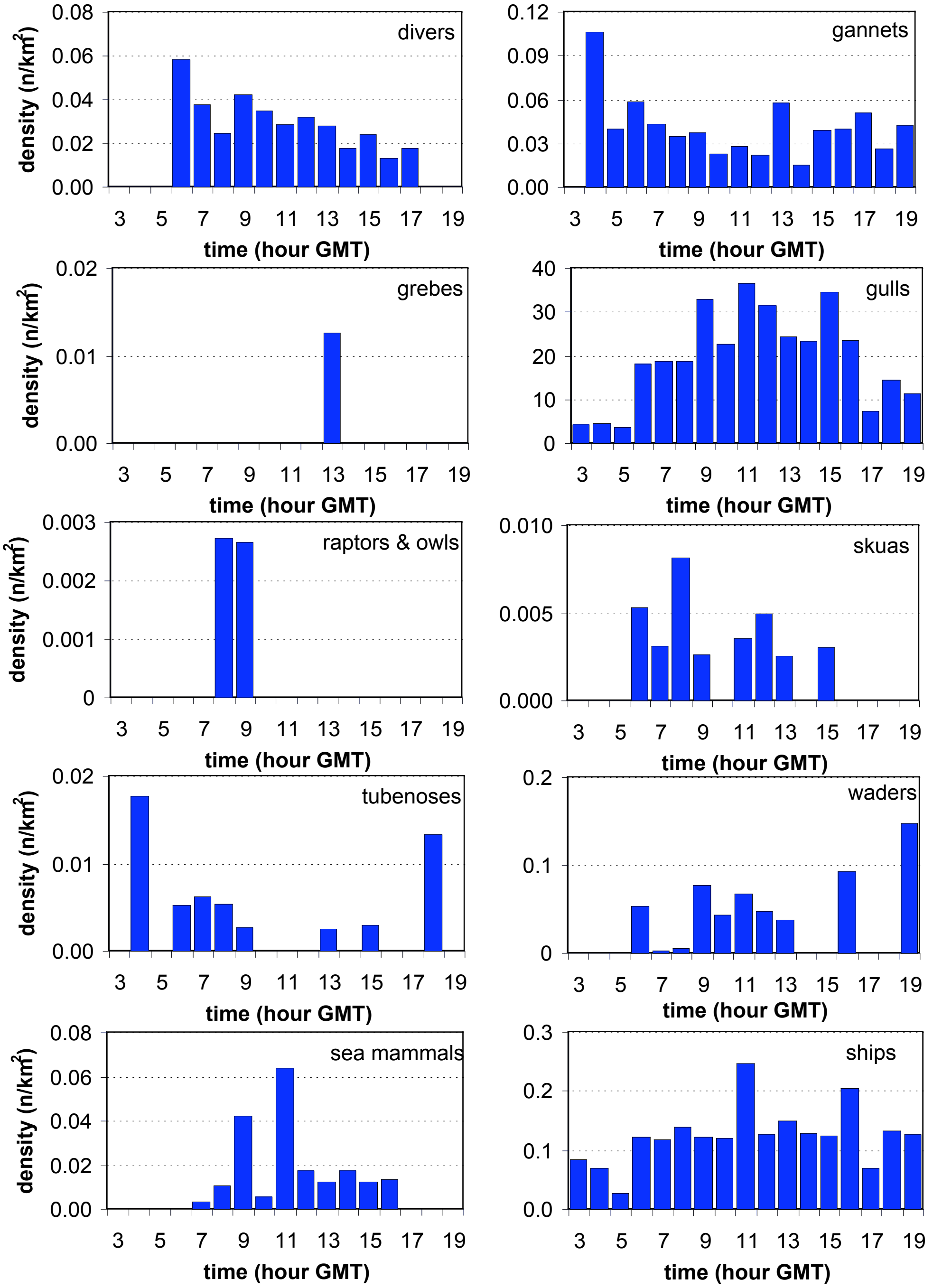


Figure 6.9 *Diurnal patterns throughout the entire observation period from October to June of bird, mammal and ship densities around the observation platform.*

In autumn (fig. 6.10), densities of alcids steadily increased until 15:00 h., after which densities suddenly dropped. Cormorants reached high densities only during the first hour of the day. Sea duck densities also peaked early in the morning and a second, lower, peak was observed during midday. Migratory species (geese & swans, land birds, other ducks and terns) showed highest densities during the morning. These species also seemed to have an increase in numbers at the end of the day. These patterns are the result of the birds' timing of migration. Many species migrate during the night, leaving the coast at dusk and returning at dawn.

A corresponding pattern was found at higher altitudes with the vertical radar, as shown in figure 8.4. An intriguing and, when compared with spring, different pattern through the night emerged of a very peaked pattern around sunset and sunrise in the highest altitude bands, with the largest peak around sunset. This is likely explained by the fact that relatively large concentration of migrant birds (mainly thrushes and other passerines) start there trans-North Sea flight from the dune area directly on the coast. The same concentrated departures happen in the morning with diurnal passerine migrants as chaffinches, pipits, starlings and others flying over sea. In spring migrants are active more evenly through the night as the source area is much wider from where the birds started their migratory flights. Moreover, these are located at much larger distances than compared to the Dutch coast as main source area in autumn.

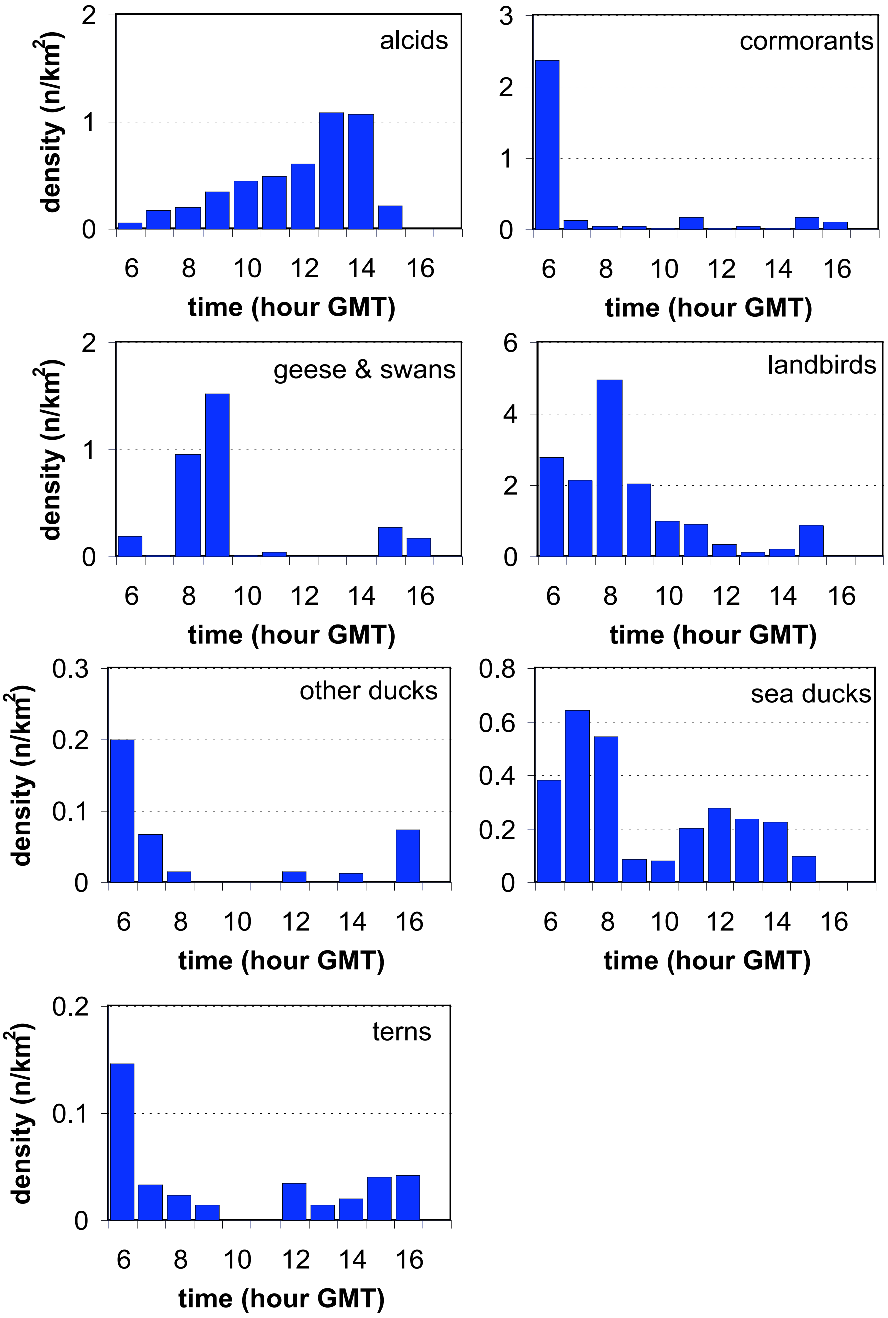


Figure 6.10 Diurnal patterns in autumn (October-November) of bird densities around the observation platform.

In winter (fig. 6.11), the diurnal patterns in densities observed in autumn disappeared. Migration of geese and swans took place in the morning. Sea ducks showed a high peak around 14:00.

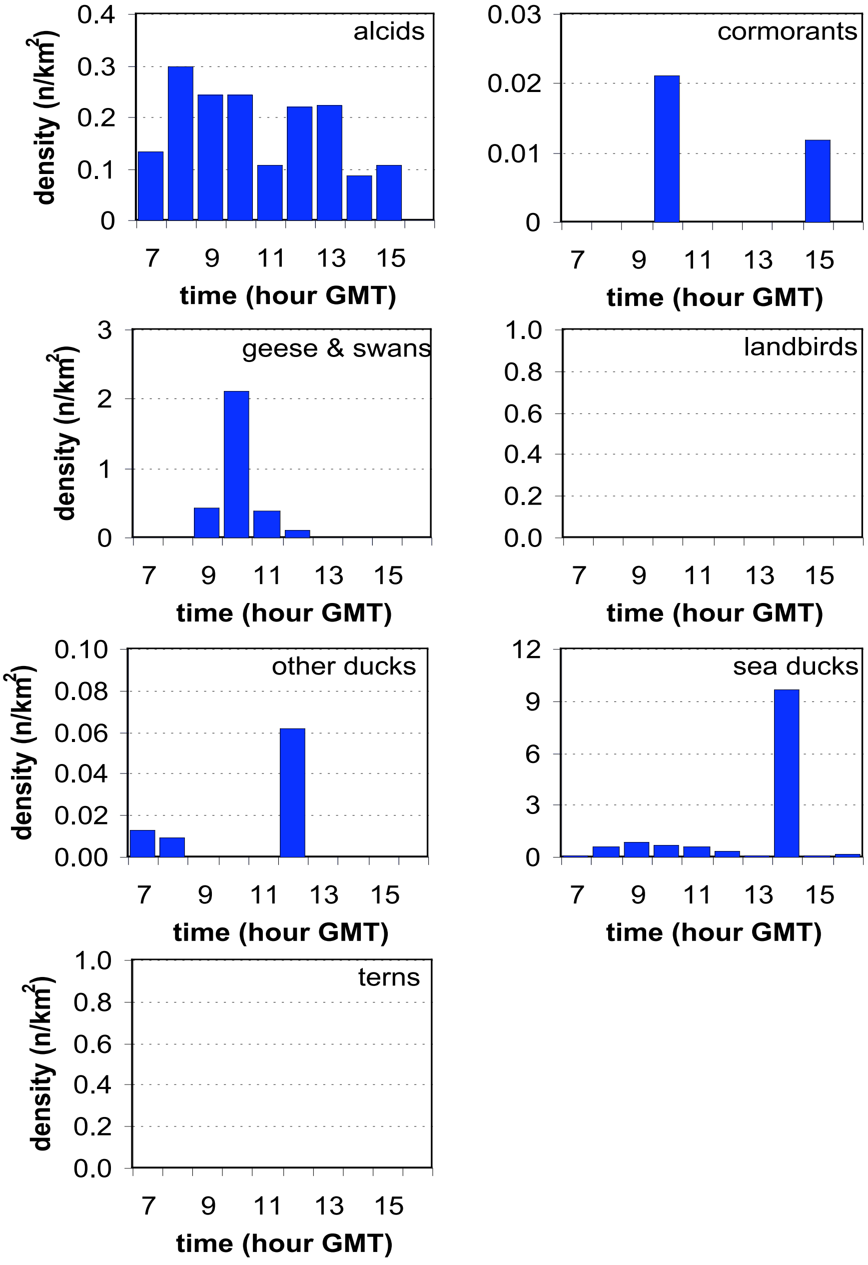


Figure 6.11 Diurnal patterns in winter (December-February) of bird densities around Meetpost Noordwijk.

In spring (fig. 6.12), geese and swans again showed a peak, but now during the afternoon. Migration of land birds was observed only during the morning. Sea duck densities peaked at the end of the day. In summer the densities of the species described in figures 6.10-6.12 were very low. Only cormorants were observed in densities up to 1 per km^2, peaking around 6:00 and 14:00.

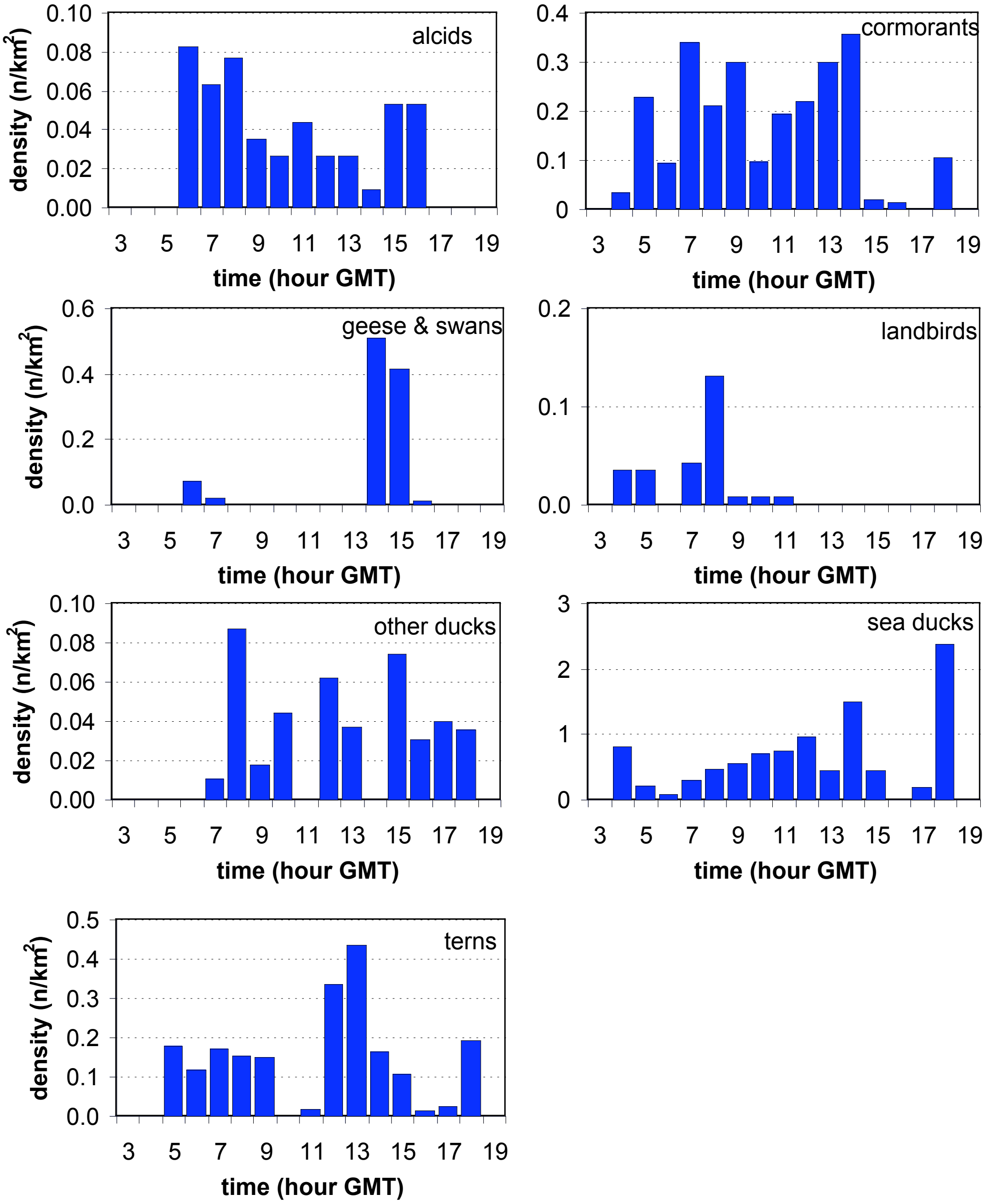


Figure 6.12 Diurnal patterns in bird densities around Meetpost Noordwijk in spring (March-May).

6.2.2 Daily patterns of species less frequent and at larger distances (sea watches)

For exploring diurnal patterns in flight activity of rarer bird species and species passing by at larger distances from the platform, sea watching data were used and divided into two periods, October-March and April-September (NB no data available for July-August). This was done in view of the marked differences in day length ('9 a.m.' has an entirely different meaning in December than in June), and of the fact that April-September include the breeding season and flights of gulls and cormorants operating from land-based breeding colonies may be organised differently in this period than at other times of the year. Clear differences in diurnal flight activity patterns indeed existed between these periods.

During October-March gull flight activity, and because of the numerical dominance of gulls also that of birds at large, showed a regular decrease throughout the day from a maximum in the early morning hours (fig. 6.13). This pattern was mainly caused by herring and lesser black-backed gulls. The early morning peak was formed by large gulls flying out to sea after roosting on land or at sea near the coast .The smaller gull species showed a flight activity that was much more evenly spread over the daylight period.

In April-June nearly all flying gulls were lesser black-backed gulls and (less numerous) herring gulls. There was no morning peak and no decreasing day trend; instead hourly averages varied around a stable mean. The two clock hours between 17:00 and 19:00 GMT were a clear exception, with much higher flight activity recorded. However, little observation effort was made in these hours (<5 hours, May and June only) so that the consistency of this peak is uncertain. Nevertheless, heavy gull traffic was observed on more than one evening in this period. These movements may have involved birds returning to land after a day's foraging at sea. Observations at the Maasvlakte, the main breeding colony of gulls observed at MpN, indicate that chick-feeding gulls make foraging flights almost only between dawn and dusk, with very little traffic to and from the colony during darkness (Van den Bergh et. al. 2002).

Flight activity of other waterbirds in October-March showed a less strong decrease over the day than that of gulls, but flux was generally higher in de morning than later in the afternoon (after 13:00 GMT; fig. 6.13). The apparently high activity in clock hour 11 may well be an artefact of a markedly lower observation effort (3.8 h instead of 11-15 h) in that hour, which usually included the coffee break at MpN. Higher flight activity in the morning was found in divers, alcids, and seaducks, but not in geese which were seen more often in the afternoon (fig. 6.14).

In April-September flight activity of non-gull waterbirds was relatively high in the early morning but decreased to a mid- to late-morning low, which was followed by an increase to maximum numbers during the afternoon (fig. 6.13). This pattern was caused predominantly by seaducks and terns; other groups hardly showed a clear diurnal pattern in activity. Peak migration of terns in the afternoon and early evening during spring has also been commonly observed during seawatches along the coast (H. Schekkerman). As terns migrate largely during the night, these movements may at least in part also concern local movements of terns flying to roosts or foraging movements.

Flight activity of landbirds across the sea during the autumn migration period was clearly concentrated in the early morning hours with a decrease towards the afternoon but a slight upsurge near dusk (Fig. 6.14). This resembles patterns of passerine migration observed over land. The occurrence of peak numbers not in the first hour after dawn but slightly later is also found in passerine migration overland. During the spring migration period, flying songbirds (mainly meadow pipits) were most observed not in the early but in the late morning hours, suggesting a start in areas at a larger distance (e.g. Delta area, Belgium, or even Southern England).

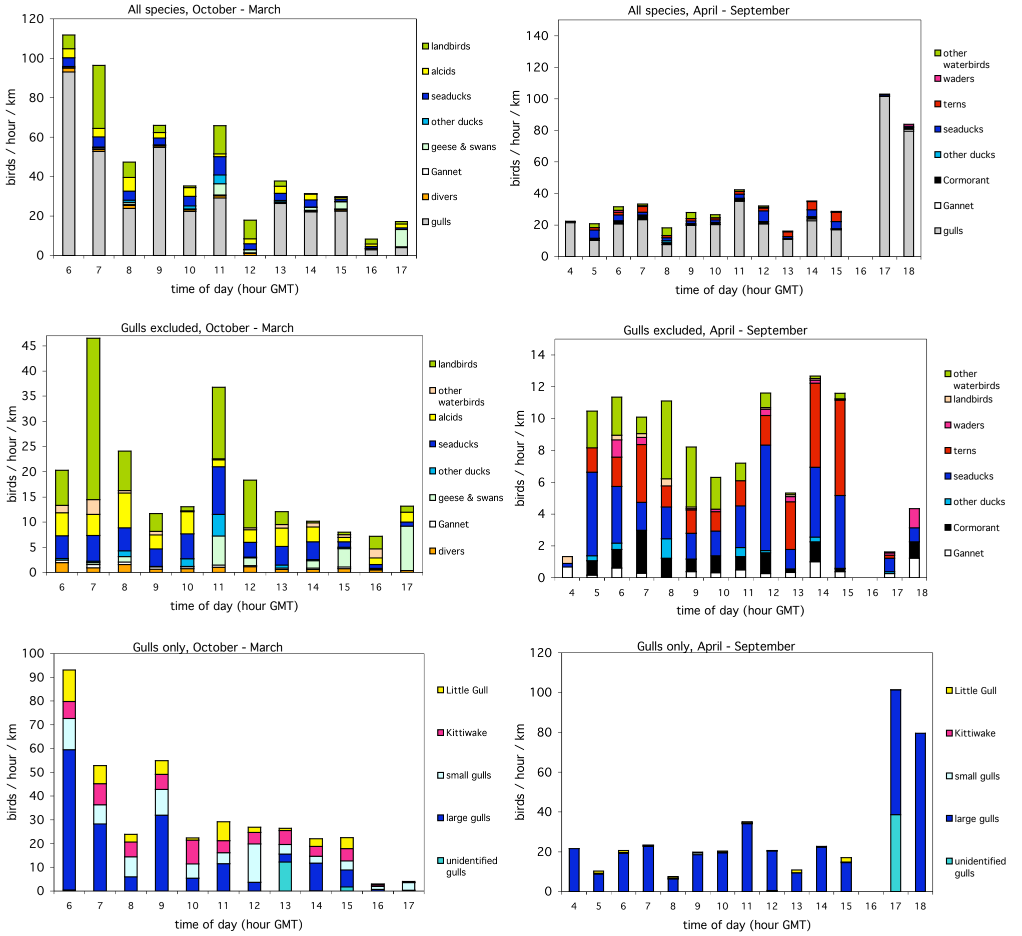


Figure 6.13 Mean traffic rate in distance zones 1-3 during sea watches from MpN by time of day, for the periods October-March (left) and April-September (right). The upper panels give the total flight activity, and the middle and lower break this down to species/group for gulls (lower panels) and other bird groups (centre panels).

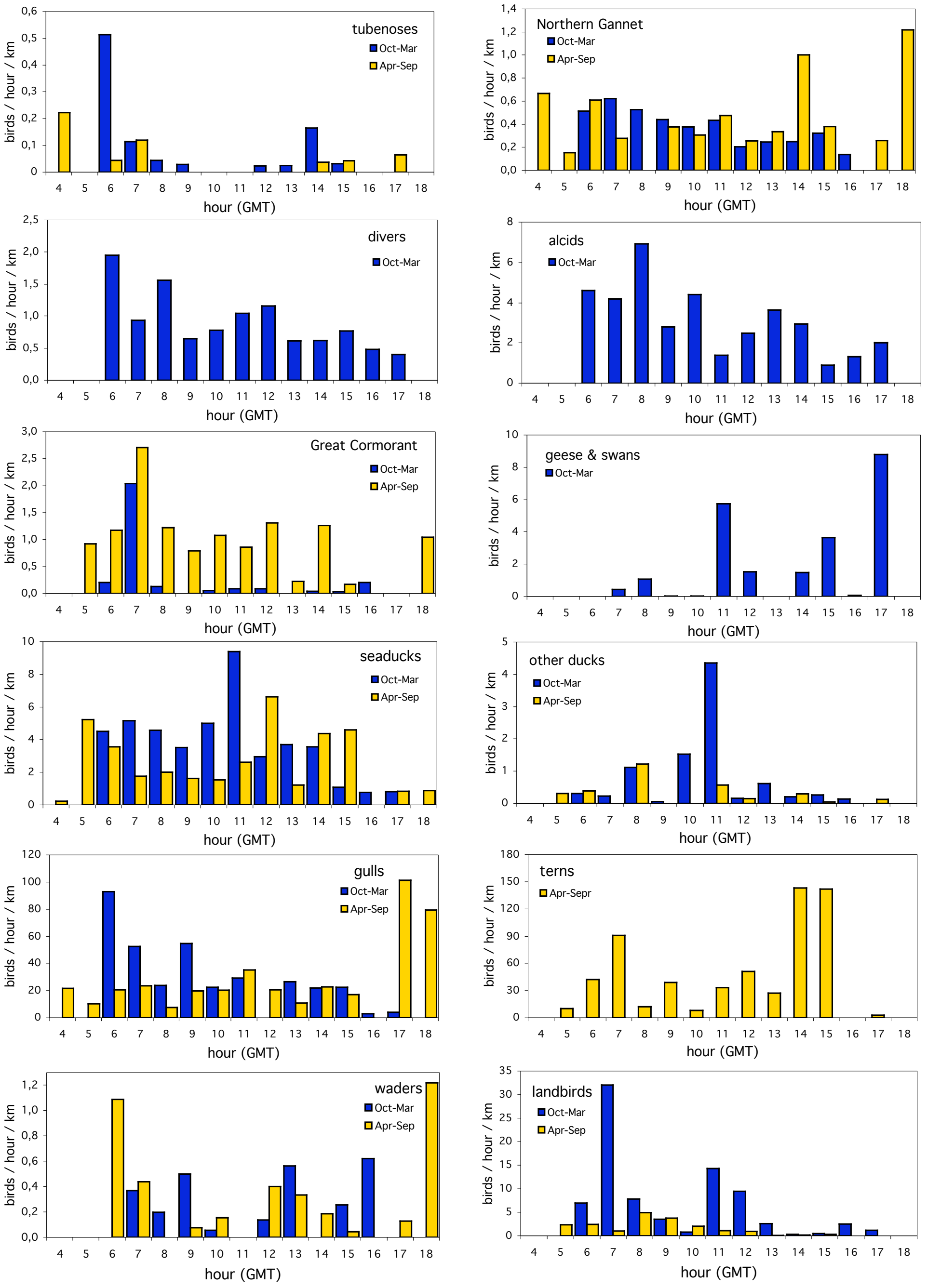


Figure 6.14 Mean traffic rate of common species groups in distance zones 1-3 during sea watches from MpN, by time of day, for the periods October-March and April-September).

6.2.3 Effect of wind speed on bird numbers

In general, flight activity of birds is lower when wind speeds are higher than with lower wind speeds. This was true for the birds flying in the study area as well. Fluxes decreased with increasing wind speeds, as shown by data from the vertical radar (fig. 6.15). This was the case for lower altitudes especially, although also at higher altitudes (except 150-250 m) fluxes decreased slightly with increasing wind speed (SPSS 13; log-transformed data; altitude 0-50m; residual analysis of wind after ANOVA on effect of month and dark/light; effect wind: $F_{1,\,2017}$=253,3 P=0,000; $r^2_{\text{month and dark/light}}$=0,56; r^2_{wind}=0,11).

Also bird numbers as determined with the panorama scans showed a relation with wind speed, although less explicit. For a given month, overall flight activity decreased significantly with increasing wind speeds. The effect was small however. Per species group, a significantly negative effect of wind speed was found for Gannets, gulls and landbirds. Cormorants and alcids showed a slight but significant increase in numbers with wind speed. Fulmars were exclusively seen during strong (north-)westerly winds (not tested statistically). Numbers of other species showed no relation with wind speed.

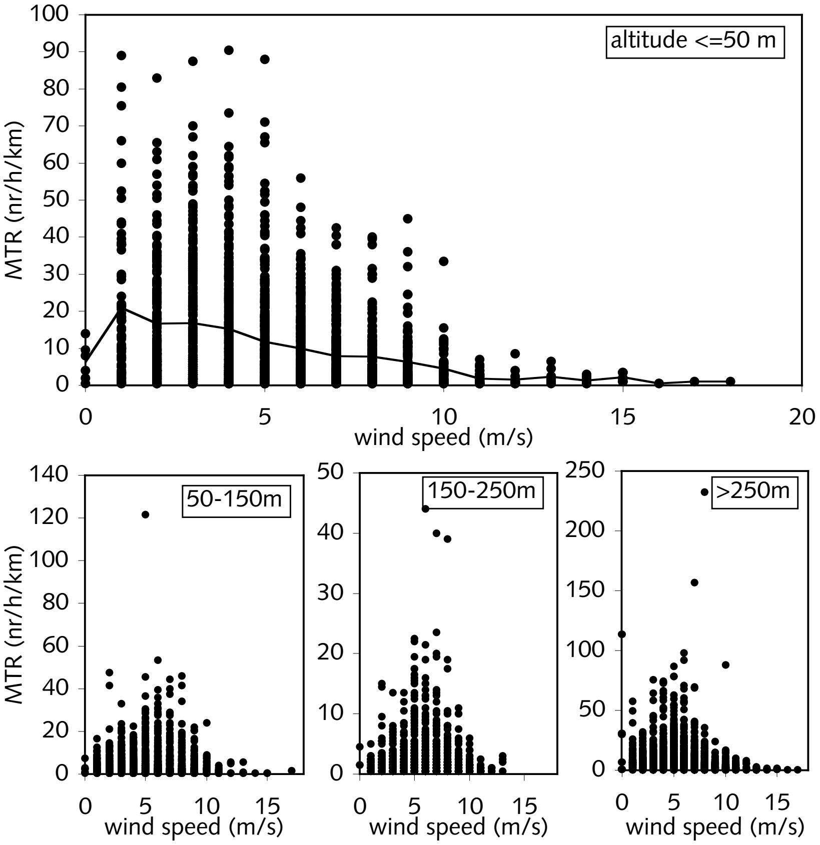


Figure 6.15 Relation between wind speed and mean traffic rate. Line in upper graph depicts averages. Values calculated on an hourly basis. Data from vertical radar, distance 500-1500 m from platform, MTR = avg. of N and S direction.

6.3 Nocturnal patterns

Nocturnal flight patterns can deviate largely from diurnal patterns. For example, some species migrate during daytime whereas others migrate at night. In addition, little is known about (flight) activity of local marine birds at night. Radar observations continued throughout the night, which gave a measure of nocturnal versus diurnal fluxes. Additional species information was obtained with visual and auditive information of nocturnal activity. This was achieved by monitoring migrating birds passing the platform by means of call-registration and moon watching. An automated recording system was developed for registration of bird calls at night, which used sound recognition to quantify fluxes at species level. This system is under development and no data could be shown for this report yet. In chapter 8 data on nocturnal fluxes at the various altitudes are presented in more detail.

6.3.1 Vertical radar

Data as obtained with vertical radar showed that fluxes at altitudes up to 250 m were lower at night then during daytime in virtually all months (Fig. 6.16, left panel). Only in October 2004 was the nocturnal low flux higher at night than during the day, probably reflecting low migration of thrushes. Flux at night was 0,5 (April, June) to 2,4 (October) times as high as flux during the day, which means that a considerable number of birds is active at night throughout the year. At night, gulls were regularly heard around the platform, and may constitute a large part of nocturnal flux at lower altitudes. In addition, local marine birds such as scoters and alcids althought assumed to be less active at night, may have constituted part of the nocturnal flux as well. This could however not be quantified at the platform, as these species are silent in flight and visual observations at night were restricted to higher altitudes (moon watching). Nocturnal activity of scoters in another part of the North Sea is discussed in Dirksen *et al* (2005).

At altitudes above 250 m (fig. 6.16, right panel), fluxes were higher at night than during the day. The difference was small in months without migration, when mostly local birds flying at lower altitudes were present in the area (November, December, September). An unknown amount of clutter was present in the data, which may increase levels of fluxes. However, flight activity does occur during daytime in the winter months, so these fluxes do represent birds, and the fact that nocturnal flux is highly similar to diurnal flux in these months, suggests that all fluxes do represent birds activity.

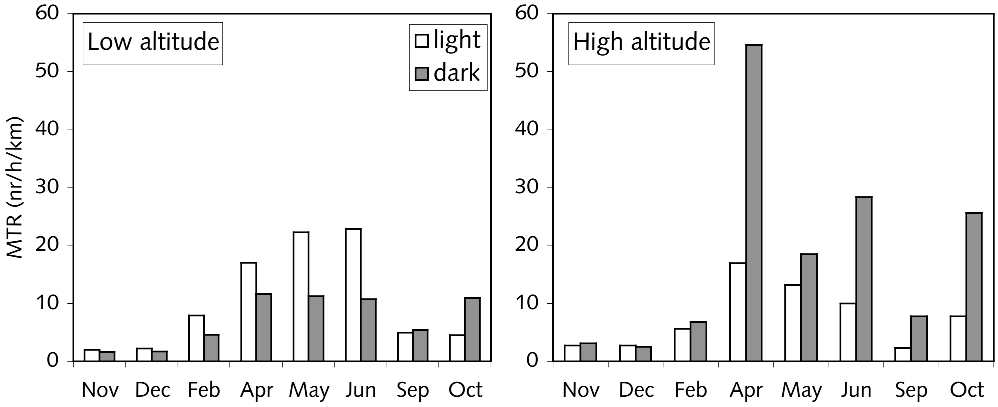


Figure 6.16 MTR during day and at night, for altitudes below (left panel) and above 250 m (right panel). Data from vertical radar, for distances of 500-1500 m to the north of the observation platform.

6.3.2 Nocturnal calls

Throughout the season, most passerines flying at night were heard in November (fig. 6.17). However, observations started late in October, due to which peak nights of migration may have been missed. Numbers of waders and swans and geese that were heard at night were low, and no evident differences in flight intensity between months could be established. Is should be noted that calls were recorded only from September to April (January excluded). During the peak of spring migration, no observations could be made from the platform.

Of the migrant species, passerines were the most abundant species group that was heard (table 6.2). Of all calls heard, 97% were of passerines. In addition, waders and swans and geese were heard. Calls of gulls flying around the platform were heard regularly, but were not recorded as most of the observations probably applied to local birds around the platform (and no flying birds). Nocturnal flight intensities of this species group are however assumed to be high, as large numbers of gulls were seen flying around fishing vessels fishing at night.

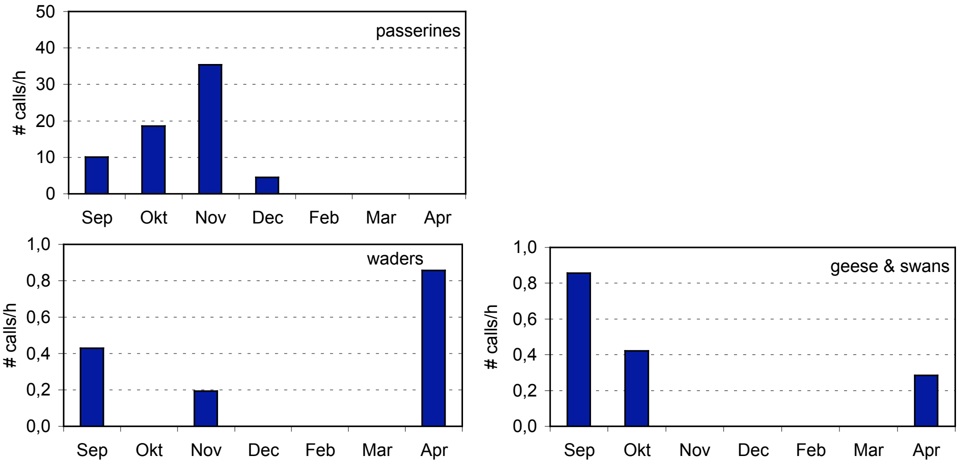


Figure 6.17 Seasonal variation in number of nocturnal calls heard at the observation platform MpN, shown for the four species groups that were heard.

Table 6.2 Species and number of calls that were heard during nocturnal call sessions. For passerines, individual birds are counted, for geese and waders flocks are counted.

group	species	calls or flocks
passerines	Redwing	337
	Song Thrush	81
	Blackbird	11
	Skylark	1
geese	Brent Goose	7
waders	Oystercatcher	2
	Snipe	2
	Greenshank	1
	Curlew	1
total	Grand Total	443

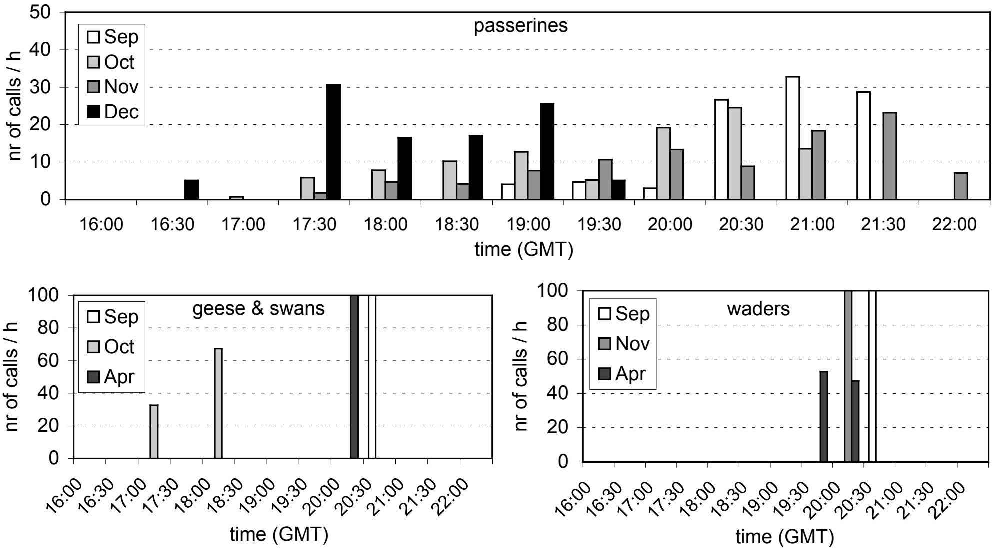


Figure 6.18 *Timing of migration of passerines, waders and geese during the evening hours, as recorded from calls heard. Data are presented as percentages of the total number of calls heard of the concerning species group in that month. Data are not corrected for the shift in the time of nightfall.*

Migration of passerines (thrushes) increased gradually after dark (fig. 6.18). The 'peak' in migrating numbers of passerines fell earlier as winter progressed and darkness fell earlier in the day. Only the observations in November, which had a similar species composition as in October, did not match this pattern. As observations were not continued throughout the night, but stopped at 21:00-22:00 h GMT, patterns throughout the night were not established from calls. These however will become clear from the radar observations.

6.3.3 Moon watching

Counting birds passing the disk of the full moon is a standardised technique to obtain quantitative estimates of numbers and flight altitudes of birds flying nocturnally up to altitudes of 1 km (Liechti *et al.* 1995). On 5 nights in October and November 2003, estimates of numbers of birds migrating in the dark were made by means of moon watching. A total of 344 birds were seen passing the disk of the moon. In October, most of these birds were thrushes, probably mostly redwings, based on calls heard simultaneously (see § 6.3.1). In November, besides thrushes also considerable numbers were seen of small passerines, waders (flocks of lapwings and curlews), and some geese (table 6.3). Observed numbers have been transformed into mean traffic rates based on calculations performed by the Schweizerische Vogelwarte, Sempach, Switzerland. In these calculations the trajectory of the moon during the night is taking into account to correct for the change in sampled air volume. The calculations are detailed enough to allow calculation of MTR's (table 6.4). It is clear that these MTR's are much higher than the nocturnal fluxes based on the vertical radar presented in § 6.3.1. The MTR's are higher in magnitude than during the day as one would expect comparable to e.g. Zehnder *et al.* (2001).

Table 6.3 *Species and number of birds seen during moon watching sessions in autumn 200*
3

date/time	species	# birds
11 Oct 03	thrush	29
18:30-20:30	curlew	2
	wader	1
12 Oct 03	small passerine	3
18:30-20:30	thrush	127
	woodcock	1
	duck	2
13 Oct 03	small passerine	1
20:00-20:30	thrush	17
5 Nov 03	thrush	1
20:00-22:10	gull	1
	unidentified	1
6 Nov 03	small passerine	21
17:35-20:30	thrush	45
	starling	1
	wader	7
	curlew	10
	lapwing	37
	duck	9
	goose	13
	duck/goose	9
	gull	3
	unidentified	3
	total	344

Table 6.4 *Mean traffic rates in the dark based on visual observations of birds passing the disk of the full moon ('moon watching'). Calculations performed by the Schweizerische Vogelwarte, Sempach, Switzerland.*

Date	MTR	N birds	Observation time
11-10-03	1606	15	47
12-10-03	2203	37	100
13-10-03	1995	14	45
5-11-03	168	3	130
6-11-03	2219	74	175

6.4 Conclusions

- Fluxes, expressed as mean traffic rates (MTR), measured during daytime by the vertical radar correlated with numbers of birds observed in the panorama scans. MTR's obtained through the different observation techniques thus were in the same order of magnitude and are similar to values measured by Van Gasteren *et al.* (2002). Although nocturnal MTR's obtained by moon watching were much higher than those obtained by vertical radar, this can be explained by the difference between nights with (moon watching, no radar) and without (radar) strong migration. The large range setting that was used for the vertical radar (1,5 NM), may have resulted in a reduced detection probability of smaller species (passerines). Variation in fluxes between day and night, and over the seasons has been established. The correlation between the various techniques was not very high, due in part to high variation in bird numbers (gulls especially) during the day.
- Detection by the radar of groups rather than individual birds (as in the panorama scans) contributed largely to this difference, as well as the fact that the radar was not operating on days with strong migration, whereas these are included in the panorama scans.
- Fluxes were highest in October, November and December (§6.1). These were dominated by flight movements of gulls, which constituted ca. 90% of all birds present in the area. Gulls were most abundant in October through December (mainly wintering Herring - and Greater Black-backed Gulls) and in May and June (mainly Lesser Black-backed Gulls from breeding colonies at the coast) (no counts of August-September).
- Fluxes throughout the day varied largely between the various species. Some species such as gulls were more active in the middle of the day, whereas others were mostly active at dawn and dusk or at night (§6.2).
- Fluxes at altitudes up to 250 m were higher during the day than at night, reflecting high activity of gulls mostly but not exclusively during day time. Many seabirds such as gulls are assumed to be less active at night, which explains the lower fluxes at night. However, considerable numbers of gulls were active behind fishing vessels at night, as visual observations showed.
- At high altitudes, fluxes were higher at night, especially during migration periods in October and April-June. Fluxes of migratory birds had higher levels at night than during the day. Moon watching shedded light on species composition and confirmed findings on nocturnal fluxes as determined with vertical radar (§6.3).
- The panorama scans and sea watches yielded clear patterns of the abundance of the various species of birds. Flight movements of gulls were dominant and were mainly determined by availability of fishing vessels, which are fishing at all hours of the day (except for the weekend, see further §7.3 and Poot *et al.* 2000). Part of the Cormorants at sea also feed behind fishing vessels. In the breeding period most movements are feeding trips between colonies and open sea. In autumn, clear migration patterns were observed in early morning. The numbers and patterns of other seabird species fit well with the known patterns on the occurrence of species under the Dutch coast according to extended sea watch data over several years (Camphuysen & van Dijk 1983, Platteeuw *et al.* 1994), with ship based observations offshore (Camphuysen & Leopold 1994, Skov *et al.* 1995), with intensity of migration

of landbirds along the Dutch coast and across the North Sea (Lensink *et al.* 1999, 2002), and when taking into account the changes in numbers of breeding pairs of species along the Dutch coast (SOVON 2002). Migratory species like geese and swans, ducks, landbirds, waders and terns show clear patterns, due to timing of migration. Only the patterns of flight movements of sea ducks and alcids are less easy to interpret and may be a mix of movements between feeding sites, of migration and of correction for drift (tide/wind).

7 Flight paths

In this chapter we present flight paths of the birds in the study area. Flight paths include results on species composition (§7.1), flight directions in general and of the various species groups through the season and during the day (§7.2), and also patterns in flight paths that were observed, such as associations of gulls with fishing vessels (§7.3). Results on flight paths are based primarily on observations with panorama scans and horizontal radar. Sea watches and nocturnal observations give additional insights. Results are summarised in §7.4.

7.1 Species composition

7.1.1 Diurnal species (panorama scans)

Gulls were by far the most numerous species group observed in the panorama scans (table 7.1). Of all birds seen within distances of 3 km, 92% were gulls. Landbirds, mostly migrants (3%), and sea ducks (2%) were the next most abundant groups, although these were far less numerous than gulls. Landbirds were mainly observed during migration in autumn and spring, with the highest numbers in October and November and lower numbers in April. The most common species seen were Starling, Meadow Pipit and Skylark. Redwings were very scarce during the day, whereas they were very common during nocturnal migration (see § 7.1.3).

About a quarter of the gulls observed, was floating on the sea surface. Other groups seen floating on the water in relatively high percentages were sea ducks (40%) and alcids (46%; table 7.1). In relation to all birds observed, the overall percentage of gulls, landbirds (all flying) and sea ducks hardly changed when looking at flying birds only.

During all 935 panorama scans, 84 species or species groups of birds were observed (table 7.3). Of these, 64 could be identified to the level of species. In the low scans, ca. 14% of all birds was determined to species level, the remainder only to group or subgroup level. In the high scans this value was 34%. In addition to birds, also sea mammals (mainly porpoises) and ships (mainly fishing vessels) were observed regularly.

Of all birds observed in the panorama scans at distances 1, 2 and 3, more than 90% was seen in the low scan (table 7.2). This indicates that most birds flew in the lower air layers. In the high scan, landbirds were remarkably numerous, indicating that migrants flew relatively high.

Results of both the low and the high panorama scan (table 7.1 & 7.2) show that at larger distances small birds were observed relatively little. For this reason most selections and analyses were made for birds seen at distance 1, 2 and 3. At these distances larger species are seen always, but among smaller species, birds or flocks are missed at distances larger than 1000 m (Lensink *et al.* 1999, Poot *et al.* 2000). This aspect is explained in more detail in § 5.4.

Table 7.1 Number and species composition of birds (groups) seen flying versus floating on the sea-surface, in the panorama scans within distance class 1, 2 and 3 and in class 4. Both the overall number of birds and the percentage of the total is given. Sea mammals and ships are excluded from the total.

	distance 1, 2, 3				distance 4			
	flying		floating		flying		floating	
	#	%	#	%	#	%	#	%
alcids	456	0,5	396	1,3	9	0,0		0,0
cormorants	709	0,8	52	0,2	601	0,8	12	0,7
divers	132	0,2	7	0,0	21	0,0		0,0
gannets	193	0,2	19	0,1	49	0,1		0,0
geese & swans	973	1,1	56	0,2	1.148	1,4		0,0
grebes	8	0,0	1	0,0		0,0		0,0
gulls	77.554	91,2	28.859	94,7	77.193	96,9	1.703	98,8
landbirds	2.782	3,3		0,0		0,0		0,0
other ducks	102	0,1	8	0,0	119	0,1	8	0,5
raptors & owls	4	0,0		0,0		0,0		0,0
sea ducks	1.630	1,9	1.077	3,5	362	0,5		0,0
skuas	14	0,0		0,0		0,0		0,0
terns	313	0,4	3	0,0	7	0,0		0,0
tubenoses	10	0,0		0,0		0,0		0,0
waders	149	0,2		0,0	121	0,2		0,0
total	85.029		30.478		79.630		1.723	
sea mammals	74				1			
ships	598		4		2.424		7	

Table 7.2 *Number and species composition of birds (groups) seen in the low and in the high panorama scans, within distance class 1, 2 and 3 and class 4. Both the overall number of birds and the percentage of the total is given. Sea mammals and ships are excluded from the total.*

	distance 1, 2, 3				distance 4			
	low scan		high scan		low scan		high scan	
	#	%	#	%	#	%	#	%
alcids	837	0,8	15	0,1	9	0,0		0,0
cormorants	654	0,6	107	0,9	510	0,7	103	1,9
divers	94	0,1	45	0,4	17	0,0	4	0,1
gannets	162	0,2	50	0,4	43	0,1	6	0,1
geese & swans	706	0,7	323	2,8	895	1,2	253	4,7
grebes	5	0,0	4	0,0		0,0		0,0
gulls	96.896	93,2	9.517	82,8	73.981	97,4	4.915	91,2
landbirds	1.701	1,6	1.081	9,4		0,0		0,0
other ducks	88	0,1	22	0,2	92	0,1	35	0,6
raptors & owls	2	0,0	2	0,0		0,0		0,0
sea ducks	2.505	2,4	202	1,8	326	0,4	36	0,7
skuas	13	0,0	1	0,0		0,0		0,0
terns	220	0,2	96	0,8	7	0,0		0,0
tubenoses	10	0,0		0,0		0,0		0,0
waders	122	0,1	27	0,2	84	0,1	37	0,7
total	104.015		11.492		75.964		5.389	
sea mammals	69		5		1			
ship	590		12		2.364		67	

Table 7.3 Species observed at MpN during panorama scans between October 2003 and June 2004, for each species in each scan-position the proportion (%) relative to the total number in a species group (table 7.2) is given.

		distance 1, 2, 3		distance 4	
		low scan	high scan	low scan	high scan
alcids	Guillemot	233	3		
	Little Auk	2			
	Razorbill	17			
	Razorbill/Guillemot	585	12	9	
cormorants	Great Cormorant	654	107	510	103
divers	diver spec.	65	43	17	3
	Red-throated Diver	29	2		1
gannets	Northern Gannet	162	50	43	6
geese & swans	Barnacle Goose	27		225	
	Bean Goose	135	1		
	Bewick's Swan			100	
	Dark-bellied Brent Goose	302	179	171	14
	goose spec.	206	107	399	156
	Greylag Goose	28	34		83
	White-fronted goose	8			
	Whooper Swan		2		
grebes	Great Crested Grebe	5	4		
gulls	Black-backed Gull spec.	7003	56	2623	215
	Black-headed Gull	419	72	12	
	Common Gull	2080	432	15	4
	Common/Herring Gull	2			1
	Great Black-backed Gull	1373	480	76	35
	gull spec.	39921	471	48890	2302
	Herring Gull	3317	790	63	35
	Her subad/Les. B-b. Gull	2			
	Kittiwake	5735	906	29	
	large gull	26250	4900	21731	2222
	Lesser Black-backed Gull	3728	1089	300	78
	Little Gull	689	14	3	
	Little/Black-headed Gull	1			
	Med. Yellow-legged Gull	12	1	1	
	small gull	6364	306	238	23
landbirds	Chaffinch		1		
	finch spec.		1		
	Great Tit	6	4		
	Grey Heron		7		
	Homing Pigeon	1	1		
	Jackdaw	3			
	lark spec.	43			
	Linnet		1		
	Meadow Pipit	167	80		
	Pied Wagtail	3			
	pipit spec.	26	26		
	Redwing	8			
	Skylark	131	80		
	Song Thrush	1			
	songbird spec.	411	96		
	Starling	867	771		
	Swallow	3			
	Swift	1			
	thrush spec.	30	3		
	Wood Pigeon		10		
other ducks	Common Shelduck	10			
	duck spec.	5	10	92	35
	Eurasian Wigeon	27	8		
	Mallard	3			
	Northern Pintail	8			
	Northern Shoveler	2			
	Red-brested Merganser	15	4		
	Teal	15			
	Tufted Duck	3			

Table 7.3 Continued.

		distance 1, 2, 3		distance 4	
		low scan	high scan	low scan	high scan
raptors & owls	falcon spec.	1			
	Hen Harrier		1		
	Merlin	1			
	Sparrowhawk		1		
sea ducks	Common Scoter	2382	148	311	36
	Eider	122	54	15	
	Velvet Scoter	1			
skuas	Arctic Skua	6			
	Great Skua	7	1		
terns	Common Tern	14			
	Common/Arctic Tern	115	71		
	Sandwich Tern	91	25	7	
tubenoses	Northern Fulmar	9			
	Sooty Shearwater	1			
waders	Bar-tailed Godwit		1		
	Dunlin	4			
	Eurasian Curlew	41	18		
	European Golden Plover	19			
	Grey Plover	6	6		
	Lapwing				2
	Red Knot	8			
	Ruddy Turnstone	7			
	wader spec.	37	2	84	35
	total	104015	11492	75964	5389
sea mammals	Harbour Seal	2			
	Porpoise	67	5	1	
ship	fishing vessel - large trawler	7	1	29	6
	fishing vessel - ordinary trawler	574	11	2317	61
	fishing vessel - twin	9		18	

7.1.2 Diurnal species less frequent and at larger distances (sea watches)

To increase the number of observations of less abundant bird species, especially seasonal migrants of the seabird species, sea watching at MpN was performed mainly as an addition to panorama scans. This is reflected in the presentation of results. Flights of gulls, being very common and showing a great directional diversity, are better described by the panorama scans and this section therefore focuses on the patterns seen in other groups, although gulls are also presented to illustrate relative abundance. In this paragraph, results are presented for flying birds only, as they form the main focus of Lot 6 of the MEP-NSW. Birds sitting on the sea surface are recorded more effectively with the panorama scans and with the ship-based surveys deployed in Lot 5. Species groups definitions are identical to those used throughout the report.

Overall species composition

In total, 77 bird species were identified during sea watches. The majority of birds was seen in distance zones 1-3, at 0-3 km distance from the platform. Table 7.4 shows that large and conspicuous birds such as cormorants, divers and large gulls, were observed more often at >3 km distance than smaller birds like passerines. The mean fluxes within 0-3 km of the platform therefore give a better picture of relative abundance of species groups, especially as detectability of passerines has been corrected for.

As expected, gulls were by far the most abundant flying birds, and made up two thirds of the total flux (table 7.4). Large gull species dominated this group (with about 60% of the gulls and 40% of total bird movements), with ratios between lesser black-backed gull, herring gull and greater black-backed gull about 6:3:1. Among the smaller gulls, black-legged kittiwake was the most abundant species followed by common gull, little gull and black-headed gull respectively. Mean flight activity of gulls was notably elevated by an exceptional observation of 4200 unidentified gulls following a passing fishing vessel in half an hour on 28 October (22% of the total number of gulls in the dataset). Removing this observation however makes little difference to the dominance of gulls in overall bird flight activity (64% instead of 67% of the mean total flux). It had a larger influence on calculated means of flight activity by month and by time of day, and was therefore omitted from those calculations.

Landbirds were the second-commonest group after the gulls, dominated by small (6%) and medium-sized passerines (4%). The fact that MpN is situated within the centre of the 'hollow bend' in the Dutch mainland coastline may partly account for the high abundance of landbirds; in good weather and with eastern winds many landbirds appear to cut this bend short across the sea. The fact that MpN could only be manned in weeks starting with calm weather conditions will have biased our observations to conditions in which overseas flights of landbirds occurred. Over an entire year, the relative share of landbirds may thus be somewhat lower than our data suggest.

Seaducks (8%) and alcids (6%, mainly guillemot and razorbill) were the commonest waterbird groups after gulls. All other groups together made up no more than 10% of the total bird movements. Of these species, only terns, geese and swans, ducks, divers, great cormorant and northern gannet exceed 1%. These proportions are somewhat influenced by the fact that our observations do not span the whole year; e.g. watches in July-September are likely to increase the share of terns in the totals.

Table 7.4 *Species group composition of flying birds observed during sea watches from MpN. Totals are given for distance zones 1-3 (0-3 km) and 4 (>3 km) separately. The mean flux (#/km/h) in zones 1-3 was calculated by averaging monthly figures. Groups are listed in decreasing order of abundance; at the bottom of the table a breakdown of the gulls is given.*

species	total counted zones 1-3 (<3km)	total counted zone 4 (>3 km)	mean flux zones 1-3 (<3 km)	% of mean flux zones 1-3 (<3 km)
gulls	16825	4328	28.2	65.5%
landbirds	1619	15	4.0	10.2%
seaducks	1968	639	3.6	8.3%
alcids	1166	149	2.5	5.7%
terns	651	113	1.2	2.7%
divers	325	80	0.7	1.7%
geese & swans	401	197	0.7	1.6%
Cormorant	332	239	0.6	1.4%
other ducks	281	42	0.5	1.2%
Gannet	192	102	0.4	0.9%
waders	155	45	0.2	0.6%
tubenoses	27	1	0.0	0.1%
skuas	25	5	0.0	0.0%
grebes	8	0	0.0	0.0%
total birds	23933	5967	43.1	100%
Little Gull	1363	32	1.5	3.4%
Kittiwake	2048	61	4.8	11.0%
small gulls	2608	159	3.5	8.2%
large gulls	9628	3527	16.6	38.5%
unidentified gulls	1178	549	1.9	4.4%

7.1.3 Nocturnal species

Migratory birds

Passerines were the most abundant species group that was heard and seen during moon watching sessions (table 6.2 in § 6.3.2 and table 6.3 in §6.3.3). Of all calls heard, 97% were of passerines. Of these, 76% were of Redwings. Similar results were obtained through moon watching, were the majority of observations concerned thrushes. Redwing calls were recorded exclusively at night, as this species migrates at night and not during daylight hours. Similarly, Meadow Pipits and Starlings migrate during daylight hours and were not recorded at all during the nocturnal sessions.

Gulls

During the nightly observations, gulls could be seen flying around the platform. In addition, large numbers of gulls were seen in association with fishing vessels at night (see §7.3). It appears that breeding birds, that show far less activity at night (van den Bergh *et al.*, 2002), stay mostly in the colonies on shore at night, whereas non-breeding birds keep on foraging at sea.

7.1.4 Species composition as observed with radar

The radar was expected to provide data that could be allotted to species groups. The large number of different echo characteristics that was recorded with each signal supposedly would have allowed an interpretation at least to a number of species groups. However, such an interpretation proved to be impossible during the course of the study. As discussed in §5.2 and §5.3, a large amount of clutter was recorded by both radars, and especially by the horizontal radar, obscuring patterns of flying birds. Analysis of the echoes therefore concentrated on separating echoes of birds from those of clutter and ships. These three groups could not be entirely separated. Consequently, analysis of echo characteristics in order to identify species groups was not possible.

7.2 Flight directions

One of the main questions in this project concerns the direction in which birds are flying above sea. In general one can distinguish three types of movements:

- seasonal migration characterised by highly directed flight movements
- local movements characterised by directed movements determined by the location of origin and/or destination areas
- local movements characterised by random movements, e.g. in search of feeding opportunities

In this paragraph we first present the general patterns in flight directions throughout the season and throughout the day, as quantified with the horizontal radar observations. As gulls form the majority of the birds flying at the study area, these general patterns are highly determined by flight directions of gulls. Subsequently we present the flight directions of the various species groups as observed with panorama scans, followed by the flight directions of rarer birds as quantified by sea watches.

7.2.1 Main flight directions and seasonal and daily patterns (horizontal radar)

Flight directions were calculated (following Lensink & Kwak 1985) for each of the months October '04 (fall migration), February '04, April '04 (spring migration) and June '04. General directions were calculated regardless weather wind was favourable for migration or not, weather a lot of clutter was present around the platform or not, weather it was day or night, etc. This yielded highly undirected flight patterns (fig 7.1). As the majority of birds flying in the area were gulls, this lack of direction reflects the random flight movements of gulls (see § 7.2.2). However, also the presence of clutter in the data, moving in any possible way (see fig 7.7), contributed to a lack of general direction. That these factor largely affected overall flight direction, is clear when we depict flight directions on several days in October with little clutter (fig. 7.2). The general direction towards the southeast is in these graphs very clear.

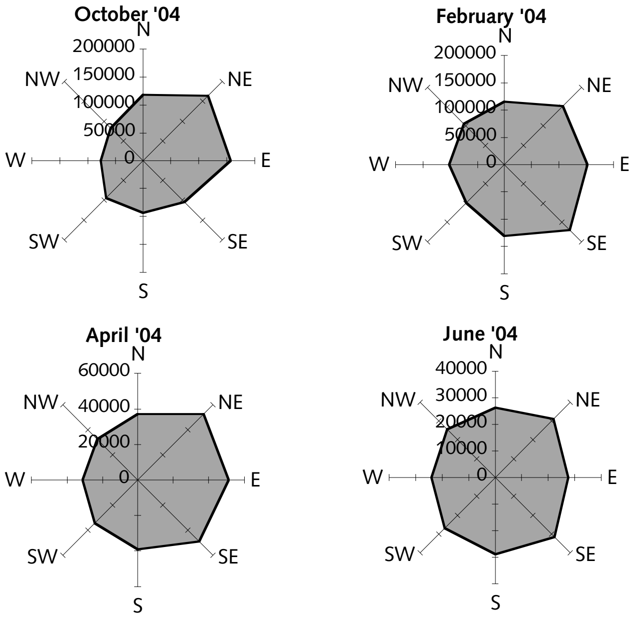


Figure 7.1 Mean flight directions per month, at a distance of 2–6 km from the platform, as observed with horizontal radar. Data of both day and night, and both favourable and unfavourable weather conditions are included. Large percentage of undirected gull flights and presence of clutter in the data results in overall flight directions without clear patterns.

Table 7.5 Summary of flight directions per month. Mean flight directions per day period were calculated and categorised as undirected or directed (vector >0,25). Percentage of day periods in that month with directed flight; Flight direction per day period of only those periods with directed flight; Vector represents directedness, 0=undirected 1=directed.

		night	dawn	day	dusk
Oct 04	% directed	57	63	52	63
	direction	198	118	108	240
		SSW	ESE	ESE	WSW
	vector	0,43	0,41	0,41	0,42
Feb 04	% directed	27	30	15	30
	direction	54	101	70	106
		NE	E	ENE	ESE
	vector	0,31	0,33	0,35	0,32
April 04	% directed	8	33	5	2
(1-19)	direction	67	57	82	174
		ENE	ENE	E	S
	vector	0,52	0,43	0,35	0,39
June 04	% directed	3	7	0	20
	direction	308	66	60	355
		NW	ENE	ENE	N
	vector	0,38	0,35	0,57	0,38

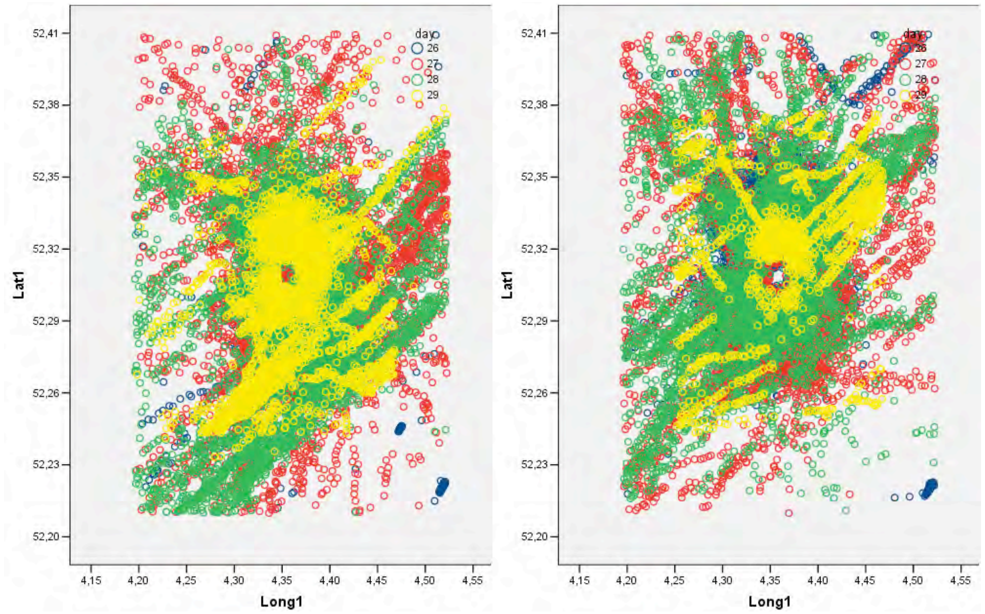


Figure 7.2 *Tracks recorded by the horizontal radar on various days in October, showing migration to the southwest. Each colour represents a different day, each dot is an individual trackID but not necessarily a different object. The left panel shows tracks during daylight, the right panel at night.*

Patterns on specific days throughout the season

When we focus on specific days, migration and local flight patterns emerge.

In October (October 19 2004) flight directions were largely oriented southwest. Migration was recorded both during night, at dawn and dusk, and during daylight, suggesting migration took place during the entire 24 h period (fig 7.3).

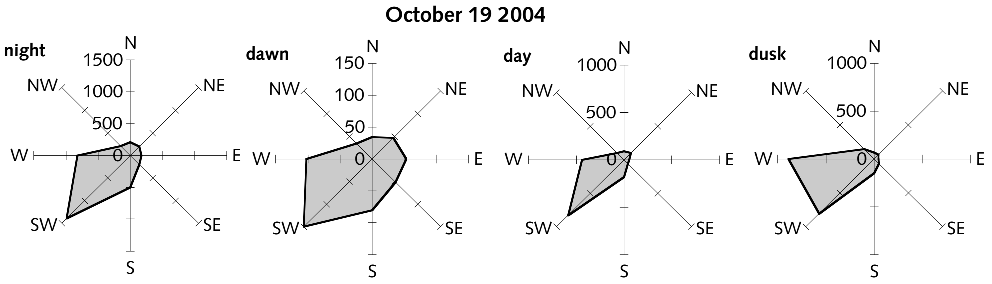


Figure 7.3 *Fall migration to the southwest on October 19 2004 during various times of the day, as observed with horizontal radar. Southeasterly wind force 6 Bft. Distance 0,5-2 km from platform.*

In February (February 16 2004), gulls were the dominant species present at sea. The flight directions reflect the local flight movements of these gulls in all directions. At night, flights mostly northeast were recorded (fig 7.4).

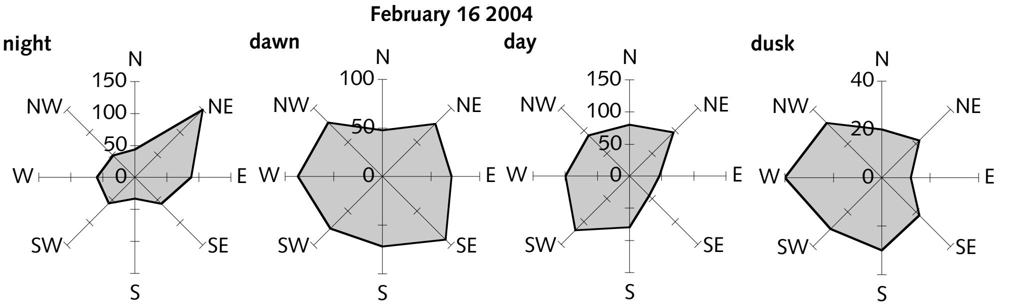


Figure 7.4 Mainly local flight movements on February 16 2004, during southeasterly wind force 4 Bft, during various times of the day, as observed with horizontal radar. Distance 0,5-2 km from platform.

Spring migration to the northeast dominated the flight directions at night and dawn on April 12 2004 (fig. 7.5). During the day less migration occurred and the northeast component became less prominent and more birds flew east and south east. These were possibly lesser black-backed gulls flying to the breeding colony at the Maasvlakte in the south. At dusk, this flight movement of the gulls to the colony became more prominent.

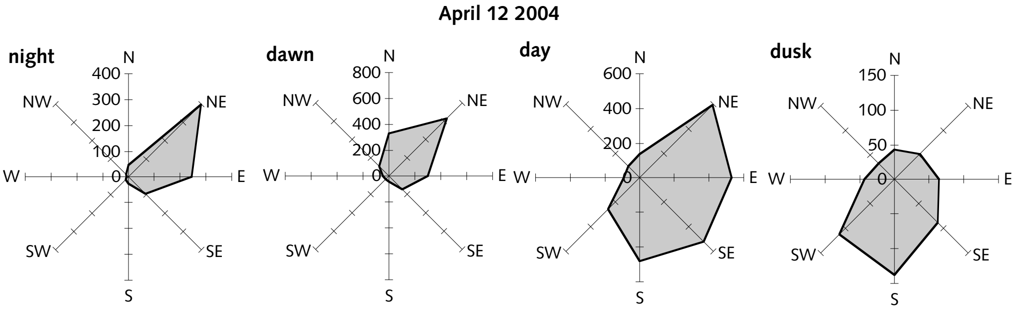


Figure 7.5 Spring migration to the northeast at night and dawn, on April 12 2004. Wind south 4 Bft. Range 0,5-2 km from platform. Observed with horizontal radar.

In June (June 1 2004), local movements of foraging gulls dominated the area, resulting in random flights without one specific direction. At dusk, general direction to the southeast reflects gulls flying to the breeding colonies. At night and at dawn, mostly flight movements parallel to the coast are observed (fig. 7.6).

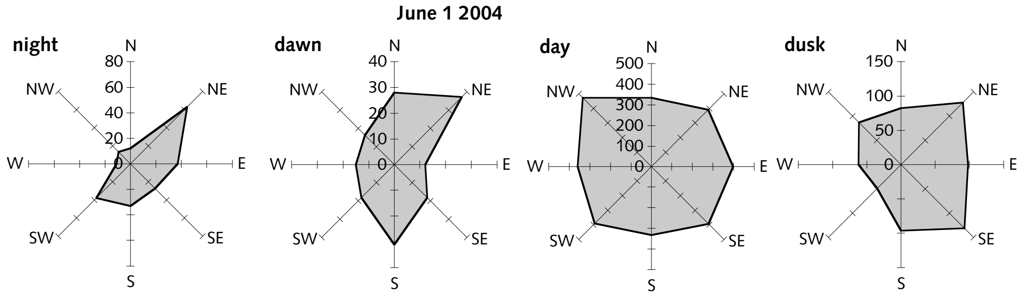


Figure 7.6 *Coast-parallel flight movements at night and dawn on June 1 2004. During day and at dusk, local flight movements of gulls foraging and flying to the breeding colony. Wind east 5 Bft. Distance 0,5-2 km from platform. Observed with horizontal radar.*

In comparison to the data recorded on June 1, data from June 2 show predominantly clutter recorded by the radar. Clutter shows no specific direction of movement (fig. 7.7). On June 4, the afternoon had a very calm sea and no clutter was detected by the radar. Large amounts of foraging gulls passed the platform, following fishing vessels, and flight directions reflect predominantly these movements (fig 7.8).

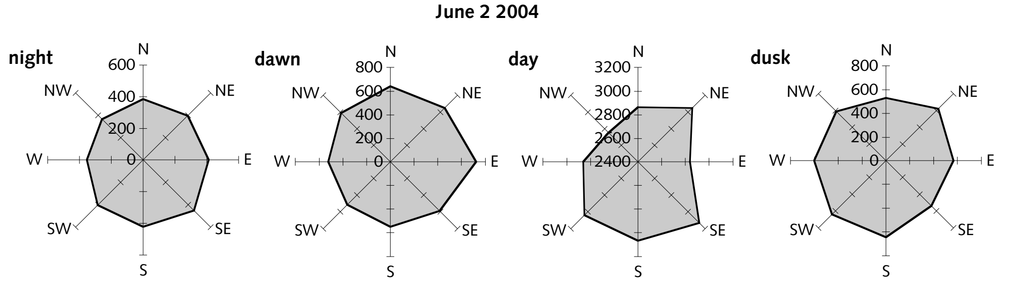


Figure 7.7 *Directions of large amounts of clutter detected on the radar during southeasterly wind force 7 Bft on June 2 2004. Very few birds were observed during the day. Distance 0,5-2 km from platform. Observed with horizontal radar.*

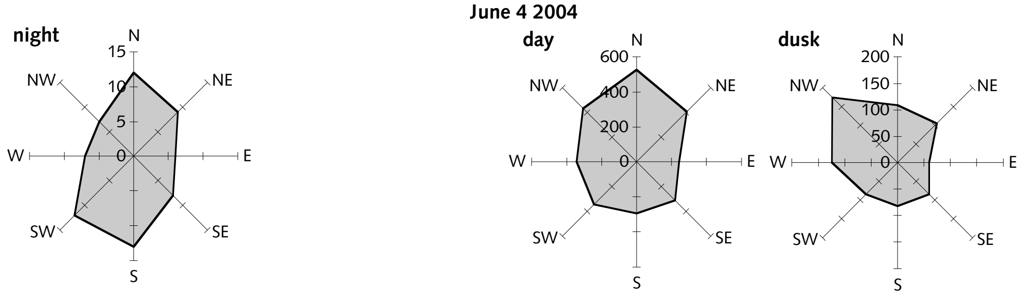


Figure 7.8 *Flight directions of large numbers of foraging gulls on the calm afternoon and night of June 4 2004 with no clutter recorded by the radar. Wind WNW force 3 Bft. Distance 0,5-2 km from platform. Observed with horizontal radar.*

7.2.2 Flight directions at night (horizontal radar)

The horizontal radar measurements shows no clear difference in heading during night or day (table 7.5). However, analysis of some particular days in each of these months during which clutter was limited, revealed that at night general flight movements are more directed while during daytime and at dusk, flight movements are more undirected (figs. 7.3-7.7). This reflects the high abundance of gulls at sea, which dominate flight patters with their semi-random flight directions following fishing vessels. At night, abundance of gulls was far lower (see chapter 8), and as a result flight directions of other species emerges. Why this pattern does not emerge from overall data per month is probably due to the large amount of clutter still present in the data. To obtain clearer results, a selection of data would have to be created in which clutter is limited.

Flight directions of birds flying at night were also established visually on the nights that moon watching was performed. The analysis of moon watching data by Sempach yielded mean flight directions of all birds seen as depicted in figure 7.9 below. In October, all three nights showed migration in south-westerly direction with on 2 nights a clear component of birds flying west and birds flying southwest to westsouthwest. These flight directions are constituted mainly by thrushes (redwing, songthrush, blackbird; see also § 7.1.3). On the 6th of November, this distinction between birds flying west and birds flying southsouthwest was most apparent. The large number of waders seen that night showed a westerly component, as did part of the thrushes.

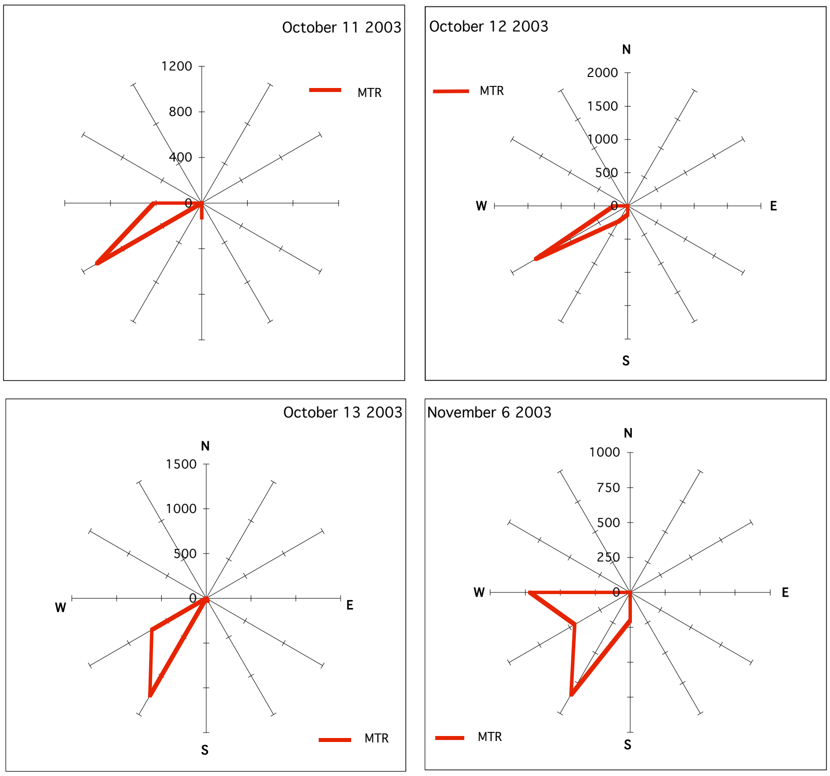


Figure 7.9 Mean flight directions at night as determined by moon watching, on 4 different nights during autumn migration.

7.2.3 Flight directions of the various species groups (panorama scans)

Flight directions vary between species groups, depending not only on the variation in place of origin and destination of migrating birds, but also on differences in behaviour of the species groups. Such differences between species groups have been quantified with the panaroma scans. The flight directions of each of the species groups is presented in figure 7.10. Below we describe the main patterns in direction found for each species group, including seasonal variation.

- *Alcids* were seen flying in all directions with a slight emphasis towards the coast. This pattern was observed in all months.
- In autumn, *cormorants* were mainly seen flying in directions around southwest with an average flight direction that was fairly directed (a=0,627). In spring, flight directions were more dichotomous with a migration component towards NE and feeding flights from colonies along the coast.
- *Divers* (mostly Red-throated Divers) had a distribution showing most flights occurred parallel to the coast. From October until January most were seen flying in southwesterly directions. In February and March the directions were distributed more evenly, as well as in April and May.
- *Gannets* were seen flying in all directions with no clear indication or directed migration. Most movements were probably linked to random flights in search for feeding opportunities.
- *Geese and swans* showed a clear pattern that easily can be linked to directed migration. Until January most were seen flying in southwesterly directions, in April some reversed movements were seen.
- *Gulls* were seen flying in all directions, and of all groups showed the most evenly distribution of flight directions. This pattern was evident in all months.
- The majority of *landbirds* was recorded in autumn. In this season a dichotomy in the directional distribution was visible. Most birds seen flew southwestward, a smaller amount south- and southeastward. The first pattern indicates migration across the North Sea to England, the second migration to the Dutch coast in reorientation after nocturnal migration across the North Sea (*c.f.* Buurma 1987). Spring migration was directed northeast, but was hardly observed as it occurred outside observation periods on the platform.
- Among the *other ducks* (non-sea-ducks) southward migration was dominant in autumn and northward migration in spring.
- *Sea ducks* showed a more pronounced pattern with migration mainly southwest in autumn and northeast in spring. In February and March both movements were equal.
- *Skuas* were seen flying in all directions, as were their main hunting objects (gulls); but note the small numbers.
- In autumn only small numbers of migrating *terns* were seen. In October most birds had already passed. In spring tern movements were heavily orientated to northeast and indicating spring migration towards breeding grounds.
- *Tubenoses* were seen flying mostly in northerly directions, but note the small numbers.
- Most *waders* migrated southward in autumn and northeastward in spring.
- Most *sea mammals* moved parallel to the coast, as did the *fishing vessels*.

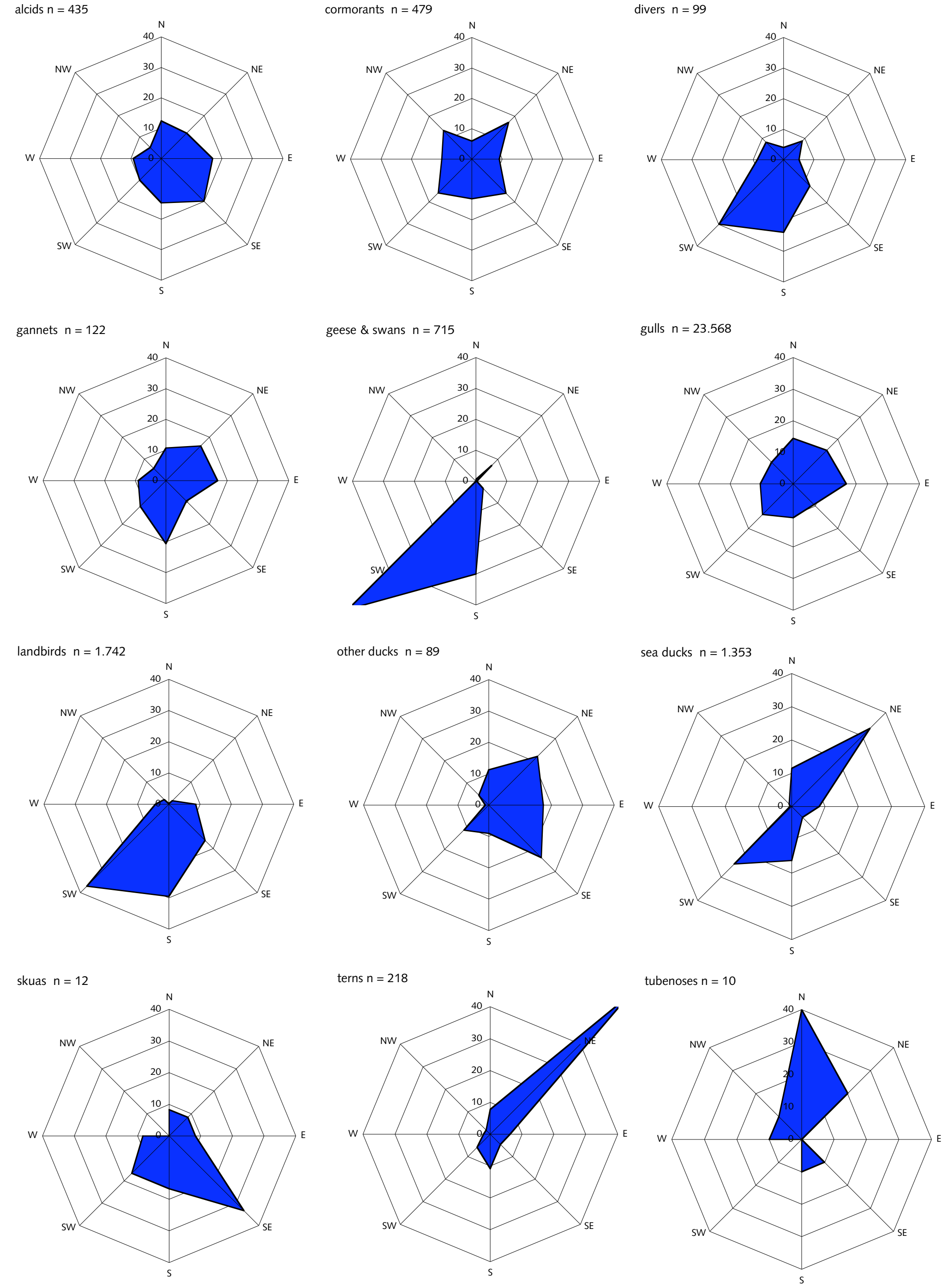


Figure 7.10 *Distribution of observed flight directions in species groups in the panorama scans between October 2003 and June 2004. Continued on following page.*

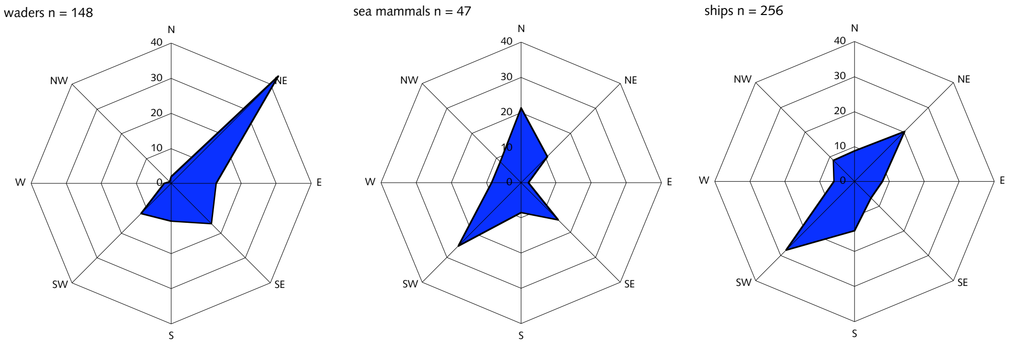


Figure 7.10 Continued.

7.2.4 Flight directions of birds less frequent and at larger distances (sea watches)

As described in § 5.5, the distribution of flight directions recorded during sea watching is unlikely to reflect the real directional distribution because of the fixed SE-NW view line and the tendency for observers to simplify direction recording into 'N(E)' and 'S(W)'. However, distributions of different species groups over the main directional categories can be compared and do give an insight in which groups show the most directional flight behaviour and which the least.

Figure 7.11 shows the directional distribution for some groups that deviated from the dominant N-S axis relatively often, and for the remaining species. Table 7.6 summarises flight directions aggregated into even fewer categories: movements parallel and perpendicular to the coastline, and undirected ('local') flights. Divers and terns showed the most clearly directional movements, with over 90% of all flights recorded as roughly parallel to the coastline, followed by alcids and ducks and geese (>80%). Whether the northward or the southward component of coastline-parallel flights was more pronounced depended on the migration season in which the group was commonest. Movements of gulls, waders and landbirds (passerines) were least directional, with c. 25% of all flights directed perpendicular to the coast, especially towards the land. For landbirds, these flights will partly pertain to birds that have flown out across the North Sea during darkness and return to the coast during the day, partly to birds cutting short the 'bend' in the coastline between Noord-Holland and the Delta area, and partly also to birds migrating between the continent and Great Britain. Gull movements will mostly involve foraging flights, and the question arises why they were recorded more frequently while flying towards the coast than while flying out to sea.

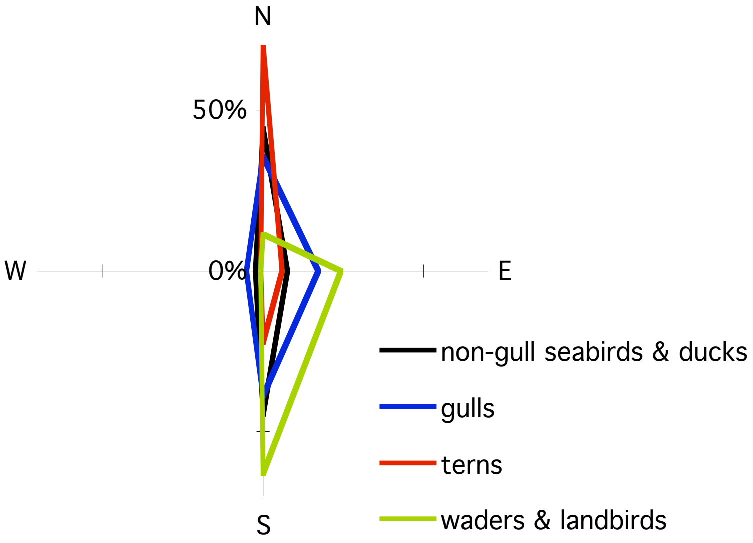


Figure 7.11 *Percentage distribution of flight directions for different species groups in distance zones 1-3 during sea watches from MpN. Recorded directions were grouped into : N (N to ENE), E (E to SSE), S (S to WSW), W (W to NNW), and localised, undirected flights (LOC, not shown).*

Table 7.6 *Flight directions of birds recorded during sea watches from MpN, divided into movements roughly parallel to the coastline (N/S), roughly perpendicular to the coastline (E/W), and 'localised' flights without a clear direction (local).*

species group	N total	N/S	E/W	local
divers & grebes	1499	94%	6%	0%
terns	651	92%	7%	1%
ducks, geese, swans	2668	90%	10%	0%
alcids	1166	89%	10%	1%
Northern Gannet	226	80%	12%	8%
Great Cormorant	276	78%	18%	4%
gulls	21025	74%	22%	4%
waders & landbirds	1781	74%	25%	1%
all birds	28234	78%	20%	2%

7.3 Bird flight activity in relation to fishing vessels (panorama scans)

The great majority of bird flight movements around MpN concerned flying gulls. Gulls are well known to be attracted to fishing vessels at sea, where they feed on discarded bycatch that is thrown overboard after hauling the nets. This phenomenon was frequently observed at MpN as well. This means that the numbers of gulls present (and flying) in a sea area, and thus at risk of colliding with wind turbines, could be greatly affected by fishing activity in that area. The Near Shore Wind farm will be closed to all ships, which means that within the NSW area no attraction by fishing vessels will occur, and this is obviously a point that has to be taken into account in comparing bird flight activity in the NSW during after its construction with the T_0-data collected at MpN. However, even when there may be no fishing activity within the boundary of the NSW, flight activity may still be increased by the presence of trawlers in its vicinity. In this paragraph we explore (1) which species groups are attracted to fishing vessels(hereafter called trawlers, as most fishing vessels operating in the coastal zone are beam trawlers), (2) how their flight activity at MpN is affected by the presence of trawlers, and (3) over what distances a 'trawler effect' is discernible. Panorama scan data are used for this as they give the most complete picture of gull flight activity, and the presence of trawlers was recorded during the scans, simultaneously with the bird counts.

7.3.1 Patterns in the presence of trawlers at MpN

Figure 7.12 illustrates the occurrence of trawlers around MpN as recorded during the panorama scans. No distinction is made between trawlers that were steaming, fishing or hauling nets; this could not always be judged well from a distance. Beam trawling for flatfish was their main objective, although shrimp trawlers were also present near the coast at times. Distribution of trawlers over distance zones (from MpN) was as follows: 0-0.5 km 0.5%, 0.5-1.5 km 4%, 1.5-3 km 15%, and >3 km 80% (N=2946). Trawler activity varied over the year with peak numbers observed in September-October and in May-June (NB: no observations in July-August), and lower activity during winter. Variation in trawler abundance in the course of the day was less regular, resulting in just a slight increasing trend in the averages. However, there was enormous variability around these means, as is indicated by the ranges given in figure 7.12. This variation occurred at the level of days, but also within days: sometimes there could be 30 trawlers around the platform at noon, while they were all gone a few hours later. For this reason all panorama scans have been treated as independent observations.

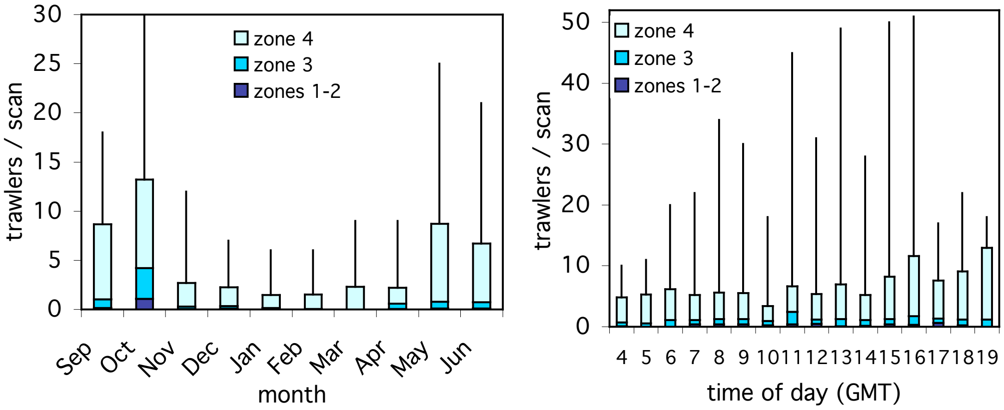


Figure 7.12 Number of trawlers observed from MpN by month (left) and by time of day (right). The bars give the mean number observed per scan, for distance zones separately; the vertical lines depict the maximum number of trawlers observed in a scan in that month/hour (the minimum number was always 0; the maximum for October was 51).

7.3.2 Bird groups associated with trawlers

During the panorama scans, it was recorded whether observed birds were visibly associated with fishing vessels. This included both birds flying and feeding around and in the wake of trawlers, but also birds on a flight course towards a trawler that was attracting a 'crowd'. However, probably only the most conspicuous flights towards a trawler are recognised as such during the scans, and the true proportion of flights that are associated with or directed towards trawlers is thus likely to be underestimated. Of all flying birds observed, 74% (64% of those flying within 3 km from the platform) were classified as 'associated with fishing vessels' (table 7.7). Gulls were the species group that was most often associated with trawlers by far (71-80%). The data suggest that the larger gulls (herring and black-backed gulls) were slightly more often associated than the smaller species (common, black-headed and kittiwake) but this is hard to judge from the data since especially the large mixed clouds of gulls behind trawlers were left unidentified, while solitary flying birds were usually identified to species. It is however obvious that Little Gulls were associated with ships to a much smaller extent than the other species. The only other bird species besides gulls that were regularly associated with trawlers were Great Cormorant and Northern Gannet. These species were also seen mixing with the gulls and feeding in the vessels' wake. Only in the Cormorant did the proportion of birds recorded as associated with trawlers exceed 10%.

Table 7.7 Proportion of birds observed in all panorama scans made from MpN that were recorded as being 'associated' with fishing vessels, for all distance zones, and for zones 1-3 (<3 km) respectively.

	All distance zones 1-4		Distance zones 1-3	
group	total	% associated	total	% associated
unidentified gulls	80260	92.1%	31645	89.8%
large gulls	51134	67.2%	27263	57.6%
small gulls	10757	46.7%	10459	48.0%
total gulls (- LG)	142151	79.7%	69367	70.8%
Cormorants	1153	13.1%	623	10.6%
Little Gulls	685	9.1%	682	9.1%
Gannets	192	3.6%	149	4.0%
sea ducks	1768	0.5%	1442	0.6%
terns	244	0.4%	237	0.4%
alcids	450	0.2%	441	0.2%
landbirds	1857	0.2%	1857	0.2%
all groups <0.1%	2172	0.0%	1086	0.0%
grand total	153742	73.8%	76587	64.3%

7.3.3 Flight activity in relation to trawler presence

Based on table 7.7, the relationship between bird flight activity and the presence of trawlers was investigated only for gulls (as a group) and for the great cormorant. In these analyses, the total number of flying birds observed per scan (*i.e.* all four altitude classes of the low scan plus the upper two classes of the high scan) was the response variable and numbers of trawlers per scan (in different distance zones) and month (to account for seasonal differences in the species' abundance) were used as explanatory variables.

Gulls

Figure 7.13 shows the results for gulls. Despite a large scatter in the data, a clear positive relationship exists between the total number of gulls within zones 1-3 and the number of trawlers within those zones, but also with the total number of trawlers in all zones. This relationship was analysed using a generalised linear regression model with a log link function (i.e. all bird numbers are transformed to logarithms) and a Poisson error distribution. The relationship turns out to be highly significant and explains no less than 56% of the observed variation in gull flight activity (table 7.8). The fact that introducing the square of the number of trawlers to a model that already includes the total number of trawlers significantly improves the model's fit to the data ($P<0.001$, table 7.8), indicates that the relationship is non-linear, with gull numbers levelling off at high trawler numbers. Perhaps, at high trawler densities all gulls in the area are already attracted, so that a further increase in trawlers does not bring more birds in. The trawler effect means that the observed seasonal pattern of gull flight activity partly is a reflection of monthly variation in trawler activity, but including an effect of 'month' in the regression model containing trawler abundance still yields a significant improvement (a further 10% of the variation explained; table 7.8), so the observed seasonal variation is partly independent of trawler abundance. The other way round, the relationship between trawler abundance and flight activity is still significant if it is included in the regression model after 'month' (P<0.001, not shown in table 7.8), so it is not an artefact resulting from trawlers being most abundant in months in which gull numbers were high anyway. Table 7.8 also shows that there is no significant month.trawler interaction, so the shape of the relationship between gull and trawler numbers (on the log scale, i.e. proportionally) does not differ between months, even if the average level of gull abundance does.

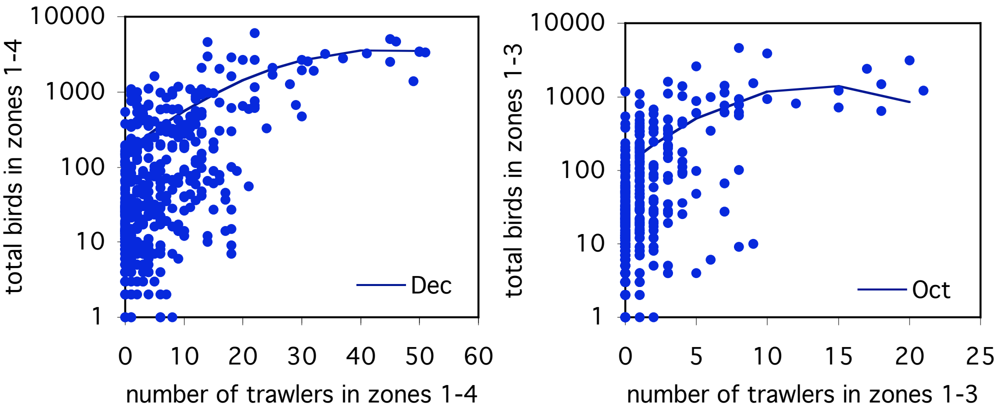


Figure 7.13 *Total numbers of gulls (logarithmic scale) recorded in distance zones 1-3 in the panorama scans, in relation to the number of trawlers recorded in the same scans in all distance zones (left) or in distance zones 1-3 (right). The lines give the predicted relationship for gull numbers in the months with the highest gull numbers, based on the analysis in table 7.8.*

Table 7.8 *Analysis of the relationship between total gull flight activity and total abundance of trawlers (distance zones 1-4), and month. Data were analysed with a generalised linear regression model with logarithmic link function and Poisson error distribution, with correction for overdispersion. The table shows the changes in deviance (a measure of how well the model fits to the observations) and associated probabilities when explanatory variables are entered one by one.*

variables added to model	d.f	change in deviance	mean deviance	deviance ratio	approximate F-probability
+ total trawlers	1	195214	195214	322.61	<.001
+ total trawlers2	1	22890	22890	42.85	<.001
+ month	8	37944	4216	14.89	<.001
+ trawlers.month	8	3215	357	1.32	0.260
residual	452	128702	285		
total	472	387965	822		

Attraction distance of gulls

To evaluate how far the attraction effect of trawlers on gull numbers reaches, we analysed how the flight activity of gulls in different selections of distance around MpN was related to trawler abundance in different distance zones. The total flight activity in zones 1-3 depended on the number of trawlers in those zones, but also on the *additional* number of trawlers present in zone 4, >3 km away from MpN (table 7.9 top; adding trawlers in zone 4 to a model containing trawlers in zones 1-3 significantly improves its fit). Gull flight activity in zones 1-2 (up to 1.5 km from MpN) was significantly associated with trawler numbers in zones 1-2 and *additionally* in zone 3, but not with the additional number in zone 4 (>3 km from MpN); table 7.9, bottom). We conclude that the local flight activity by gulls is affected by the presence of trawlers at distances up to a few kilometres distance. This means that even if no fishing vessels will be allowed in the Near Shore Wind Farm, numbers of gulls flying within the area will still be affected at times by the presence of trawlers in the surroundings.

Table 7.9 Analyses of the relationship between gull flight activity in distance zones 1-2 and 1-3 respectively, and abundance of trawlers in different distance zones. Data were analysed with a generalised linear(regression) model with logarithmic link function and Poisson error distribution, with a correction for overdispersion. The table shows the changes in deviance and associated probabilities when explanatory variables are entered one by one, s '+trawlers in zone 4' denotes the effect of trawlers in that zone in addition to that of trawlers in zones 1-3.

variables added to model	d.f.	change in deviance	mean deviance	deviance ratio	F probability
Gulls in zones 1-2					
+ trawlers in zones 1-2	1	29422	26395.2	301.8	<.001
+ trawlers in zone 3	1	4956	5123.0	50.8	<.001
+ trawlers in zone 4	1	14.4	0.2	0.15	0.701
residual	469	58124	124		
total	472	92516	196		
Gulls in zones 1-3					
+ trawlers in zones 1-3	1	88894	88894	469.1	<.001
+ trawlers in zone 4	1	5749	5749	30.3	<.001
residual	470	116797	249		
total	472	211440	448		

Great Cormorant

Figure 7.14 and table 7.10 illustrate the association between flight activity of Cormorants and the abundance of trawlers. As in gulls, the number of Cormorants observed increased with trawler abundance. Although the quadratic term was significant which suggests that the relationship flattens out at higher trawler numbers, the regression model predicted decreasing numbers at trawler numbers higher than 15-20. This is more likely reflects the scarcity of observations at these high trawler numbers rather than a real effect; therefore just the linear trend is shown in figure 7.14. In Cormorants, the abundance of trawlers explains a much smaller proportion of the observed variation in flight activity (16%) than it did in gulls (56%). Cormorants feed independently at sea away from ships far more often than gulls do, as is also visible from the much lower proportion of birds recorded as directly associated with ships (table 7.7). That a trawler effect does exist means that the observed seasonal pattern of Cormorant flight activity partly is a reflection of monthly variation in trawler activity, but including 'month' in the regression model containing trawler abundance still yields a significant improvement (a further 13% of the variation explained; table 7.10), so the observed seasonal variation is for a large part independent of trawler abundance. The other way round, the relationship between trawler abundance and flight activity is still significant if it is included in the regression model after 'month' (P<0.001, not shown in table 7.8), so it is not an artefact resulting from trawlers being most abundant in months in which Cormorants are numerous anyway.

Attraction distance of Cormorants

Analysis of Cormorant activity with trawler abundance in different distance zones suggests that also in this species, the effect of trawlers is discernible over distances up to several kilometres (table 7.11). Cormorant numbers in zones 1-2 (within 1,5 km from MpN) were affected by the presence of trawlers in zones 1 and 2, but additionally also by trawlers in zone 4 (>3km away from the platform), as were Cormorant numbers in distance zones 1-3.

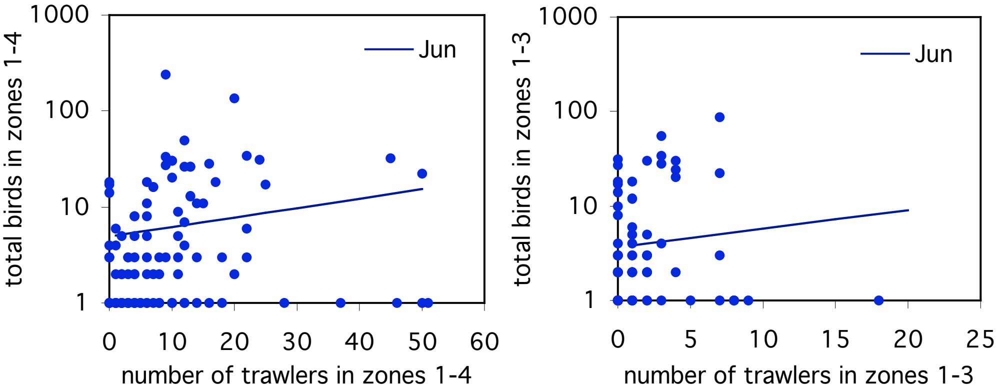


Figure 7.14 Total numbers of great cormorants (logarithmic scale) recorded in distance zones 1-3 in the panorama scans, in relation to the number of trawlers recorded in the same scans in distance zones 1-3 (left) or in all distance zones (right). The lines show linear relationships in the months with highest numbers.

Table 7.10 Analysis of the relationship between flight activity of great cormorants and total abundance of trawlers (distance zones 1-4), and month. Explanation as for table 7.9. The month.trawler interaction is significant, so the shape of the relationship between cormorant and trawler numbers differs between months.

variables added	d.f.	change in deviance	mean deviance	deviance ratio	F probability
+ total trawlers	1	488.7	488.7	53.3	<.001
+ total trawlers^2	1	508.5	505.5	55.5	<.001
+ month	9	788.0	87.6	9.55	<.001
+ trawlers.month	9	186.7	20.7	2.26	0.017
residual	452	4143.4	9.2		
total	472	6115.5	13.0		

Table 7.11 Analyses of the relationship between flight activity of great cormorants in distance zones 1-2 and 1-3 respectively, and abundance of trawlers in different distance zones. Explanation as for table 7.9.

variables added	d.f.	change in deviance	mean deviance	deviance ratio	approximate F probability
Cormorants in zones 1-2					
+ trawlers in zones 1-2	1	25.7	25.7	13.4	<.001
+ trawlers in zone 3	1	0.8	0.8	0.4	0.520
+ trawlers in zone 4	1	117.2	117.2	61.3	<.001
residual	469	1202.0	2.56		
total	472	1252.7	2.840		
Cormorants in zones 1-3					
+ trawlers in zones 1-3	1	109.3	109.3	20.8	<.001
+ trawlers in zone 4	1	171.9	171.9	32.7	<.001
residual	470	2951.1	6.3		
total	472	3232.4	6.8		

Nocturnal activity

The present analysis is restricted to flight activity during daylight, whereas collision risks are far greater in darkness. During our visits to MpN (e.g. in October) we observed that even at night, trawlers that were discarding fish were sometimes accompanied by flocks of gulls, though we were not able to quantify these associations. On the other hand, Van den Bergh *et al.* (2002) describe how flight activity of gulls from and to breeding colonies at the Maasvlakte was very much reduced or absent during darkness in June-July, and observations at breeding colonies of cormorants suggest the same (H. Schekkerman, colony at Castricum near NSW-site). Possibly, it is the non-breeding fraction of the gull population (immatures and non-breeding adults) that visits trawlers at night.

7.4 Conclusions

- A total of 64 species were identified in panorama scans throughout the observation period (October 2003 – September 2004). In the area of the observation platform, 90% of all birds were gulls, 3% were migrating landbirds and 2% were sea ducks. When focussing on the rarer birds and birds flying at larger distances from the platform (sea watches), the percentage of gulls decreased to 66%, landbirds increased to 10% and seaducks and alcids increased to 8% and 6% respectively. These differences are due to the difference in observation technique: in sea watches the focus lay on birds with northerly or southerly directed flights, and thus sea ducks and migrating landbirds were detected relatively more, whereas in the panorama scans birds flying locally were detected more.
- The majority of flight movements at lower altitudes originated from gulls. Thus, the general pattern showed mostly local flights. In autumn a larger fraction of flight movements was headed southwest, in spring north east.
- Directed migration, especially in spring and autumn, was observed in most species groups, as were other more local movements. In alcids, gannets, gulls, skuas and tubenoses, most movements observed seemed to be linked to local or inter-local movements rather than migration, although in the sea watches most alcids seen were flying parallel to the coast, revealing both migration and tide-related correctional flights.
- The three most abundant groups around the platform were gulls, landbirds and sea ducks. Movements of gulls were almost entirely local, and often (up to 80% of all gulls) related to fishing vessels. Abundance of fishing vessels largely explained flight activity (*i.e.* abundance) of gulls up to several kilometers away. Overall, 74% of all movements observed was related to fishing vessels. Flight patterns of landbirds revealed two patterns, one of birds migrating towards England, and the other of birds flying to the Dutch coast after nocturnal migration across the north sea. Sea ducks showed a flight patterns related to autumn and spring migration and to correctional flights in relation to the tide.
- Horizontal radar measurements indicate that at night flight movements were mostly parallel to the coast or slightly more northeast and southwest ward than that. Local undirected movements seemed to be far less abundant at night. However, due to large amounts of clutter with no specific direction this pattern was obscured.
- Nocturnal moon watching observations of flight directions of thrushes, waders, small passerines and geese and ducks during autumn migration, showed flight directions southwest parallel along the coastline as well as more westwards to Great Britain.

8 Flight altitudes

Flight altitudes are an important issue in the framework of measuring the potential effects of wind turbines on birds. Only birds flying at the same altitude as rotors of wind turbines are in potential risk of collision. Furthermore, as the risk of collision is larger in the dark it is important to emphasise on differences in patterns of flight altitudes between day and night. As the flight altitude of birds is related to behavioural aspects of the various species, patterns of flight altitudes will be described based on different information sources. Firstly the flight altitudes in the studied part of the North Sea will be described by the observations obtained by the vertical radar both during the day and at night (§8.1). These results are compared with visual observations during daytime in §8.2. In addition, altitude information is available on species group level from the large data set on visual observations during the day (§8.3). During the night altitude information on altitude profiles (§8.4) has been gathered by moon watching. These altitudes could be specified to species level, aided indirectly by acoustic registrations both by ear and automatically by microphone (§8.5). Unfortunately the amount of simultaneous information (both vertical radar and additional field observations at the same time) gathered is limited. Results are summarised in §8.6.

8.1 Flight altitudes in general for day and night (vertical radar)

The general patterns of altitudes at which birds were flying relative to the platform position were recorded by the vertical radar both at night and during the day. The upper limit was set to 3 km (1,5 NM). Figures 8.1 A & B show the average numbers of tracks per hour per km for four altitude classes (0-50 m, 50-150 m, 150-250 m and >250 m, with the 50-150 m altitude band overlapping with the height of the future rotor blades) for different observation periods, with a distinction between night and day. For the presentation here we have chosen to present data in the distance class 500-1500 m in a horizontal plane at either side from the platform (vertical beam being directed parallel to the coast, with a vertical observation window north of the platform and one south). At this distance detection loss is limited compared to further away, especially for the relatively small sized birds. At the same time at some distance from the platform gulls and other birds directly attracted or related to the platform are kept out.

The vertical radar operated almost optimally for the period April-June 2004 (fig. 8.1A). Unfortunately in the rest of the observation period data gathered was limited as the radar was often out of order due to technical problems (these data are presented in figure 8.1B).

The data recorded with the vertical radar revealed strong differences in flight activity between day and night between different altitude bands. During the day the highest flight activities occur in the two lowest altitude bands, while at night the highest intensities were recorded in the two highest altitude bands. This pattern was found both during spring and summer and in the other periods of the year (fig. 8.1 A&B).

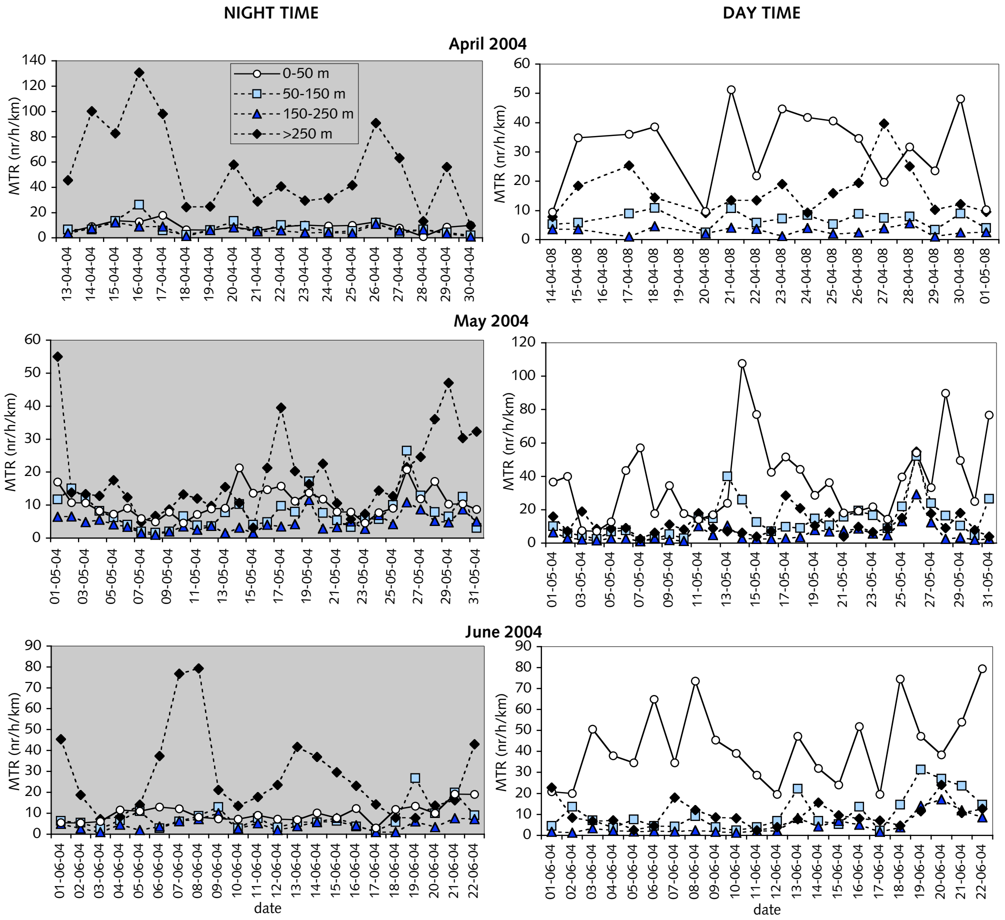


Figure 8.1A Mean traffic rate (MTR) in the period April-June 2004, at night (left panels) and day (right panels), for 4 different altitude bands (0-50 m, 50-150 m, 150-250 m and >250 m). Data given for distance zone 500-1500m, as registered by the vertical radar at the north side of the platform.

This general pattern becomes even more apparent if for the different days the flight activity during 24 hours is depicted for the four different altitude bands for April and May 2004 (fig. 8.2). Indeed, with increasing altitude the pattern at night is completely opposite of that during the day, with low flying birds during the day and high flying birds mainly during the night. This strongly indicates that we deal here with different groups of birds, very likely migrant birds in the night at the higher altitudes (e.g. waders and passerines), while the flight movements at the lower altitudes during the day belong to local birds (day active gulls) and moving large waterbirds (seabirds, geese, ducks, waders etc.).

The patterns emerging from the visual observations (see § 8.2) on timing of movements during the day fit very well with the pattern for the lower altitude band as recorded by the vertical radar during daylight. In figure 8.1A it is clear that the largest peaks at high altitudes occurred in the first half of April, while in May these peaks were rare, with on 1 May the largest peak.

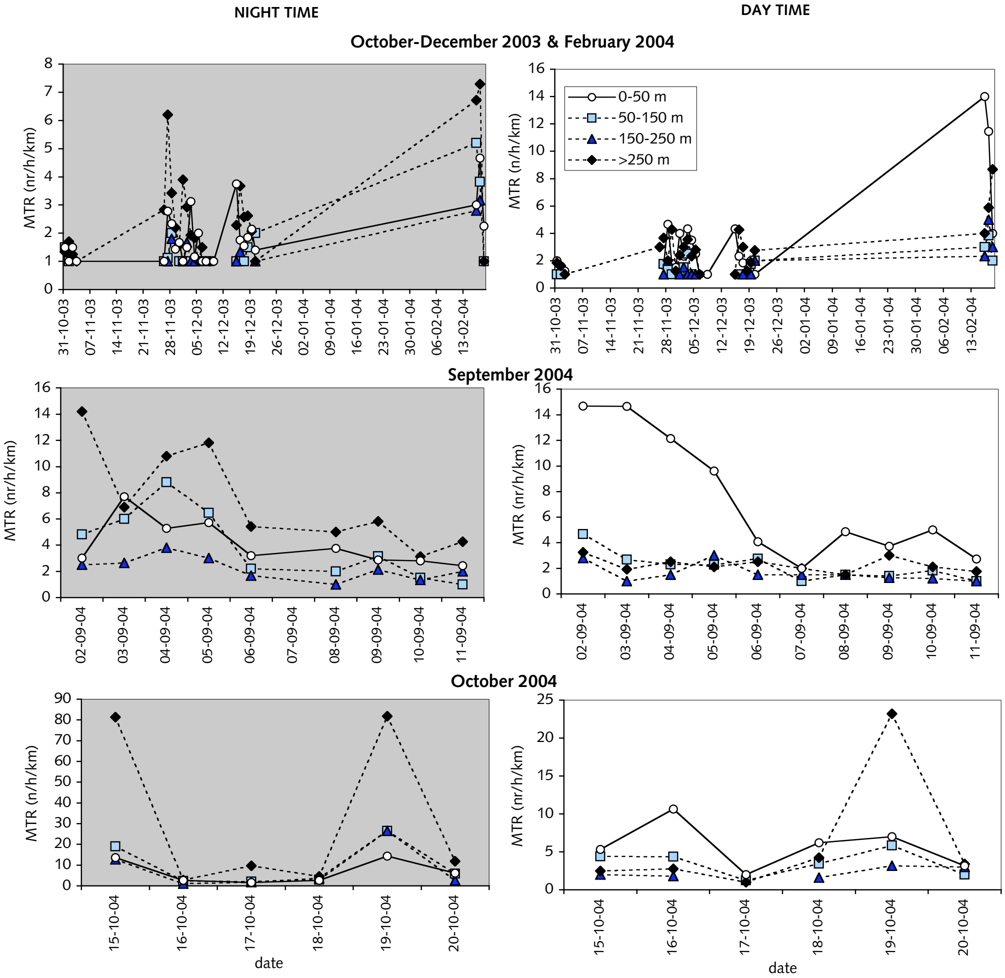


Figure 8.1B Mean traffic rate (MTR) in various autumn and winter periods 2003-2004, at night (left panels) and day (right panels), in 4 different altitude bands (0-50 m, 50-150 m, 150-250 m and >250 m). Data given for distance zone 500-1500m, as registered by the vertical radar at the north side of the platform.

It is clear from figure 8.2 that in May the intensity of flight movements at 0-50 m is higher than in April. This similar pattern was also found by the panorama scans (fig. 9.1) and by sea watching (fig. 6.11). It is very likely that this is caused by higher numbers of lesser black backed gull in May compared to April, these birds being the dominant species at sea around the platform in this time of year. During the day in May also higher activity at higher altitudes during the day occurred, probably explained by the regular soaring activities of these gulls, as confirmed by visual observations (although it can not be ruled out that at some days also other birds as e.g. swifts and swallows, and migrant birds fly during the day at higher altitudes, missed by the field observers). In the lower air layer a bimodal pattern of flight activities around sunrise and sunset is visible, most clearly in April, but also in May, likely explained by flights of mainly gulls to and from roosts on the coast.

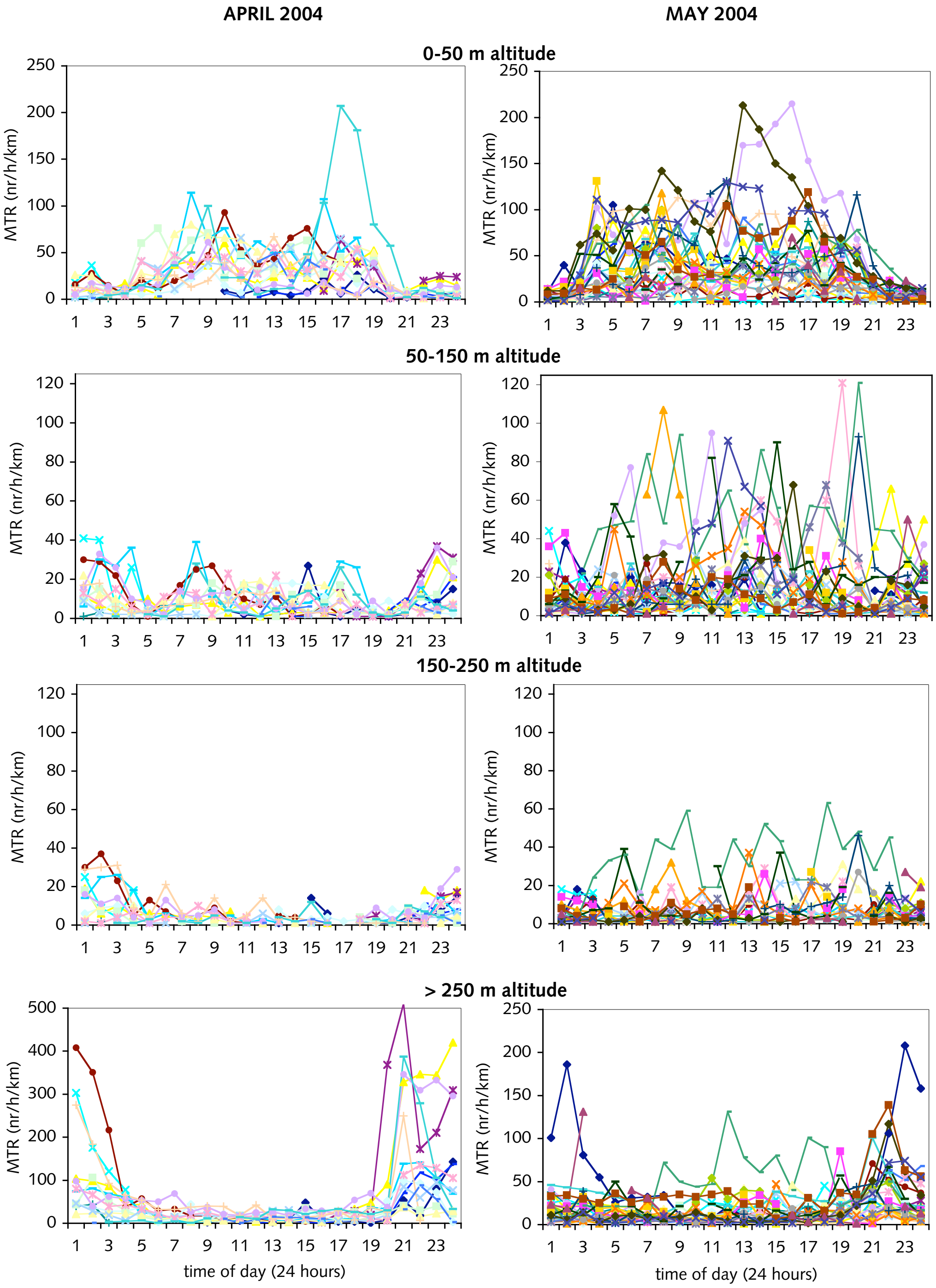


Figure 8.2 Mean Traffic Rate (MTR) in April (left) and May (right) 2004, for 4 altitude bands (0-50 m, 50-150 m, 150-250 m and >250 m, from upper to lower panel). Data given for distance zone 500-1500 registered by the vertical radar at the south side of the platform.

The difference in altitude distributions now apparent in figures 8.1 and 8.2 between the light and dark period agree with expectations, especially in the lower altitude bands, because during the night many birds (e.g. gulls and other seabirds searching for food on eye sight) are supposed to be less active, but nevertheless there is still some activity. Visual observations at night have shown that indeed relatively large numbers of gulls can still be active in the working lights of active fishing vessels in case these ships are present.

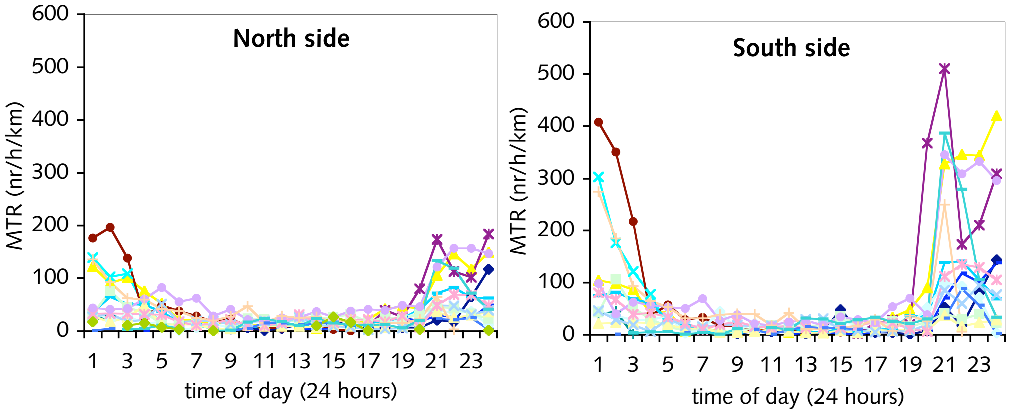


Figure 8.3 *Mean traffic rate (MTR) registered by the vertical radar, compared between north (left panel) and south side (right panel) of the radar, in April 2004 at the highest altitude band (>250m). Data for distance zone 500-1500m.*

Table 8.1 *Percentage of recorded tracks at north side of vertical radar compared with the south side, for different altitude bands, and with a distinction between days with high altitude migration (strong migration) and days with less intense flight movements.*

Altitude	Period of migration intensity (strong migration; >300 MTR at >250 m at south side of radar)	% recorded tracks at north side compared to south side
>250m	weak migration (n days = 42)	79.1
	strong migration (n days = 7)	60.1
	all nights April-May	76.4
150-250m	weak migration	82.2
	strong migration	64.9
	all nights April-May	79.7
50-150 m	weak migration	95.5
	strong migration	66.8
	all nights April-May	91.4
0-50 m	weak migration	99.3
	strong migration	101.6
	all nights April-May	99.7

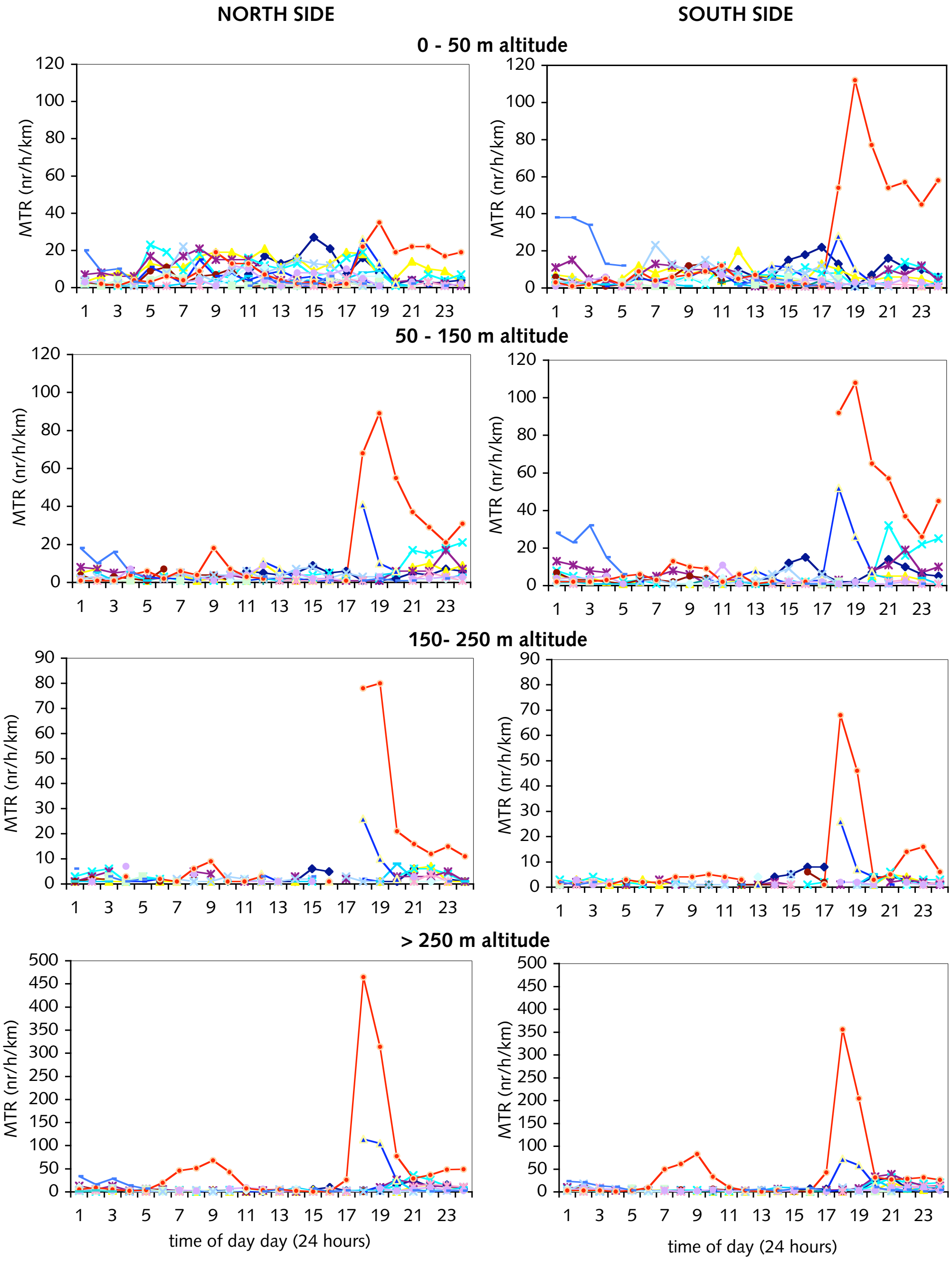


Figure 8.4 Mean traffic rate (MTR) registered by the vertical radar, compared between north (left panel) and south side (right panel) of the radar, in September-October 2004 for 4 altitude bands. Data for distance zone 500-1500m.

As shown in earlier studies with vertical marine surveillance radars detection loss occurs when birds fly not perpendicular through the radar beam due to the position of the birds body in the radar beam, creating differences in reflectivity of the birds (reflecting surface expressed as radar cross section) (Poot *et al.* 2003). The largest reflectivity or radar cross section of a bird occurs when the bird is beamed from aside. Relatively the smallest radar cross section occurs when a bird is beamed on the rear. A relatively better reflectivity is achieved when the birds flies head on into a beam, with the chest creating a relatively large radar cross section, but less than from aside (Eastwood 1967). In case of spring migration at the North Sea with many migrants coming back from the British continent, birds are mainly heading from ENE to NNE. Relatively most migrants are then to be expected to fly head on into the southern side or beam of the vertical radar at the south side of platform; thus the radar beam at the south side will more easily detect birds because of a larger radar cross section compared to the northern beam, where overall relatively more birds will be beamed on the tail. Indeed there is a considerable difference between the number of recorded tracks between the southern and the northern side of vertical radar (fig. 8.3, table 8.1). At the days with the strongest migration (defined as the nights with large numbers of tracks higher than 250 m) at the northern side only 60 % of the intensity is recorded as compared to the south side. Although the number of days with the vertical radar operating was limited, in figure 8.4 indeed, as to be expected, this is the other way around, when the recorded intensity at high altitudes is highest in the northern beam. Because of flight directions more directed SSW to WSW in autumn, relatively most birds are more beamed head on at the northern side of the vertical radar. It is clear from table 8.1 that the strongest detection loss happened in the higher altitude bands and was hardly present in the lower altitude band. This is likely explained by the fact that migrants on average consist of smaller species, while in the lowest air layer probably large species as gulls and waterbirds as ducks and geese were involved. The radar cross sections of these birds are so big that they are detected from any direction.

Taking into account the detection loss described above, one has to bear in mind that when differences exist between the two sides of the vertical radar, the MTR has to be corrected in two ways. Firstly, the MTR recorded at the best side is still suboptimal, as the birds are detected head on. Based on own studies the MTR must be elevated by a factor between 1 and 2 to achieve full detection like when the birds are beamed from aside. Secondly, the MTR needs to be corrected to arrive at an MTR of a 'true' perpendicular stream (Poot *et al.* 2003). In case of the lowest altitude band this does not seem to play a serious role as here mostly large species are involved, but already in altitude band 50-150 m at good migrations days this detection loss cannot be ignored (table 8.1).

Migration of other species than seabirds and gulls in the offshore situation only seem to occur at days/nights with favourable (wind) conditions, when the birds take most advantage of these favourable winds at the higher altitudes. Most migration occurs therefore above 150 m, while local and migration movements of seabirds occur in the lower air layers, and then well below rotor height.

8.2 General patterns of flight altitudes during daytime (panorama scans)

In this paragraph patterns in flight altitudes are described based on visual observations only (panorama scans). Of all flying birds observed during the day with the panorama scans (excluding birds associated with fishing vessels, figure 8.5 left graph) 54% flew at the lowest altitude band (with an average altitude of 11.3 m). This is in accordance with the general pattern recorded by the vertical radar during the day. When also the birds associated with fishing vessels are included (mainly gulls and some cormorants) this percentage was even 75% (fig. 8.5 right graph). As is clear from the above figures, a considerable part of the flying birds was associated with fishing vessels (64.9%, of which 99.9% gulls) and flew for 94% in the two lowest altitude bands. Excluding all gulls flying low and associated with fishery vessels, 45% of the birds were flying in the three altitude bands which overlap with rotor height (25% when including associated birds) (average altitudes 43, 104 and 135 m). We are aware that relatively more birds will be missed at the far end and in the higher altitude bands of the panorama scan view of a field observer (see also vertical radar data), nevertheless we estimate that the general pattern of the highest flight activities in the lowest altitudes during daytime is realistic. Detailed information on species composition based on the visual observations (especially based on the patterns of the largest species groups) confirms this judgement.

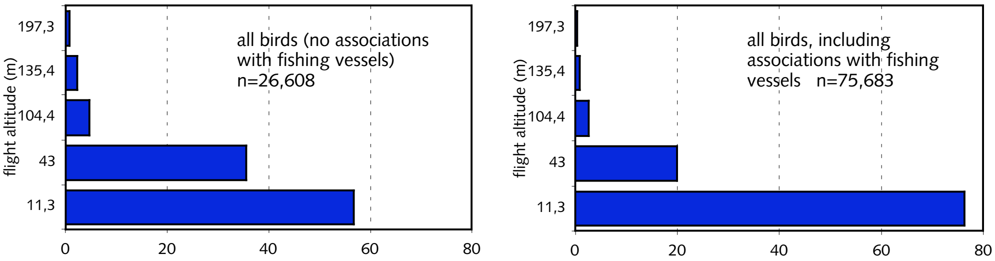


Figure 8.5 Range and frequency distribution of the flight altitudes of all birds (except gulls and cormorants associated with fishing vessels) flying at sea near Meetpost Noordwijk during the day (based on visual observations by the panorama scan method). Left figure presents the flight altitudes of birds that are not associated with fishing vessels, right figure presents flight altitudes of all birds including those associated with fishing vessels.

8.3 Altitudes of the various species groups during the day (panorama scans)

Based on the observations of the panorama scans, information is available about differences between various species groups during the day. Many birds flew at low altitudes during the day, but flight altitudes varied between as well as within the observed species groups (table 8.2). In grebes, tubenoses, alcids, skuas, divers, sea ducks and other ducks, landbirds, gannets and waders, more than half of the birds flew in the lowest altitude band. Of these species groups especially grebes, tubenoses and alcids were hardly seen flying at higher altitudes. The other species with better flight properties (e.g. soaring flights in the afternoon by gulls and gannets) showed a higher variation in flight altitudes, increasing the average altitude somewhat. As gulls are dominant in the species composition of birds flying during the day, they are discussed further in § 8.3.1 and § 8.3.2.

Within each species group there is a large amount of variation in flight altitude, due to for instance environmental circumstances, behavioural activities (eg., foraging or roost migration), or differences between species. Ranges in flight altitudes of each species group are presented in figure 8.6. Based on these graphs, some patterns can be distinguished:

- Flights occurred in general in the lowest altitude band of 11,3 m on average or less for alcids, divers, sea ducks, skuas and tubenoses.
- Flight altitudes varied largely in especially cormorants, geese & swans, gulls, ducks other than sea ducks, and waders. In these species, flight altitudes commonly varied between 0 and 200 m. In migrating birds such as geese & swans and waders, this variation may be caused by differences in wind direction and wind speed.

Table 8.2 Average altitude of birds flying at sea near Meetpost Noordwijk, presented for each species group observed (calculated on flock level). Species groups are listed from lowest to highest average flight altitudes.

species group	average altitude	StdDev	n flocks
grebes	11,3	-	1
tubenoses	11,3	0,0	9
alcids	11,9	4,4	305
skuas	16,2	11,9	13
sea ducks	18,5	19,0	158
divers	19,0	16,1	82
cormorants	23,8	22,4	154
gannets	25,6	15,8	131
landbirds	27,0	25,6	213
terns	27,6	18,7	120
waders	28,6	45,4	37
other ducks	34,8	32,8	40
geese & swans	35,2	37,1	30
gulls	36,8	33,3	8535
raptors & owls	73,8	53,3	3

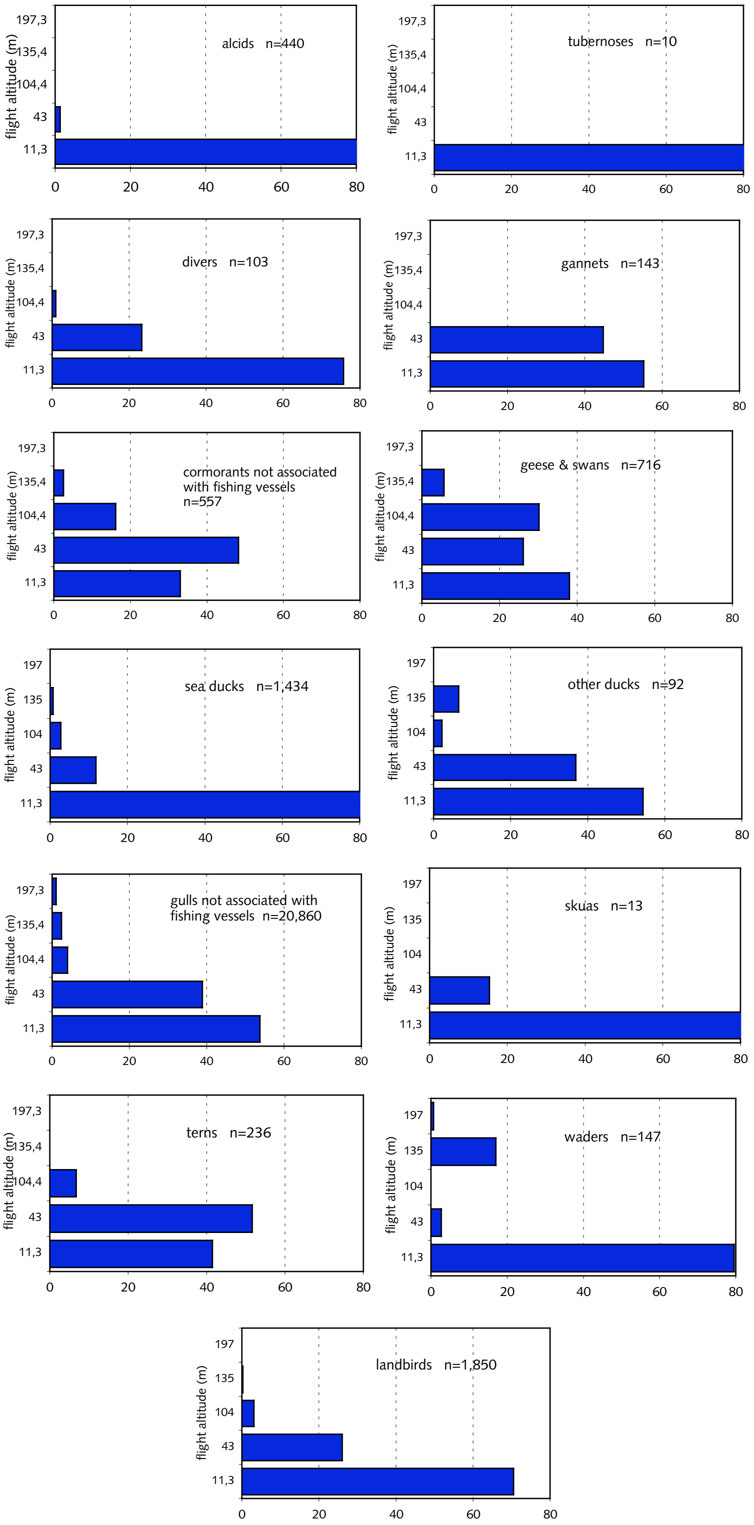


Figure 8.6 Range and frequency of flight altitudes for the different species groups observed near Meetpost Noordwijk in the panorama scans. Gulls and landbirds are further analysed lower species (group) level, presented in figure 8.7 - 8.10.

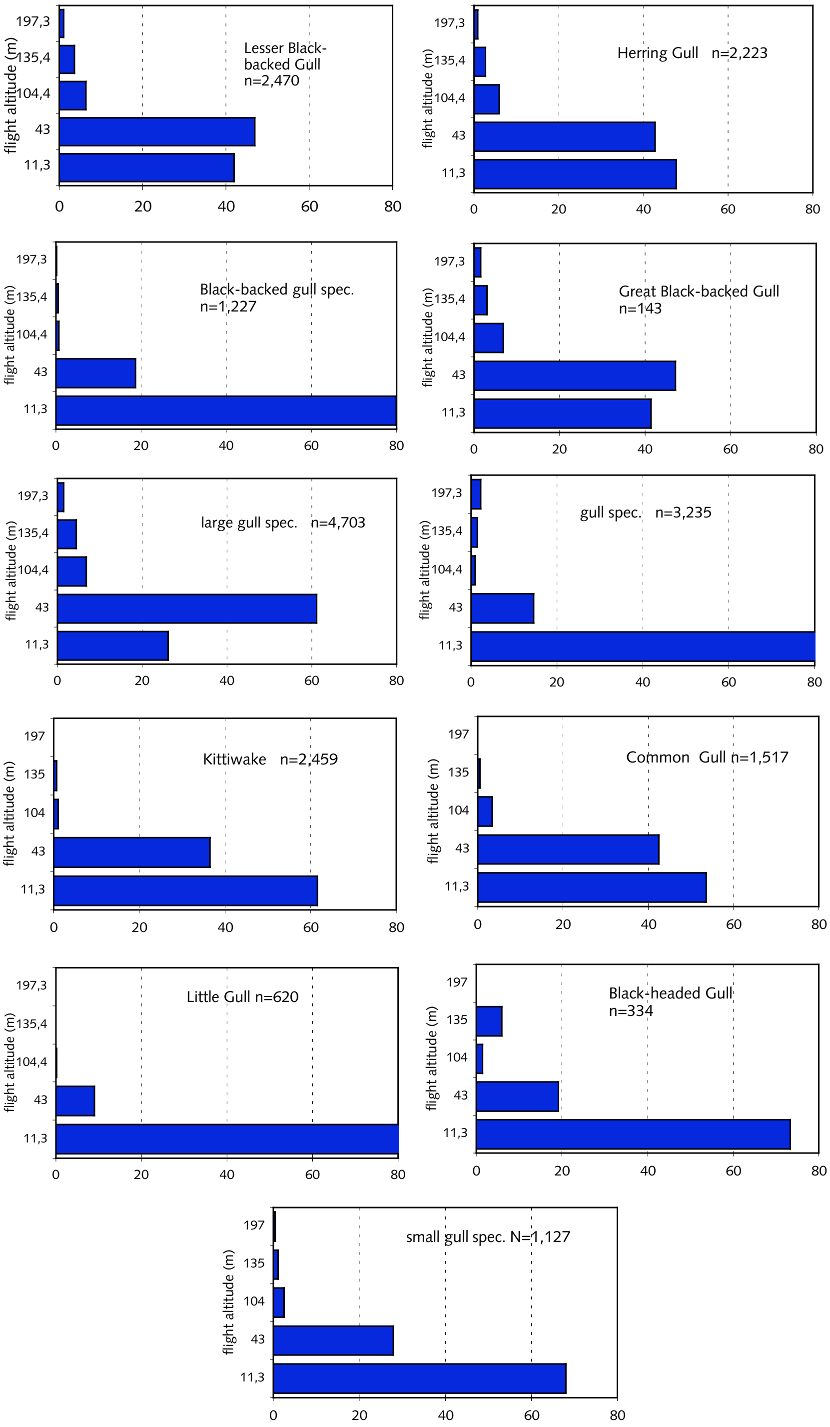


Figure 8.7 *Range and frequency distribution of the flight altitudes of the various species of gulls flying at sea during daytime near Meetpost Noordwijk during panorama scans. Species groups reflect those birds that could only be identified to that specific level, and do not include birds that were identified to species level.*

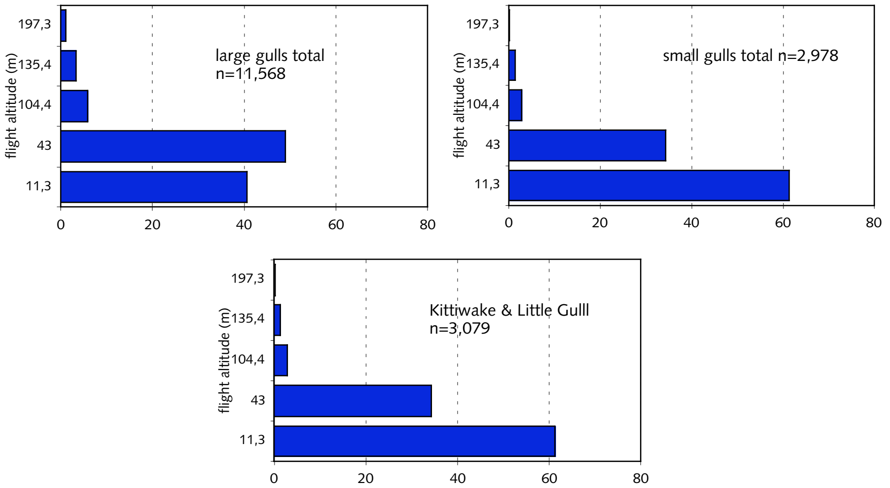


Figure 8.8 Range and frequency distribution of the flight altitudes of aggregated species groups of gulls (based on size and feeding ecology) flying at sea during daytime near Meetpost Noordwijk during panorama scans. Species group 'gull spec (n=3,235) is not included in this presentation (see figure 8.3).

8.3.1 Altitudes of the various gull species

The larger gull species (Great- and Lesser Black-backed Gulls and Herring Gull) flew significantly higher than the smaller species of gulls (Common Gull, Black-Headed Gull, Kittiwake, Little Gull). The range in flight altitudes was large for the larger species of gulls, as is depicted in figure 8.7. Flight altitudes were considerably more confined to the lowest altitude band in Black-Headed/Common Gulls and Kittiwakes/Little Gulls.

8.3.2 Birds associated with fishing vessels

Of all gulls observed during the panorama scans, 70.2% was associated with fishing vessels. Of all cormorants, 10.6% was associated with fishing vessels. No other species were associated with fishing vessels in substantial amounts. As these associated birds are scavenging on fish discards from the ships, their flight altitudes differ from the flight altitudes of conspecifics that are not associated with ships. The mean altitude of not-associated gulls was higher than that of associated gulls (compare figure 8.8 with 8.5). When foraging behind ships, gulls hardly fly at altitudes higher than 15 m. Similarly, non-associated cormorants flew on average higher than associated cormorants. These results indicate that behaviour can influence the flight altitudes of birds and that it is indeed important to distinguish between free ranging gulls and cormorants and conspecifics following fishing vessels.

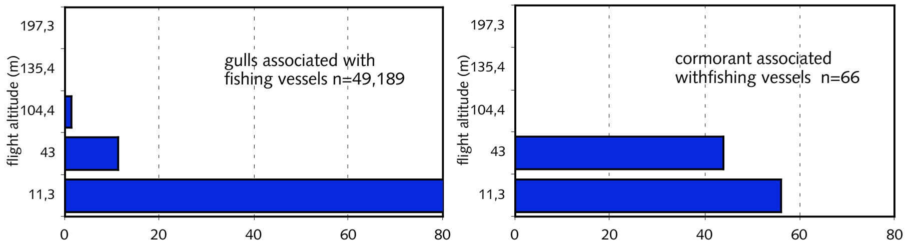


Figure 8.9 Range and frequency distribution of flight altitudes of gulls and cormorants associated with fishing vessels. For comparison, see for flight altitudes of non-associated gulls and cormorants figure 8.5.

8.3.3 Passerines

The species group "landbirds" consists almost exclusively of migrating passerines. These are divided into thrushes, Starlings, and small passerines, which include finches, pipits, wagtails, etc. Most thrushes flew by at altitudes of 43 m on average (fig. 8.9). Starlings were flying lower, with flocks regularly flying very low over sea. Small passerines were observed flying at the widest range of altitudes, to a maximum of average 135 m.

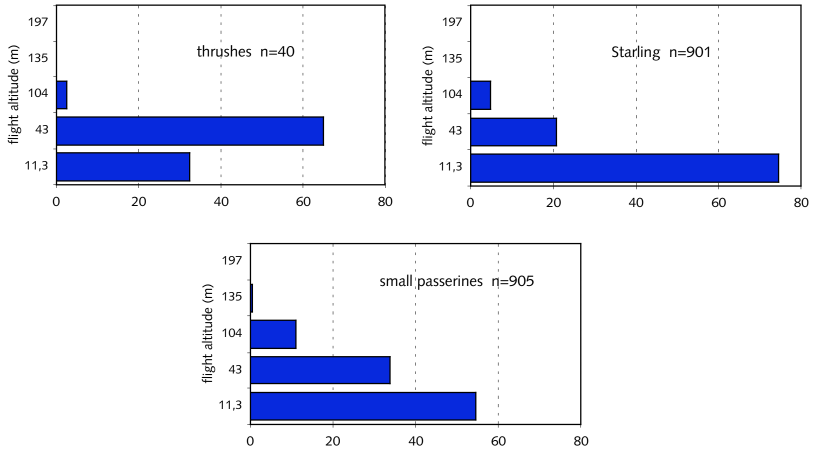


Figure 8.10 Range and frequency of flight altitudes for different passerine groups observed near observation platform Meetpost Noordwijk in the panorama scans.

8.4 Additional information on flight altitudes at night (moon watching)

In addition to the vertical radar observations also altitude information was obtained by counting birds passing the disk of the full moon. In this way quantitative estimates of numbers and flight altitudes were recorded of birds flying nocturnally up to altitudes of 1 km (Liechti *et al.* 1995). On 5 nights in October and November 2003, estimates of numbers of birds migrating in the dark were made by means of moon watching. Flight altitudes were high, mostly between 200 and 600 m, but ranging up to even 1.000 m (fig. 8.11). In November, flight altitudes were higher than in October. This was mainly due to a difference in species composition in combination with wind conditions (more waders in November vs. thrushes and other passerines in October).

Unfortunately, on the nights that moon watching was carried out, the vertical radar was not functioning. Especially 12 October 2003 was a day on which bird migration activity over the North Sea rated among the most intense, as confirmed by radar (pers. comm. RNLAF through Van Gasteren) and field observations (www.trektellen.nl). It is plausible to assume that more nights than just peak nights such as 12 October 2003 would have yielded similar altitude profiles. In the vertical data now only one night in October 2004 is available (fig. 8.4).

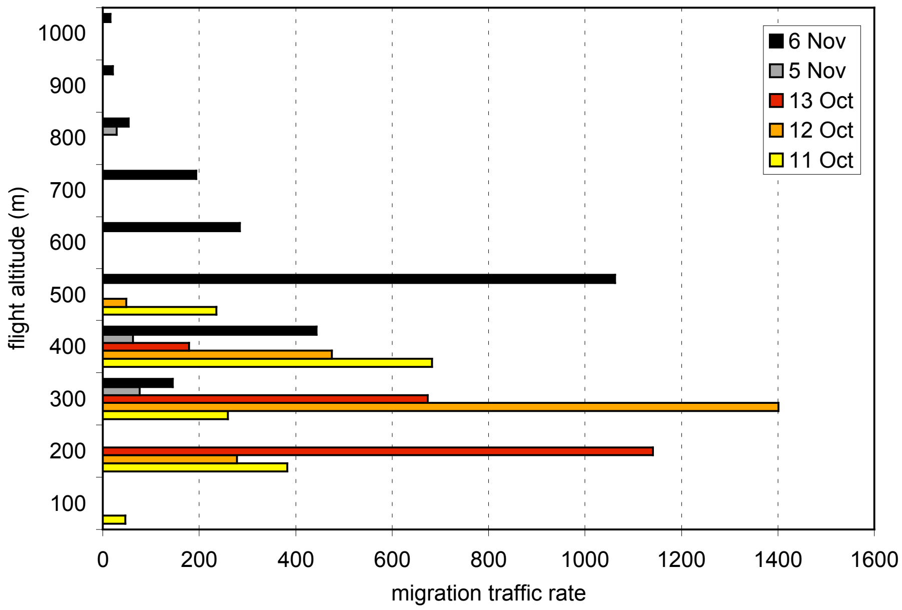


Figure 8.11 Flight altitudes of birds migrating in the evening hours, as registered by moon watching.

8.5 Altitudes of the various species groups at night (moon watching & calls)

Based on the visual observations of birds passing the disk of the moon some information is available on species composition on 5 nights in October-November 2003. In October, most of the birds were thrushes, probably mostly redwings, based on calls heard simultaneously (see §6.3.2 & 6.3.3). On the night in November, besides thrushes also considerable numbers were seen of waders (flocks of lapwings and curlews), some geese, and small passerines (table 6.3). On all nights the largest numbers of migrating birds were flying on altitudes higher than 200 m, although one should bear in mind that by moon watching very low flying birds at the same height and lower as the platform can not be recorded. We know that substantial gull activity occur at night around active fishing vessels, based on observations of fishing vessels close enough around the platform. This hints at a possible dichotomy of flight altitudes of local versus migrating birds flying above the North Sea.

8.6 Conclusions

- The recordings of flight movements by the vertical radar, although limited throughout the year, are confirmed by the additional visual observations during the day and night. Migration of other species than seabirds and gulls in the offshore situation only seem to occur at days/night with favourable (wind) conditions when the birds take most advantage of these favourable winds at the higher altitudes. Most migration occurs therefore above 150 m, while local and migration movements of seabirds occur in the lower air layers, and then most of the time well below rotor height.

- The observations during daytime have shown that more than 50% of the birds flew in the lowest altitude band of an average height of 11.3 m. Of many pelagic species, such as alcids, divers, tubenoses and sea ducks, an even larger proportion flew here. When birds associated with fishing vessels are included (mainly gulls, and a small proportion of cormorants), this percentage increases to as much as 75%. In the altitude bands from 43 up to 200 m on average, the percentage of birds was considerably less than in the lowest air layer. It seems plausible that this is the result of a dichotomy in flight altitudes between local and migrating birds flying above the North Sea; either birds fly low over water (mainly local, and migrating seabirds and some species of waterbirds, e.g. seaducks and divers), or they fly at least above hundreds meter high (migrating, and then are easily missed by field observers).

- Visual observations during the night in autumn 2003 have shown that largest numbers of migrating birds were flying above 200 m. At the same time visual observations have shown that considerable numbers of gulls are also active during the night when active fishing vessels are available. Although no extensive visual observations were possible in the lowest altitude band at night, it is plausible that at low altitudes a relatively high activity of gull movements must occur between fishing vessels.

9 Discussion

9.1 Evaluation of radar observations

Technique

To quantify flight patterns of local and migrating marine birds and migrating non-marine birds in the study area at the North Sea, we employed an automated radar system recording both fluxes, flight paths and flight altitudes of the birds in the study area. The advantages of this system are that it can 1) quantify birds flying at night and 2) automatically register flight patterns 24 hours a day, 365 days a year. As this study aimed to gather baseline data to evaluate the effects of a wind farm on flying birds, observations of nocturnal flight patterns are crucial, as the risks of collision with wind turbines are highest in the dark. In addition, flight patterns of birds off shore are highly variable, depending on factors such as weather conditions, time of year and day, and factors affecting population size. In comparison to visual observations, which are restricted largely to daylight hours and cannot easily be performed year-round, the advantages of an automatic radar system thus are indispensable when quantifying flight patterns of birds off shore year round.

In addition to these radar observations, we used an array of visual and auditive observation techniques to obtain a more detailed insight in species composition, and to build a database covering all aspects of flight patterns, to the highest extent possible. This visual database served as a backup of the database generated by the radars, and as a means to calibrate and ecologically interpret the radar observations. Thus, by using e.g. the flagged echoes and the panorama scans, radar observations of daylight flight patterns could be interpreted and extrapolated to nocturnal flight patterns.

Analysis and results

The goals of the radar observations have in general terms been met. The horizontal radar has collected data for almost a full year (80% of all days in the study period), both day and night. The vertical radar has collected data on 30% of all days. Due to technical problems, the vertical radar has been inactive for a large number of days, unfortunately including important periods of migration.

Analysis of the radar data (§5.1-5.3), as well as comparisons between visual and radar observations (chapters 6-8), have shown that the vertical radar data correspond for a large part with patterns in space and time observed visually. However, we know that the radars did not detect all birds flying by the observation platform, as could be established by means of visual observations and simultaneous inspection of the radar screens, as well as by flagging. In the horizontal radar it has become clear that the same flock of birds can be lost and found back repeatedly and therefore be recorded several times. Therefore only the vertical radar has been used to determine fluxes, as with the more narrow vertical beam this is of less a problem. Furthermore, the radars have recorded a large quantity of echoes called clutter that did not belong to birds, but to waves (mostly). Although software had been developed to exclude clutter from the data and record birds only, the results show that this has not effectively been the case, creating an extra effort to identify recorded echoes. In the vertical radar data, this problem is restricted mainly to the lower altitudes (< ca. 10 m), although at higher altitudes also a fraction of unexplained echoes have been recorded (roughly estimated at 5-10% of the records). In the horizontal radar data, clutter from waves was recorded through the entire range of distances away from the radar, although it centered around the platform, and formed a major part of all echoes recorded (at least 85%). As a result, echoes of flying birds were buried between the echoes of clutter, and the analysis-tool originally designed for species group identification had to be used mainly to separate bird-echoes from clutter.

Bird echoes were separated from echoes of clutter, ships, etc. by using the dataset of flagged echoes, and performing classification and regression tree analysis. This proved also to be a strong tool to separate a large percentage of clutter from bird echoes (§5.1: flagged horizontal radar data correctly classifying 99% of clutter) despite the fact that the amount of clutter in the horizontal radar data was so large. After filtering out echoes classified as clutter, a variable percentage of data still consisted of clutter, depending on the weather conditions on different days. The largest problem in the analysis of horizontal data was that the same flock of birds were recorded several times as different birds by the software because the radar lost flocks of birds, e.g. in between the waves. This meant that echo densities or fluxes were hard to calculate. Subsequently, the horizontal radar data were analysed for patterns in flight directions that could be positively related to the fluxes recorded by the vertical radar and the visual observations during the day. In this way the horizontal data were interpreted in type of flight movements (migrants vs. local seabirds) and species groups by analysing patterns during the season and in relation to environmental conditions. The analysis of the vertical radar revealed that diurnal patterns in the lowest altitude band (0-50 m) could very well related to observations during the day.

9.2 The use of different visual observation techniques

Sea watches and panorama scans

Sea watching was primarily an additional method to the panorama scans, intended to obtain more records of less numerous bird species, notably seasonal migrants. Did it serve this purpose? The total numbers of birds seen with the two methods are compared in table 9.1. Because of the difference in observation methods, it is not the absolute totals that are of interest, but differences between species groups in the ratio between these totals. This ratio varies strongly by species group: while almost three times as many flying tubenoses were seen during sea watches as during panorama scans, nine times as many gulls were recorded in the panorama scans. There was indeed a tendency for the scarcer species groups to be observed more often during sea watches. This was especially true for the more pelagic seabird groups (tubenoses, divers, skuas, alcids) and terns, while species that usually migrate over land or forage in nearshore waters from a land-based central place (landbirds, geese, waders, cormorants and gulls) were seen more in the panorama scans. This is understandable as sea watches were made while looking only towards the west, while panorama scans covered all directions of view. Any group that passes east of the platform more often than west of it, is thus likely to be recorded more in the panorama scans, and vice versa. When the correlations were made not on the basis of hourly records (individual scans) but on daily averages (n=26), the correlations were not improved. For number of birds, they were similar to the hourly correlations (r=0.25-0.30), but for the number of groups they were even negative (-0.-4 to -0.11); however none of these was significant. One explanation for this is that there is very significant variability in bird flight activity within days (morning migration peak, roosting flights of gulls, trawlers present for a few hours and then moving elswhere) that is 'squashed out' when records are averaged over the day. A further reason why panorama scans yielded more gulls and landbirds will have been their flight altitude (relatively often at higher altitudes which sea watches do not cover). In summary, sea watches add to the panorama scans especially by giving a better picture of movements of pelagic seabird groups other than gulls.

Table 9.1 Comparison of total numbers of flying birds seen during panorama scans and during sea watching at MpN, for distance zones 1-3 (<3 km) and for the total including zone 4. Species groups are ordered by decreasing ratio between total number seen in sea watches relative to panorama scans.

species group	panorama scans		sea watching		ratio seaw:panscan	
	<3 km	total	<3 km	total	<3 km	total
tubenoses	10	10	27	28	2.70	2.80
divers	139	160	325	405	2.34	2.53
terns	316	323	651	764	2.06	2.37
skuas	14	14	25	30	1.79	2.14
alcids	852	861	1166	1315	1.37	1.53
other ducks	110	237	281	323	2.55	1.36
gannets	212	261	192	294	0.91	1.13
grebes	9	9	8	8	0.89	0.89
sea ducks	2707	3069	1986	2625	0.73	0.86
waders	149	270	155	212	1.04	0.79
landbirds	2782	2782	1619	1634	0.58	0.59
cormorants	761	1374	332	571	0.44	0.42
geese & swans	1029	2177	401	598	0.39	0.27
gulls	106411	185307	16825	21153	0.16	0.11
total birds	118537	202336	21630	27096	0.18	0.13

9.3 Comparison of flight patterns on sea, shore and inland

9.3.1 Diurnal flux and species composition

The panorama scan methodology has been applied at two other places in the Netherlands to quantify the intensity of bird flight movements in the lower air layers. These measurements gave us the opportunity to compare the intensity of flight movements of birds at the study area at the North Sea with flight intensities in two different habitats, being on shore and inland. The method has been used during a full year at Eindhoven Airport. This airport is an inland location with accompanying bird species composition. Observations were carried out from a 20 m high hill along the runway. The second location was at the end of a 3 km long pier near IJmuiden, at the coast of North-Holland, where observations were carried out for one week in October

1999 and one week in November 1999. In the second week the observations were made from halfway the pier within the harbour, due to stormy weather.

Data gathered on the two locations have been published (Lensink *et al.* 2000, Poot *et al.* 2000) and compared before in relation to bird strike risk assessments. The unit of presentation in those studies was n birds or kilogram biomass per cubic kilometre at an instantaneous moment as the impact of a collision on the aircraft was the main focus. For the purpose of estimating collision risks with wind turbines the appropriate unit is mean traffic rate expressed as the number of birds passing a line of one kilometre in one hour (n/km/h).

Comparing height ranges

At the platform, maximum height of view in the upper panorama scan was about 140 m. At Eindhoven Airport the observations were carried out from a 20 m high point, which is a similar height as on the platform. The binocular view however was positioned halfway the horizon, which yielded a lower height range. A second panorama scan was carried out directly after the first one, with the horizon in the lower part of the binocular view. The observations in the height band in the binocular view at 3/4 from the lower part of this second panorama scan were added to the observations of the first panorama scan, thus yielding a height range of 120 m. At the Pier van IJmuiden the observation position was about 8 m above sea level. The binocular view had the horizon fixed at 1/4 in the lower part, and this was the only panorama scan position used. This yields a height range of about 120 m, which is similar to the height range observed at Eindhoven.

When comparing the number of birds observed it is clear that the largest numbers of birds flew relatively low during the day. Therefore the effect of the incomplete match in coverage of the higher height range is assumed to be neglectable.

Species composition

The harbour area near IJmuiden is where the North Sea channel arrives at sea. Besides being an active fishing harbour with an ample availability of discards for gulls, fishing vessels were regularly active in the shallow coastal zone. Because of this, this area is extremely rich in gulls. The location is situated about 30 km northeast of the observation Platform Noordwijk. In this manner IJmuiden was more comparable to the platform than Eindhoven, with respect to species composition and numbers of birds (fig. 9.1; domination of gulls). The species composition at Eindhoven Airport was very different, with several species of land birds that were never observed at sea (see Lensink *et al.* 2000).

Mean traffic rate

First, all observations within the 1500 m radius of the panorama scan were used to arrive at a comparable measure of bird density by dividing the average number of birds per panorama scan by the surface area of the panorama scan (7.07 km^2). Subsequently the density of birds was multiplied by an assumed average flight speed of the average bird. Taking into account species composition, flight behaviour and influence of wind conditions on the ground speed of birds, one can assume that the average flight speed lay between 30 and 50 km/hour. In this way one arrives at the mean traffic rate (n birds/km/h), which is shown for all three locations in figure 9.2.

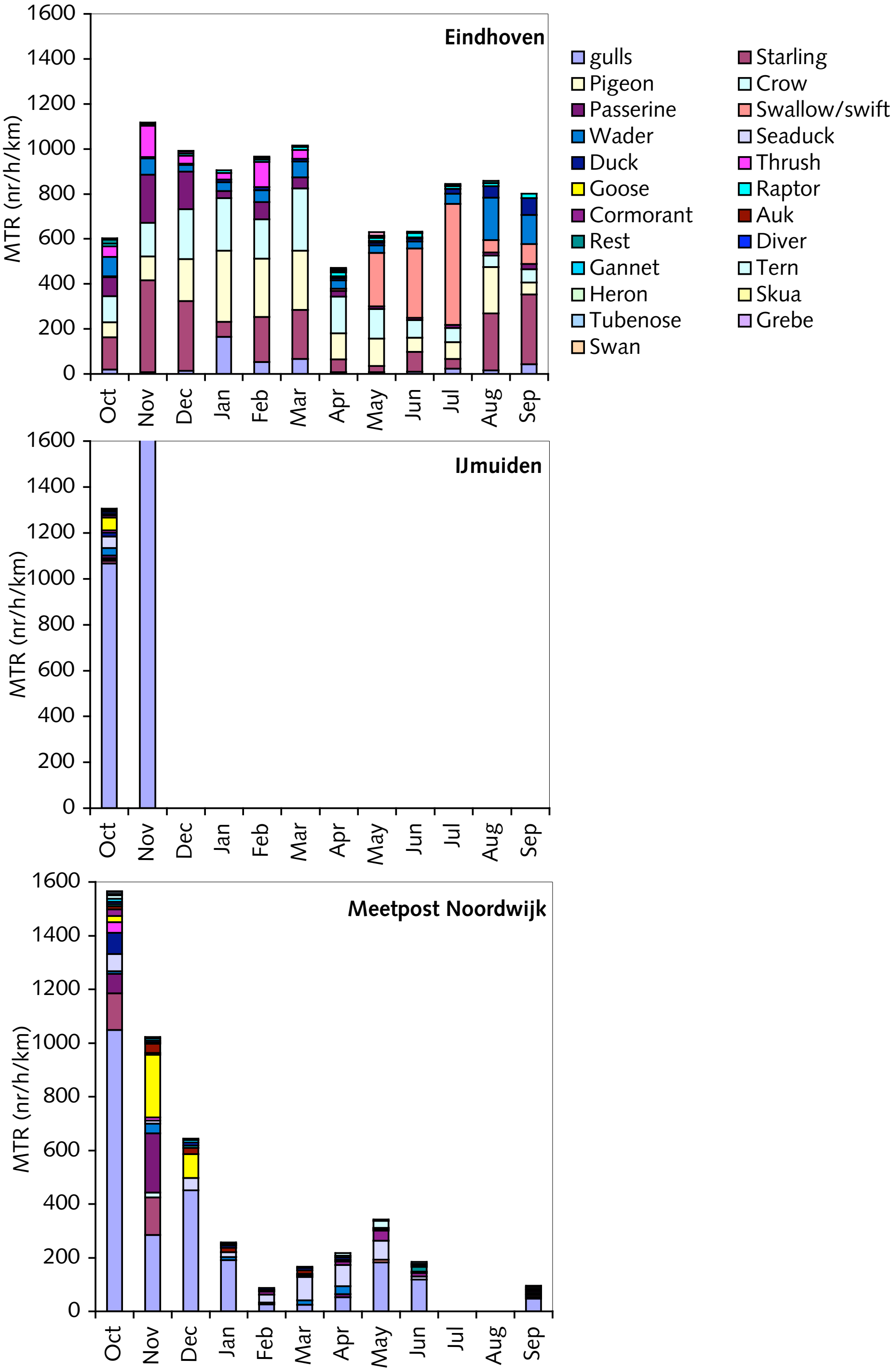


Figure 9.1 Comparison of flight intensities and species composition of birds inland (Eindhoven Airport), at the coast (Pier of IJmuiden; max. MTR = 3200) and off shore (Platform Noordwijk).

MTR at Eindhoven was in most months two to three times higher than at the observation platform. At Arnhem, a location with relatively low fluxes of migratory birds, MTR in autumn was estimated to be 660 birds/h/km (data 15 aug-30 nov; daytime only; altitudes up to 100 m; pers. comm. R. Lensink). The results presented in this report suggest that fluxes over sea, away from the coast, are lower than fluxes over land. Only in autumn did fluxes reach levels that were higher than over land. For IJmuiden, counts are only available for October and November. MTR of October is similar to that established at the observation platform, and consisted largely of gulls. In November, MTR at IJmuiden was three times higher than at the platform. This was due mainly to the fact that far fewer gulls were observed at the platform. Fluxes of migrating birds show peak levels in the coastal region (Lensink 2002). Further out at sea, fluxes decrease again (van Gasteren *et al.* 2002). The figure shows data only for fluxes at lower altitudes during the day. Migration patterns at night and at higher altitude will deviate from this pattern.

9.3.2 Nocturnal flux and species composition

During registration of nocturnal calls three species of thrushes were the most numerous; *i.e.* Redwing, Songthrush followed by Blackbird (table 9.2). Other species registered were Skylark (1, October), Curlew (1, October), Brent Geese (1 flock, October) and Oystercatcher (1, March).

Table 9.2 Average number of registered calls per hour of three species of thrushes during the beginning of the night (ca. two hours after sunset) at Observation Platform Noordwijk in 2003-2004. Note that data in September are sampled in both 2003 and 2004 (table 4.4). Data for Twenthe are from Lensink (1986) and were collected in October 1984, following the exact same protocol. The first line gives the number of hours that calls were registered on the platform.

	sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
Near shore: observation platform MpN, beginning of night												
hours observed	8,3	9,5	5,2	5,1	0	1,6	3,0	3,5	0	0	0	0
blackbird	0,0	0,4	0,8	0,6		0	0	0				
songthrush	5,6	2,6	1,7	0,0		0	0	0				
redwing	0,0	15,5	32,9	3,9		0	0	0				
Inland: Twenthe, beginning of night												
blackbird		0,5										
songthrush		3										
redwing		25										
Inland: Twenthe, end of night												
blackbird		1,5										
songthrush		25										
redwing		40										

Thrushes are among the species migrating abundantly across the North Sea (Buurma 1987, Lensink *et al.* 1999). Data from MpN fit into this picture. Most observations were done in the early evening. Most birds registered would have started their journey from the Dutch coast earlier that evening. Comparable data on nocturnal calls were collected at an inland location in the eastern part of the Netherlands in 1984 (Lensink 1986). Observations were made during a number of nights in de second week of October at airbase Twenthe and lasted the whole night. During the beginning of the night about the same intensity was registered as on the observation platform off shore. At Twenthe Airbase, peak numbers were recorded at the end of the night. These quantities are however in the same order of magnitude as in the beginning of the night. Thus, the data from MpN can be considered more are less representative for nocturnal broad front migration across the North Sea (table 9.2).

Calling birds, registered by observers, are flying in the lower air layers. It is assumed that birds were recorded up to about 150 m distance. This means that the number of calls is representative for the number of birds passing a line of 300 m. In addition, not every flying bird is calling every moment. Therefore birds can pass by, without being recorded by a human ear. Based on calling frequency, it is estimated that about 20% of the birds passing is registered. Based on these two assumptions, the number of calls was used to calculate the mean traffic rate, *i.e.* the number of birds passing a line of 1 km during 1 hour (table 9.3).

Table 9.3 Comparison of nocturnal flight intensity off shore and inland, of three species of thrushes. Intensities are expressed as mean traffic rate (nr birds/km/h) and give an average over several observation nights. Peak numbers can during certain hours reach levels that are tenfold higher than those presented here. Basal data in table 9.2. Calculations are explained in the text.

	mean traffic rate			
	sep	oct	nov	dec
Near shore: observation platform MpN, beginning of night				
blackbird	0	6	12	9
songthrush	85	39	26	0
redwing	0	232	494	59
Inland: Twenthe, beginning of night				
blackbird		8		
songthrush		45		
redwing		375		
Inland: Twenthe, end of night				
blackbird		23		
songthrush		375		
redwing		600		

9.3.3 Differences in flight activity between Meetpost Noordwijk and the Near Shore Windfarm site

The data described in this report are meant to form a baseline, against which data on flight activity of birds in the area of the Near Shore Windfarm (NSW), to be collected after the turbines have been erected, can be compared. Of course, such a comparison is most powerful if pre- (T0) and post-construction (T1) data are collected at the site where the windfarm is built. In the case of NSW, however, there was no suitable platform available in or close to the windfarm area that allowed the installation and operation of the radar system and could also harbour a group of observers carrying out the visual observations. Meetpost Noordwijk was chosen as the best alternative available. It has very good facilities, and is situated at the same distance from the coast as the NSW. However, it is approximately 40 km further south along the Dutch mainland coast, and this could mean that the number and type of flight movements may differ from that at NSW. In this section, we briefly discuss differences and similarities in bird flight activity that are to be expected between the two locations.

There is no database that allows bird flight activity to be compared directly between the MpN and NSW locations, except the counts of seabirds present in the ESAS database and the database of RIKZ (summarised in Leopold *et al.* 2004). However, these data mainly refer to locally operating (foraging) birds, and migrants are less well represented by these counts. What is available is data from several thousands of hours of sea watching from coastal sites. These data were summarised in Camphuysen & Van Dijk 1983 and Platteeuw et al. 1994. In these publications, migration data are reported for "Zuid-Holland" (ZH: the coast from Zeeland up to IJmuiden, data dominated by Scheveningen and Noordwijk), "Noord-Holland" (NH: Castricum to Den Helder, data predominantly from Camperduin), and "Wadden coast". For each of the periods covered by the reports, we derived a ratio between the mean strength of passage (number passing per hour, daytime only, effort throughout the year concentrated in passage periods and in the mornings) in NH and ZH for each major bird group. For 1974-79, this was based on the overall hourly averages (total birds seen / total effort in hours); for 1980-89 on hourly averages in the best weeks during the first and second half of the year. The ratios were then averaged for the two periods. If the resulting index is >1, the species or group is more abundant at (the coast of) NH than ZH.

Species groups are ordered by their mean ratio in table 9.4. Most of the 'real' seabirds are more than twice as abundant in NH than in ZH: tubenoses, alcids, gannets and little gull (skuas, terns and kittiwake were only slightly more abundant there). Brent goose is the only "non-seabird" that was more than twice as abundant in NH. In this species the higher abundance in NH is caused by birds 'cutting off' the concave bend in the Dutch coastline while travelling between France/Zeeland and the Wadden Sea, or on spring migration from southern England. A similar effect also occurs in several other species during spring migration (Little Gull, Sandwich Tern, several ducks including scoters, divers).

Species groups that were notably more abundant in ZH (ratio <0.5) include grebes, geese and swans other than Brent Goose, and Cormorant. The higher abundance of geese reflects the major flyway through the interior of the Netherlands (IJsselmeergebied, IJssel Valley) to the Delta area and Belgium, that largely bypasses Noord-Holland but partly reaches the coastline further south. The much higher abundance of grebes is the result of the abandonment of inland waters, notably Lake IJsselmeer, when these freeze over; the birds then fly SW and hence hit the coast mainly south of NH. The same is true for several duck species (particularly diving ducks), but this does not show up in the ratios because it is counteracted by higher numbers along the NH coast on spring migration. The higher abundance of Cormorants also reflects the main SW exit route from the IJsselmeer area, while another factor may be that in the 1980s there was a breeding colony of this species near the ZH coast (Voorne), but not at the NH coast. The Voorne birds foraged partly at sea. In recent years this has changed notably and breeding colonies depending on maritime foods have been established both along the ZH and NH coasts. In spring and summer, Cormorants have become much more abundant everywhere at sea, but especially in NH.

A few major bird groups are lacking in table 9.4. The commoner gull species were counted only during sea watches in NH, and thus there are no figures to compare. During the breeding season however, MpN is within reach for foraging Lesser Black-backed Gulls (and to a lesser extent Herring Gulls) from the large colonies at the Maasvlakte. Since the large gull colonies in the dunes of NH have been vacated due to disturbance and predation by foxes, NSW is no longer in the regular feeding zone of large breeding colonies of gulls, and numbers at sea might be lower in the spring and summer months than around MpN. At other times of the year, this difference will probably disappear and local food availability (trawler distribution) will be the main driver of gull distribution.

Migrating landbirds (except large ones like raptors and herons) are also not usually counted during coastal sea watches. At MpN, passing landbirds derive from three very different sources. The first is birds that travel over sea parallel to the coastline either to intentionally cut off the ‘bend’ in the mainland coastline when conditions are good, or after being blown somewhat off course during eastern winds. The second consists of birds on autumn migration towards SW Europe that have started crossing the North Sea in a SW direction during the night but at dawn find themselves far out at sea and then reorient towards the coast in a SW direction. The third consists of birds that cross the North Sea in a westerly direction in autumn in order to winter in the British Isles. The relative abundance of birds from the second and third groups at sea off NH and ZH is not well known, but may be in the same order of magnitude. The abundance of landbirds migrating over sea parallel to the coastline is likely to be much smaller at NSW than at MpN. While MpN lies in the centre of the concave bend in the coastline, NSW lies near its top. Moreover, migrant landbirds accumulate along the Dutch coast in increasing numbers from N to S during autumn migration (but not during spring).

The differences described here for the coastal situation in NH and ZH will at least partly be reflected at 12 km distance from the coast, but probably with a few modifications. First, further from the coast the predominance of 'pelagic' seabird groups increases (for a quantification of this effect, see Leopold *et al.* 2004). The difference in abundance of these pelagic groups may therefore be less between MpN and NSW than between coastal ZH and NH. Second, birds that cut off the bend in the Dutch coast on spring migration will fly further out at sea when they pass Noordwijk but nearer the coastline when passing Egmond. For these species (e.g Brent Goose) as well, the difference between MpN and NSW may be smaller than that between coastal ZH and NH. Depending on the propensity to fly far out at sea or closer inshore, this might even mean that some species in which number flying along the coast is higher in NH than ZH, the difference may be reversed at 12 km offshore.

To summarise, relative to the situation at MpN, the more northerly location of NSW may produce the following differences in flight activity of bird groups:

- *Smaller* numbers of geese and swans, grebes, ducks during frost-flights, landbirds (passerines) migrating parallel to the coastline, and foraging flights of gulls during the breeding season.
- *Larger* numbers of pelagic seabirds (tubenoses, alcids, gannet; unknown to what extent) and possibly of brent goose, divers, seaducks and little gull.
- *Similar* numbers of other groups like terns, skuas, waders, and landbirds migrating in directions perpendicular to the coastline.

Table 9.4 Ratios between abundance (n passing per hour of observation) of major bird groups along the coast of Zuid-Holland (ZH) and Noord-Holland (NH), in two time periods. Ratios >1 indicate higher abundance in NH. See text for data sources and calculation of ratios.

species (-group)	NH:ZH 1974-79	NH:ZH 1980-89	NH:ZH average
tubenoses	1.8	14.9	8.4
alcids	3.5	6.5	5.0
seaducks	5.5	3.9	4.7
Brent Goose	2.6	5.6	4.1
Gannet	2.7	2.4	2.5
divers	2.3	2.6	2.5
Little Gull	1.6	2.4	2.0
terns	1.1	1.5	1.3
skuas	0.8	1.8	1.3
other ducks	1.0	1.6	1.3
Kittiwake	1.9	0.6	1.2
waders	1.1	1.2	1.1
grebes	0.5	0.4	0.5
Cormorant	0.3	0.3	0.3
other geese & swans	0.4	0.1	0.2

10 Conclusions

Below, we briefly present the main findings regarding fluxes, flight paths and altitudes of local and migrating marine birds and migrating non-marine birds in the near shore study area around the observation platform Meetpost Noordwijk at the North Sea. These findings are presented again in §10.2 for the main species groups. In §10.3 finally we summarise our findings regarding the methods used.

10.1 Flight patterns

Fluxes

- Mean traffic rates (MTR, n flocks/km/h) of flocks flying during daytime in the study area varied between 100 and 1000. Radar observations yielded MTR's ranging between 50 and 1000. Panorama scans yielded MTR's in the same range, but with lower means (average ca. 100, maximum 1500). MTR of rarer species flying at lower altitudes (sea watches) lay around 10 birds/km/h on average.
- Fluxes of birds migrating at night were considerably higher. MTR's measured by means of moon watching lay at values of 2000 birds/km/hour and more (nocturnal call registration by field observers yielded a maximum MTR of 500 birds/km/hour). These values reflect peak MTR's as they were collected during nights with intense migration.
- Fluxes at altitudes up to 250 m were higher during the day than at night, reflecting high activity of gulls mostly but not exclusively during day time.
- At high altitudes, fluxes were higher at night, especially during migration periods in October and April-June.
- Fluxes were highest in October, decreasing to lowest levels in January through March, and reaching a lower peak again in May-June.
- The different species groups showed varying patterns of abundance throughout the day.

Flight paths

- The majority of birds active at sea during the day were gulls (70 to 90% of all birds). Sea ducks and alcids formed ca. 5% of all birds, and migrating landbirds (mainly thrushes and small passerines) also formed ca. 5%. In total, 64 species of birds were identified.
- The high abundance of gulls was highly related to the presence of fishing vessels. These vessels attracted gulls and also cormorants from distances up to several kilometers. Of all gull movements, 80% was related to fishing vessels. As gull movements form the majority of all flight movements, 74% of all movements was related to fishing vessels.
- Also at night flight movements of gulls in relation to fishing vessels were observed frequently.
- Directed migratory movements mostly occurred in spring and autumn and were observed in most species groups. For gulls, alcids, gannets, skuas and tubenoses most

movements were local or interlocal, related to foraging behaviour. In alcids and sea ducks, correctional flights in relation to the tide were regularly observed.
- Migration was directed both parallel to the coast and across the North Sea (to and from Great Britain).
- Nocturnal migration in autumn consisted largely of thrushes (Redwing, Song Thrush and Blackbird), as well as waders, ducks and geese.

Altitudes
- During daytime, the large majority of all birds (50 to 75%) flew below 27 m, based on visual observations. The pelagic species groups alcids, divers, tubenoses and sea ducks the proportion of birds flying this low was even higher. Also gulls, mostly associated with fishing vessels flew at these low altitudes.
- Between 43 and 200 m (average of altitude band), the percentage of birds was considerably smaller than in the lowest air layer. This may reflect a dichotomy in flight altitudes of two separate groups: migrating birds flying higher at several hundred meters and local birds flying low above the water.
- Nocturnal migration mostly occurred above 200 m, both confirmed by moon watching as well as radar observations.
- Occasional observations of nocturnal flight movements of gulls showed that flight altitudes of this group occurred at much lower altitudes. Activity at low altitudes of a large number of gulls associated with fishing vessels may explain why also at night a pattern was observed of large numbers of birds flying low, migration reflected in higher fluxes at higher altitudes.
- Flight movements of bird flocks at altitudes higher than 250 m are mainly restricted to the night and indicate massive migration movements. These temporal high fluxes in the higher altitude bands were also recorded in the lower air layers, but fell within the variation of fluxes.

10.2 Species groups

Data presented for the individual species group are based on visual observations only and therefore represent only those birds flying during daytime at altitudes up to 200 m. The information summarised below can be found in paragraphs 6.1.2, 6.1.3, 7.2.3, 7.2.4, 8.3-8.5.

Local and migrating marine birds
- *Gulls.* Gulls comprised ca. 90% of all flight movements in the study area. Their abundance was highly correlated with occurrence of fishing vessels. Gulls were most abundant in October-December and in May-June (no observations in July-August). Abundance of the various gull species varied over the season according to the ecology of the species. Gulls were active throughout the day, possibly slightly less in the hours around dawn and dusk. At night activity was less, based on the fact that fluxes up to altitudes of 250 m were lower at night than during the day. However, gulls remained active over sea at night to some (unknown) extent, probably these were mainly gulls related to nocturnally active fishing vessels. Gulls flew mostly to

and from fishing vessels. thus, flight paths were largely determined by the location of fishing vessels. To a lesser extent flight paths were registered of Lesser Black-backed (and Herring) Gulls flying to and from the coastal breeding colonies. Flight altitude ranged up to 200 m. The majority however flew below 50 m. Little Gulls flew mostly at altitudes below 15 m. Flight altitude of gulls associated with fishing vessels was lower than that of non-associated gulls.

- *Cormorants.* Abundance was low from November to March. Numbers increased from April to July. Cormorants were active throughout the day. Flight altitudes ranged up to ca. 150 m but lay mostly around 50 m.
- *Divers.* Most birds were observed in November / December (migration). Abundance was low from January to March, and was minimal in the summer months. Birds were active throughout the day, but were most common in the morning. Flight altitude ranged up to 125 m but lay mostly around 10 m.
- *Alcids.* Most birds were observed in November / December (migration). Abundance was low from January to March, and was minimal in the summer months. Birds were active throughout the day. Flight altitude ranged up to ca. 50 m but lay mostly around 10 m.
- *Gannets.* Abundance was highest in October-December and in April-June. Birds were active throughout the day. Flight altitude ranged up to ca. 75 m.
- *Sea ducks.* Sea ducks were regularly present from October until May. Birds were active throughout the day, with a peak in the early morning. Flight altitude ranged up to ca. 150 m but lay mostly around 10 m.
- *Terns.* Abundance of migrating terns was low in all months except April and May. Birds were mostly seen in the morning in autumn while they were active throughout the day in spring. Flight altitude ranged up to 100 m but lay mostly below ca. 75 m.
- *Tubenoses (Fulmars).* Birds were occasionally seen during strong (north)westerly winds. Activity was highest at the start and end of the daylight period. Flight altitude lay around 10 m, no birds were observed at higher altitudes.

Migrating non-marine birds

- *Geese & swans.* Birds were mostly seen in October-December, with occasional passages until April. Birds flew by in the morning in autumn and winter and in the afternoon in spring. Activity reflected birds flying to the UK. Flight altitude ranged up to ca. 150 m.
- *Waders.* Waders were occasionally seen in most months, with peaks during autumn and spring migration. Wader activity peaked at the end of the day. Flight altitude ranged up to 200 m (max. altitude visible), but lay mostly around 10 m. Moon watching revealed that altitudes of waders migrating at night ranged up to ca. 1000 m, with most birds migrating at around 600 m.
- *Songbirds.* Migrating birds were most abundant in October-November and April. Starlings were observed until December. Activity was concentrated on the (early) morning. Flight altitudes ranges up to ca. 200 m (max. altitude visible) but lay mostly around 10 m. Moon watching revealed that altitudes of thrushes migrating at night ranged up to ca. 500 m, with most birds migrating between 200–400 m.

10.3 Radar methodology

- The DeTect radar system automatically registered bird flocks 24 hours a day, for a substantial part of the 365 days a year. The vertical radar was used to determine fluxes and describe temporal patterns at different altitude bands. The horizontal radar was used to analyse flight paths and spatial patterns (with also a temporal component). Because of its ability to measure flight patterns in the dark, during fog or rain, and around the clock, use of the radar has yielded indispensable information on flight patterns.
- The radars proved to be unable to withstand the harsh climatic conditions out at sea. Especially the vertical radar broke down repeatedly in storms. Due to technical problems the vertical radar only was operating properly during the period April-June 2004.
- As in all other studies so far conducted in offshore situations, sea clutter is a main problem when observing flight movements of birds. Also the DeTect radar system was interfered by sea clutter. By using a statistical approach we were able to separate birds from the largest part of clutter in the vertical radar data. Most likely we lost an unknown part of birds with removal of the clutter, as in other studies, implying that flux estimates are minimum values. Field observations during the day have shown that during days with strong winds flight activity offshore is very low compared to calm days.
- Birds and clutter could not be separated adequately for the horizontal radar data. This was due to several reasons. Signal characteristics did not differ enough between signals of clutter and birds tot allow differentiation on that level. Tracks of single objects were not recognized by the system as belonging to the same object. As a result the tracks of birds which should have been long compared to those of waves, were too short to be able to use track length to distinguish birds from clutter. At the same time, bird tracks were thus subdivided into multiple tracks, with resulting analytical problems. In addition, the amount of clutter in the data was so large, that even removal of over 90% of the clutter still left too large amount of clutter in the database. Thus, the horizontal radar data were highly correlated to wave height and – direction and represented clutter rather than birds, especially on days with high waves from SW through W to N.
- For the observation periods for which data are available, the fluxes obtained through the vertical radar are lower than compared to the fluxes determined in autumn by moon watching and to other studies on bird migration in autumn. In spring the intensity of migration is lower, opposed to what was recorded by the radar, and the species composition might be different compared to autumn. These findings can be explained by the fact that the vertical radar not operative during nights with peak migration in autumn, thus reducing average flux measured in autumn. This is backed up by the fact that fluxes obtained by moon watching and call registration in autumn showed higher levels than those obtained by radar during this period. Possibly also smaller species such as migrating songbirds were not detected adequately by the

radar, due to the large range of 1,5 NM at which the radar was set. At lower range settings, detectability of smaller species is higher.

- We have experienced detection limitations of the radar. In the vertical radar at larger distances and altitudes there is a difference in detection capacity between the two sides of the radar. This is explained by the fact that birds are either beamed on the head or on the tail, implying a difference in radar cross section and hence a difference in reflection. In spring more birds at higher altitudes were detected at the south side of the radar, in autumn at the north side. This phenomenon mainly occurred on days with flight activity at altitudes higher than 50 m and was strongest (down to 60% of birds in one side of the radar compared to the other) at the highest altitudes. Highest flight intensities were registered at night, indicating that birds were mainly migrants and likely overall consisting of smaller sized species compared to the lowest altitudes where during the night probably only gulls and large waterbirds are active.
- Results obtained with the vertical radar yielded reliable measurements of fluxes and flight altitudes, despite severe hard- and software problems. Results obtained with the horizontal radar were of limited use for measurements of flight paths due to the problems with sea clutter and track identification.

11 Literature

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Appendix 1

Names and abbreviations of species and species groups

abr.	species name	group	subgroup	NLsoort	NLgroep
RD	Red-throated Diver	divers		roodkeelduiker	duikers
PD	Black-throated Ddiver	divers		parelduiker	duikers
YD	Great Northern Diver	divers		ijsduiker	duikers
GD	White-billed Diver	divers		geelsnavelduiker	duikers
DO	Little Grebe	grebes		dodaars	futen
FU	Great Crested Grebe	grebes		fuut	futen
RF	Red-necked Grebe	grebes		roodhalsfuut	futen
KD	Horned Grebe	grebes		kuifduiker	futen
GF	Black-necked Grebe	grebes		geoorde fuut	futen
NS	Northern Fulmar	tubenoses		noordse stormvogel	stormvogels
KP	Cory's Shearwater	tubenoses		Kuhls pijlstormvogel	stormvogels
GC	Sooty Shearwater	tubenoses		grauwe pijlstormvogel	stormvogels
NP	Manx Shearwater	tubenoses		noordse pijlstormvogel	stormvogels
SV	Storm Petrel	tubenoses		stormvogeltje	stormvogels
VS	Leach's Petrel	tubenoses		vaal stormvogeltje	stormvogels
JG	Northern Gannet	gannets		Jan van Gent	Jan van Gent
AA	Great Cormorant	cormorants		aalscholver	aalscholvers
KO	European Shag	cormorants		kuifaalscholver	aalscholvers
WA	Little Bittern	passerines	other large birds	woudaapje	zangvogels
RR	Squacco Heron	passerines	other large birds	ralreiger	zangvogels
RK	Cattle Egret	passerines	other large birds	koereiger	zangvogels
KZ	Little Egret	passerines	other large birds	kleine zilverreiger	zangvogels
GZ	Great Egret	passerines	other large birds	grote zilverreiger	zangvogels
BR	Grey Heron	passerines	other large birds	blauwe reiger	zangvogels
RP	Purple Heron	passerines	other large birds	purperreiger	zangvogels
ZO	Black Stork	passerines	other large birds	zwarte ooievaar	zangvogels
OO	Glossy Ibis	passerines	other large birds	zwarte ibis	zangvogels
LL	Eurasian Spoonbill	passerines	other large birds	lepelaar	zangvogels
CC	Bewick's Swan	geese & swans	swans	kleine zwaan	ganzen & zwanen
WZ	Whooper Swan	geese & swans	swans	wilde zwaan	ganzen & zwanen
RT	Bean Goose	geese & swans	anser geese	rietgans	ganzen & zwanen
KR	Pink-footed Goose	geese & swans	anser geese	kleine rietgans	ganzen & zwanen
KG	White-fronted goose	geese & swans	anser geese	kolgans	ganzen & zwanen
GG	Greylag Goose	geese & swans	anser geese	grauwe gans	ganzen & zwanen
CG	Greater Canada Goose	geese & swans	branta geese	grote Canadese gans	ganzen & zwanen
BG	Barnacle Goose	geese & swans	branta geese	brandgans	ganzen & zwanen
RG	Dark-bellied Brent Goose	geese & swans	branta geese	rotgans	ganzen & zwanen
WR	Pale-bellied Brent Goose	geese & swans	branta geese	witbuikrotgans	ganzen & zwanen
RH	Red-breasted Goose	geese & swans	branta geese	roodhalsgans	ganzen & zwanen
NG	Egyptian Goose	other ducks	large ducks	Nijlgans	overige eenden
CA	Ruddy Shelduck	other ducks	large ducks	casarca	overige eenden
BE	Common Shelduck	other ducks	other ducks	bergeend	overige eenden
SM	Eurasian Wigeon	other ducks	swimming ducks	smient	overige eenden
KR	Gadwall	other ducks	swimming ducks	krakeend	overige eenden
WI	Teal	other ducks	swimming ducks	wintertaling	overige eenden
WE	Mallard	other ducks	swimming ducks	wilde eend	overige eenden
PE	Northern Pintail	other ducks	swimming ducks	pijlstaart	overige eenden
ZT	Garganey	other ducks	swimming ducks	zomertaling	overige eenden
SE	Northern Shoveler	other ducks	swimming ducks	slobeend	overige eenden
TE	Common Pochard	other ducks	diving ducks	tafeleend	overige eenden
KE	Tufted Duck	other ducks	diving ducks	kuifeend	overige eenden
TO	Scaup	other ducks	diving ducks	topper	overige eenden
EI	Eider	sea ducks		eider	zee-eenden
IJ	Long-tailed Duck	other ducks	diving ducks	ijseend	overige eenden
ZZ	Common Scoter	sea ducks		zwarte zee-eend	zee-eenden
ZG	Velvet Scoter	sea ducks		grote zee-eend	zee-eenden
BD	Goldeneye	other ducks	other ducks	brilduiker	overige eenden
NN	Smew	other ducks	mergansers	nonnetje	overige eenden
MZ	Red-brested Merganser	other ducks	mergansers	middelste zaagbek	overige eenden
ZG	Goosander	other ducks	mergansers	grote zaagbek	overige eenden
BC	Marsh Harrier	raptors & owls		bruine kiekendief	roofvogels & uilen
BK	Hen Harrier	raptors & owls		blauwe kiekendief	roofvogels & uilen

Appendix 1 Continued

abr.	species name	group	subgroup	NLsoort	NLgroep
SC	Sparrowhawk	raptors & owls		sperwer	roofvogels & uilen
SL	Merlin	raptors & owls		smelleken	roofvogels & uilen
BO	Boomvalk	raptors & owls		boomvalk	roofvogels & uilen
FP	Peregrine Falcon	raptors & owls		slechtvalk	roofvogels & uilen
WH	Moorhen	passerines	other large birds	waterhoen	zangvogels
FA	Eurasian Coot	passerines	other large birds	meerkoet	zangvogels
SO	Oystercatcher	waders		scholekster	steltlopers
KL	Avocet	waders		kluut	steltlopers
BB	Common Ringed Plover	waders		bontbekplevier	steltlopers
GP	European Golden Plover	waders		goudplevier	steltlopers
ZP	Grey Plover	waders		zilverplevier	steltlopers
KI	Lapwing	waders		kievit	steltlopers
KA	Red Knot	waders		kanoet	steltlopers
DL	Sanderling	waders		drieteenstrandloper	steltlopers
PS	Purple Sandpiper	waders		paarse strandloper	steltlopers
BS	Dunlin	waders		bonte strandloper	steltlopers
HS	Woodcock	waders		houtsnip	steltlopers
LI	Black-tailed Godwit	waders		grutto	steltlopers
LP	Bar-tailed Godwit	waders		rosse grutto	steltlopers
RW	Whimbrel	waders		regenwulp	steltlopers
WU	Eurasian Curlew	waders		wulp	steltlopers
TU	Redshank	waders		tureluur	steltlopers
GU	Greenshank	waders		groenpootruiter	steltlopers
SL	Ruddy Turnstone	waders		steenloper	steltlopers
MJ	Pomarine Skua	skuas		middelste jager	jagers
KJ	Arctic Skua	skuas		kleine jager	jagers
GJ	Great Skua	skuas		grote jager	jagers
DW	Little Gull	gulls	little gull	dwergmeeuw	meeuwen
VM	Sabine's Gull	gulls	small gulls	vorkstaartmeeuw	meeuwen
KM	Black-headed Gull	gulls	small gulls	kokmeeuw	meeuwen
SR	Common Gull	gulls	small gulls	stormmeeuw	meeuwen
MK	Lesser Black-backed Gull	gulls	large gulls	kleine mantelmeeuw	meeuwen
BM	subad/Herring Lesser Bb	gulls	large gulls	jonge zilver/kleine	meeuwen
ZM	European Herring Gull	gulls	large gulls	zilvermeeuw	meeuwen
GM	Yellow-legged Gull	gulls	large gulls	geelpootmeeuw	meeuwen
MG	Great Black-backed Gull	gulls	large gulls	grote mantelmeeuw	meeuwen
DM	Kittiwake	gulls	kittiwake	drieteenmeeuw	meeuwen
GS	Sandwich Tern	terns		grote stern	sterns
VD	Common Tern	terns		visdief	sterns
SN	Arctic Tern	terns		noordse stern	sterns
VN	Common/Arctic Tern	terns		visdief/noordse stern	sterns
DS	Little Tern	terns		dwergstern	sterns
ZS	Black Tern	terns		zwarte stern	sterns
ZK	Guillemot	alcids		zeekoet	alken
AZ	Razorbill/Guillemot	alcids		alk/zeekoet	alken
AL	Razorbill	alcids		alk	alken
ZC	Black Guillemot	alcids		zwarte zeekoet	alken
AK	Little Auk	alcids		kleine alk	alken
PP	Atlantic Puffin	alcids		papegaaiduiker	alken
HD	Wood Pigeon	passerines	other large birds	houtduif	zangvogels
TT	Collared Dove	passerines	other large birds	Turkse tortel	zangvogels
BU	Tawny Owl	raptors & owls		bosuil	roofvogels & uilen
RU	Long-eared Owl	raptors & owls		ransuil	roofvogels & uilen
VU	Short-eared Owl	raptors & owls		velduil	roofvogels & uilen
GW	Swift	passerines	small passerines	gierzwaluw	zangvogels
VL	Skylark	passerines	small passerines	veldleeuwerik	zangvogels
BZ	Swallow	passerines	small passerines	boerenzwaluw	zangvogels
BP	Tree Pipit	passerines	small passerines	boompieper	zangvogels
GR	Meadow Pipit	passerines	small passerines	graspieper	zangvogels
OE	Rock Pipit	passerines	small passerines	oeverpieper	zangvogels
GK	Yellow Wagtail	passerines	small passerines	gele kwikstaart	zangvogels
GGK	Grey Wagtail	passerines	small passerines	grote gele kwikstaart	zangvogels
WK	Pied Wagtail	passerines	small passerines	witte kwikstaart	zangvogels
RB	Robin	passerines	small passerines	roodborst	zangvogels
ME	Blackbird	passerines	medium passerines	merel	zangvogels
KV	Fieldfare	passerines	medium passerines	kramsvogel	zangvogels
ZL	Song Thrush	passerines	medium passerines	zanglijster	zangvogels

Appendix 1 Continued

abr.	species name	group	subgroup	NLsoort	NLgroep
KW	Redwing	passerines	medium passerines	koperwiek	zangvogels
GL	Mistle Thrush	passerines	medium passerines	grote lijster	zangvogels
TJ	Chiffchaff	passerines	small passerines	tjiftjaf	zangvogels
FI	Willow Warbler	passerines	small passerines	fitis	zangvogels
ZW	Coal tit	passerines	small passerines	zwarte mees	zangvogels
PM	Blue Tit	passerines	small passerines	pimpelmees	zangvogels
KS	Great Tit	passerines	small passerines	koolmees	zangvogels
KU	Jackdaw	passerines	other large birds	kauw	zangvogels
SP	Starling	passerines	medium passerines	spreeuw	zangvogels
VI	Chaffinch	passerines	small passerines	vink	zangvogels
SY	Siskin	passerines	small passerines	sijs	zangvogels
KN	Linnet	passerines	small passerines	kneu	zangvogels
WW	Witje	butterfly	butterfly	witje sec.	vlinder
AT	Atalanta	butterfly	butterfly	atalanta	vlinder
BV	Porpoise	sea mammals		bruinvis	zeezoogdieren
Z3	undetermined seal	sea mammals		zeehond spec.	zeezoogdieren
Z2	Grey Seal	sea mammals		grijze zeehond	zeezoogdieren
Z1	Harbour Seal	sea mammals		gewone zeehond	zeezoogdieren
XX	nullbird	nullbird		nulvogel	nulvogel
OD	diver spec.	divers		ongedetermineerde duiker	duikers
OP	tubenose spec.	tubenoses		ongedetermineerde pijl	stormvogels
XG	goose spec.	geese & swans	unidentified geese	gans spec.	ganzen & zwanen
XE	duck spec.	other ducks	unidentified ducks	eend spec.	overige eenden
#V	falcon spec.	raptors & owls		valk spec	roofvogels & uilen
XS	wader spec.	waders		steltloper	steltlopers
#D	Little/Black-headed Gull	gulls	small gulls	dwergmeeuw/Kokmeeuw	meeuwen
#K	small gull	gulls	small gulls	kleine meeuw spec.	meeuwen
#G	large gull	gulls	large gulls	grote meeuw spec.	meeuwen
#S	Common/Herring Gull	gulls	large gulls	stormmeeuw/zilvermeeuw	meeuwen
#M	Black-backed Gull spec.	gulls	large gulls	mantelmeeuw spec.	meeuwen
#X	gull spec.	gulls	unidentified gulls	meeuw spec	meeuwen
#J	skua spec.	skuas		jager spec	jagers
XJ	Arctic/Pomarine Skua	skuas		kleine/middelste jager	jagers
PF	Homing Pigeon	passerines	other large birds	postduif	zangvogels
XW	lark spec.	passerines	small passerines	leeuwerik spec.	zangvogels
XP	pipit spec.	passerines	small passerines	pieper spec.	zangvogels
XK	wagtail spec.	passerines	small passerines	kwikstaart	zangvogels
XL	thrush spec.	passerines	medium passerines	lijsterachtige	zangvogels
XZ	songbird spec.	passerines	small passerines	zangvogel spec.	zangvogels
XV	finch spec.	passerines	small passerines	vinkachtige	zangvogels
UH	fishing vessel	ship	fishing vessel	hektrawler	schepen
UK	fishing vessel	ship	fishing vessel	viskotter	schepen
US	fishing vessel	ship	fishing vessel	tweespan	schepen
UB	non-fishing vessel	ship	non-fishing vessel	niet-vissersboot	schepen
UZ	sailing ship	ship	non-fishing vessel	zeilboot	schepen

Appendix 2

Main observation forms

The type of observation the form was used for is indicated in the upper right hand corner

Date:
Hour (ZULU):

Weather Temp : Clouds (x/8): Wind (dir. + Bft):
Precip (%): Sun (%): Sea state*:

Panorama Scan

Observer:
Secretary:

Observ. site: Lower ring / Helideck

Visibility (km):
N: S: W: E:

Page: of

Sectors (per 45 degrees):
1: N-NW 5: S-SE
2: NW-W 6: SE-E
3: W-SW 7: E-NE
4: SW-S 8: NE-N

Distance	Height:
1 0 - 500 m	Binocular
2 500 - 1500 m	view in 4
3 1500 - 3000 m	layers:
4 > 3000 m	1 - 2 - 3 - 4

Direction of flight:
[illegible]
N
nnw nne
NW NE
wnw ene
W Loc. St. E
wsw ese
SW SE
ssw sse
S

Associated with:
11 = cetaceans
12/3 = front/line in sea
14/5/6 = wood/litter/oil
18/21 = own/other ship
22/5 = buoy/stick
23/4 = beacon platform
20 = fishing vessel
27/8/9 = ice/land/shallows

Behaviour codes:
30/1 = holding/without fish
32 = feeding chick
33 = "feeding"
34/5 = wading/scooping
36/7 = aerial pursuit/skimming
38/9 = hydroplaning/pattering
40/1 = scavenging/at trawl
42/3 = dipping/surf seizing
44 = surface pecking
45 = deep plunging
46 = shallow plunging
47 = pursuit plunging
48 = pursuit diving
49 = actively searching
60 = resting/asleep
61/2 = courtship display
65 = guarding chick
66 = preening/bathing
91 = kleptoparasitised
92/3 = attacked (bird/mm)

MSFAs:
50 = "participant"
51/2 = joined / joining
53 = scrounger type
54 = solitary diver
55 = beater (e.g. dolphins)
56 = social feeder/diver

BinPos 1/2 / 1/8	Time	Sector	Species	Number	Dist.	Height	Direct.	Assoc.	Behav.	Notes /Mixed flocks/MSFA/Prey

Sea state: Note wave height from computer inside. **Add**: 0 = sea like mirror / 1 = ripples, no foam / 2 = small wavelets / 3 = crests break / 4 = numerous white caps / 5 = moderate waves, some spray / 6 = larger waves, more spray.

Floating matter: Note **trawlers** as birds: per sector and distance class, use behavioural codes: 1 = active / 2 = nets down/hauling / 3 = steaming / 4 = ankering / 8 = long line of foam / 9 = much seaweed / 10 = oil slick visible.

Appendix 2 Continued

Date: **Hour** (GMT):	**Temp :** **Clouds** (/8): **Precip.** (%): **Sun** (%):	**Wind** (direction + Bft): **Sea state*:**	**Sea Watching**
Observer: **Secretary:**	**Observ.site:** Helidesk / Lower Ring **Look out direction:** West / North / East / South	**Visibility** (km):	**Page:** of

Sectors (per 45°):
1: N-NW 5: S-SE
2: NW-W 6: SE-E
3: W-SW 7: E-NE
4: SW-S 8: NE-N

Distance:
1: 0 – 500 m
2: 500 – 1500 m
3: 1500 – 3000 m
4: > 3000 m

Direction of flight
Loc = local, Sit = sitting
N
NNW NNE
NW NE
WNW ENE
W Loc, Sit E
WSW ESE
SW SE
SSW SSE
S

Associated with:
11 = cetaceans
12/3 = frontline in sea
14/5/6 = wood/litter/oil
18/21 = own/other ship
22/5 = buoy/stick
23/4 = near/on platform
26 = fishing vessel
27/8/9 = ice/land/shallows

Behaviour codes:
30/1 = holding/without fish
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40/1 = scavenging/at trawl
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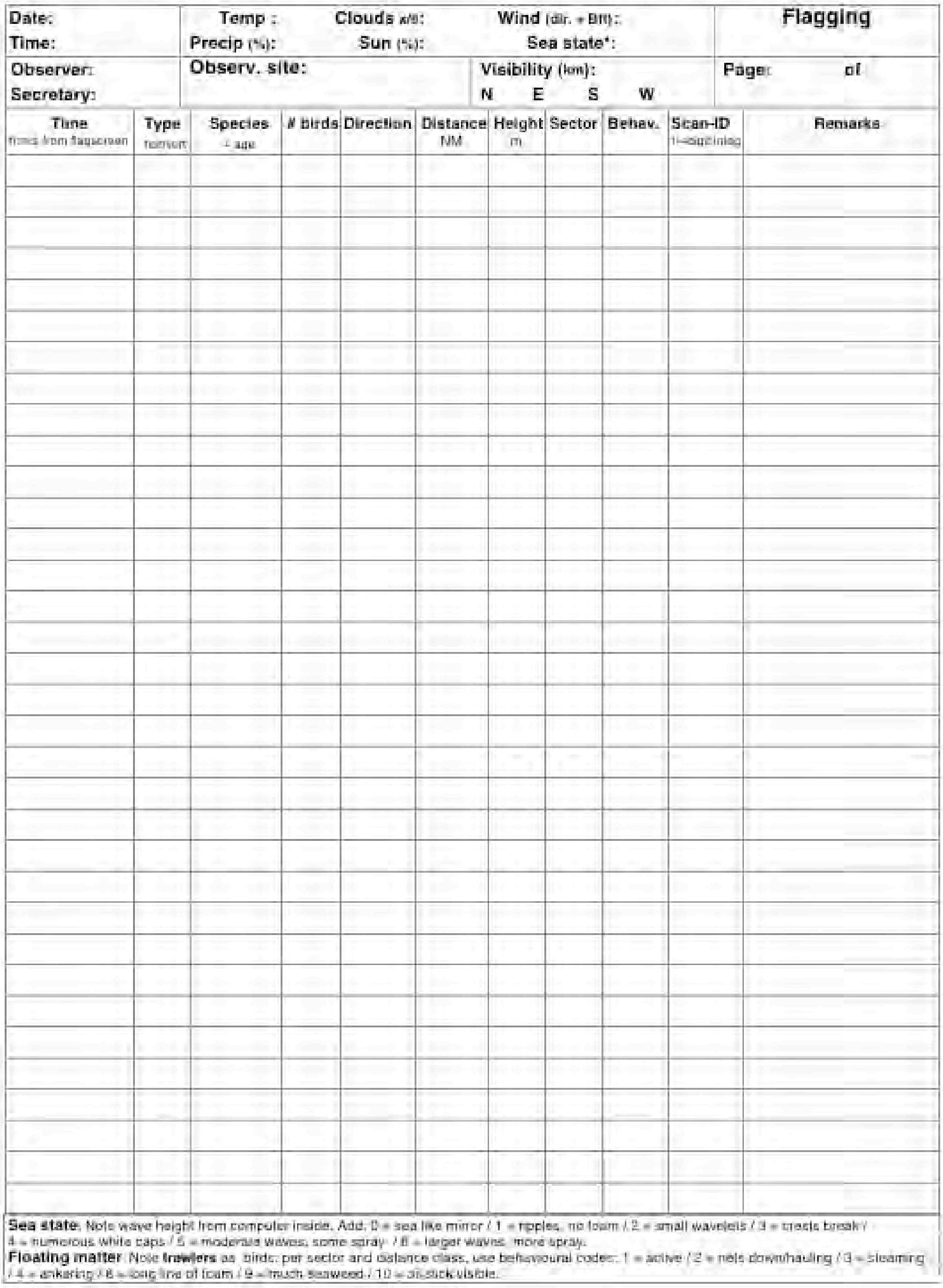
46 = shallow plunging
47 = pursuit plunging
48 = pursuit diving
49 = actively searching
60 = resting/asleep
61/2 = courtship display
65 = guarding chick
66 = preening/bathing
91 = kleptoparasitised
92/3 = attacked (bird/mm)

MSFA's:
50 = "participant"
51/2 = joined / joining
53 = scrounger type
54 = solitary diver
55 = beater (e.g. dolphins)
56 = social feeder/diver

Time (5-min)	**Species**	**Age**	**Number**	**Distance**	**Direction of flight**	**Altitude** (m)	**Remarks/Mixed flocks/MSFA/Prey**

Sea state: Note wave height from computer inside. Add: 0 = sea like mirror / 1 = ripples, no foam / 2 = small wavelets / 3 = crests break / 4 = numerous white caps / 5 = moderate waves, some spray / 6 = larger waves, more spray.
Floating matter: Note **trawlers** as birds: per sector and distance class, use behavioural codes: 1 = active / 2 = nets down/hauling / 3 = steaming / 4 = ankering / 8 = long line of foam / 9 = much seaweed / 10 = oil slick visible

Appendix 2 Continued



Date: **Time:**	**Temp :** **Clouds** x/8: **Precip** (%): **Sun** (%):	**Wind** (dir. + Bft): **Sea state*:**	**Flagging**
Observer: **Secretary:**	**Observ. site:**	**Visibility** (km): **N E S W**	**Page:** **of**

Time [illegible] from flagscreen	**Type** [illegible]	**Species** + age	**# birds**	**Direction**	**Distance** NM	**Height** m	**Sector**	**Behav.**	**Scan-ID** [illegible]	**Remarks**

Sea state: Note wave height from computer inside. Add: 0 = sea like mirror / 1 = ripples, no foam / 2 = small wavelets / 3 = crests break / 4 = numerous white caps / 5 = moderate waves, some spray / 6 = larger waves, more spray.

Floating matter: Note **trawlers** as birds: per sector and distance class, use behavioural codes: 1 = active / 2 = nets down/hauling / 3 = steaming / 4 = ankering / 8 = long line of foam / 9 = much seaweed / 10 = oil-slick visible.

Appendix 3

Appendix to ‘Flagging analysis’ § 5.1.

Spearman correlations between variables between variables from the horizontal radar. Variables were natural log or square root transformed if necessary. In that case the name is prefixed with ln or sqrt. Bold correlation coefficients show high values between (-)0.6 and (-)0.8. Blue coeffficients designate extreme high correlation values, between (-)0.8 and (-)1.

	Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	lnECHOPTRK	1																					
2	TRACKQ	-0.52	1																				
3	TRACKTYP	**-0.74**	**0.74**	1																			
4	*lnSTT*	**0.96**	-0.27	**-0.61**	1																		
5	lnMVEL	-0.09	-0.14	0.03	-0.14	1																	
6	lnVEL	-0.07	-0.10	0.00	-0.11	**0.77**	1																
7	lnMAXA	**0.64**	-0.34	-0.51	**0.62**	-0.11	-0.09	1															
8	lnAREA	0.24	-0.09	-0.19	0.24	-0.13	-0.12	**0.62**	1														
9	lnMMRANGE	0.59	-0.29	-0.42	0.57	-0.16	-0.14	**0.64**	0.42	1													
10	*lnMINRANGE*	-0.41	0.23	0.36	-0.39	0.14	0.13	-0.15	0.02	-0.36	1												
11	lnRANGE	-0.26	0.16	0.29	-0.24	0.18	0.16	-0.06	0.08	-0.29	**0.94**	1											
12	BEARING	0.07	-0.09	-0.09	0.05	-0.02	-0.01	0.03	0.05	0.01	0.00	-0.01	1										
13	HEADING	-0.02	0.04	0.00	-0.01	0.03	0.07	-0.01	0.01	-0.03	-0.01	0.00	0.08	1									
14	TRACKDIS	-0.10	-0.07	0.07	-0.14	**0.60**	**0.71**	-0.13	-0.12	-0.09	0.46	0.48	0.02	0.01	1								
15	lnMAXSEGMENT	0.21	-0.06	-0.13	0.21	-0.14	-0.15	0.49	**0.80**	0.36	-0.06	-0.02	0.03	0.01	-0.17	1							
16	*lnPERIMETER*	0.21	-0.07	-0.16	0.21	-0.12	-0.10	**0.62**	**0.96**	0.39	0.05	0.10	0.05	0.02	-0.12	**0.75**	1						
17	ORIENTAT	-0.03	-0.02	0.04	-0.04	0.09	0.07	-0.04	-0.06	-0.01	0.04	0.07	-0.18	0.02	0.06	-0.01	-0.08	1					
18	*lnELLIPSEMAJ*	0.20	-0.06	-0.16	0.21	-0.12	-0.10	**0.62**	**0.95**	0.39	0.05	0.10	0.04	0.02	-0.12	**0.73**	**1.00**	-0.09	1				
19	*lnELLIPSEMIN*	0.25	-0.12	-0.20	0.24	-0.14	-0.13	0.52	**0.91**	0.40	-0.02	0.03	0.06	0.00	-0.11	**0.76**	**0.77**	-0.02	**0.74**	1			
20	lnELLIPSERAT	0.03	0.04	-0.02	0.05	-0.03	0.00	0.36	0.43	0.14	0.10	0.12	0.00	0.04	-0.05	0.27	**0.65**	-0.11	**0.68**	0.01	1		
21	lnELONGATION	-0.09	0.09	0.10	-0.07	0.04	0.08	-0.09	-0.35	-0.14	0.14	0.13	-0.08	0.03	0.07	-0.43	-0.18	0.00	-0.15	-0.57	0.40	1	
22	sqrtCOMPACTNE	-0.09	0.03	0.07	-0.09	0.03	0.02	-0.34	-0.41	-0.15	-0.07	-0.10	-0.07	-0.08	0.04	-0.29	-0.56	0.15	-0.58	-0.12	**-0.74**	-0.23	1
23	*lnHEYWOOD*	0.02	0.04	-0.01	0.04	-0.03	-0.01	0.36	0.43	0.14	0.10	0.12	0.00	0.03	-0.06	0.27	**0.66**	-0.11	**0.69**	0.02	**1.00**	0.38	**-0.73**
24	*lnHYDRORADIU*	0.26	-0.12	-0.21	0.25	-0.13	-0.13	0.54	**0.94**	0.41	-0.01	0.04	0.06	0.00	-0.12	**0.77**	**0.81**	-0.03	**0.79**	**1.00**	0.08	-0.53	-0.17
25	*lnWADDELDISK*	0.24	-0.09	-0.19	0.24	-0.13	-0.12	**0.62**	**1.00**	0.42	0.02	0.08	0.05	0.01	-0.12	**0.80**	**0.96**	-0.06	**0.95**	**0.91**	0.43	-0.35	-0.41
26	*lnMEANINTERC*	0.21	-0.11	-0.18	0.20	-0.10	-0.11	0.49	**0.88**	0.36	-0.05	0.00	0.08	0.00	-0.12	**0.78**	**0.79**	-0.06	**0.77**	**0.89**	0.19	**-0.74**	-0.25
27	*lnMAXINTERCE*	0.21	-0.06	-0.16	0.23	-0.11	-0.08	**0.62**	**0.92**	0.38	0.08	0.14	0.04	0.03	-0.10	**0.67**	**0.98**	-0.08	**0.98**	**0.70**	**0.69**	-0.03	**-0.61**
28	*TYPEFACT*	-0.07	0.01	0.03	-0.08	-0.05	-0.05	-0.30	-0.33	-0.15	-0.11	-0.14	-0.04	-0.03	-0.02	-0.14	-0.51	0.10	-0.54	0.01	**-0.82**	-0.36	**0.82**
29	*lnCHORDX*	0.19	-0.06	-0.11	0.19	-0.16	-0.17	0.42	**0.72**	0.34	-0.05	0.00	-0.01	-0.02	-0.16	**0.88**	**0.61**	0.07	0.59	**0.78**	0.04	-0.42	0.03
30	lnCHORDY	0.18	-0.09	-0.18	0.17	-0.06	-0.03	0.38	**0.71**	0.29	0.02	0.05	0.07	-0.01	-0.03	0.29	**0.61**	-0.06	0.59	**0.75**	0.06	-0.41	0.03
31	lnAVREFLECTI	0.04	0.04	0.02	0.05	-0.19	-0.15	0.09	0.08	0.48	-0.19	-0.24	-0.05	-0.07	-0.05	0.07	0.04	0.01	0.03	0.14	-0.11	-0.09	0.12
32	lnMAXREFLECT	0.17	-0.03	-0.11	0.18	-0.21	-0.16	0.31	0.46	**0.64**	-0.28	-0.30	0.00	-0.04	-0.08	0.39	0.40	-0.04	0.38	0.49	0.03	-0.28	-0.04
33	lnMINREFLECT	-0.12	0.08	0.15	-0.11	-0.03	-0.01	-0.33	-0.56	-0.20	0.03	0.01	-0.02	-0.02	0.04	-0.46	-0.57	0.05	-0.57	-0.46	-0.35	0.22	0.29
34	lnSTDDEVREFL	0.02	0.03	0.03	0.03	-0.10	-0.08	0.20	0.34	0.33	-0.03	-0.03	0.00	-0.01	0.00	0.30	0.31	0.02	0.30	0.34	0.08	-0.17	-0.06
35	*sqrtRANGEREFL*	0.24	-0.10	-0.20	0.24	-0.16	-0.14	0.44	**0.70**	0.60	-0.25	-0.24	0.03	-0.01	-0.10	0.59	**0.65**	-0.08	**0.63**	**0.68**	0.21	-0.35	-0.21
36	lnWAVEHAVG	-0.26	0.19	0.22	-0.23	0.11	0.09	-0.19	-0.11	-0.29	0.28	0.24	-0.06	0.12	0.14	-0.13	-0.09	0.11	-0.08	-0.13	0.02	0.12	-0.01
37	lnWAVEHMAX	-0.26	0.20	0.22	-0.23	0.11	0.09	-0.19	-0.11	-0.28	0.28	0.24	-0.06	0.11	0.13	-0.13	-0.08	0.11	-0.08	-0.13	0.02	0.12	-0.02
38	WDIRAVG	0.03	-0.03	-0.06	0.03	-0.09	-0.02	0.03	0.02	0.05	0.04	0.02	0.01	-0.10	0.06	0.03	0.00	-0.02	0.00	0.05	-0.05	-0.08	0.01
39	*WDIRMAX*	-0.09	0.05	0.07	-0.09	-0.05	0.00	-0.08	-0.04	-0.05	0.13	0.10	-0.01	-0.09	0.09	0.00	-0.05	-0.01	-0.05	-0.01	-0.05	-0.04	0.06
40	WLAVG	0.00	0.01	0.02	0.00	0.00	0.04	0.02	0.01	0.07	0.03	0.03	0.03	-0.11	0.07	0.04	0.00	0.02	0.00	0.01	-0.01	-0.01	0.03
41	*WLMAX*	0.00	0.00	0.01	0.00	0.00	0.03	0.02	0.00	0.08	0.02	0.02	0.03	-0.10	0.05	0.03	0.00	0.03	0.00	0.01	-0.01	-0.02	0.03
42	*WLMIN*	-0.01	0.01	0.03	-0.01	0.00	0.05	0.02	0.01	0.07	0.04	0.03	0.03	-0.11	0.08	0.04	0.01	0.01	0.00	0.01	0.00	-0.01	0.02
43	WINDDIR	0.00	0.07	-0.03	0.02	-0.11	-0.06	0.03	0.07	0.02	0.11	0.12	0.02	-0.02	-0.02	0.04	0.06	0.02	0.05	0.07	0.00	-0.02	-0.01
44	WVMS	-0.13	0.13	0.14	-0.11	0.09	0.06	-0.04	-0.01	-0.12	0.16	0.16	-0.11	0.07	0.05	-0.05	0.01	0.11	0.01	-0.04	0.05	0.07	0.00
45	*WVMAXMS*	-0.11	0.10	0.12	-0.09	0.10	0.06	-0.04	-0.02	-0.11	0.15	0.16	-0.09	0.06	0.07	-0.06	0.00	0.10	0.00	-0.04	0.04	0.06	0.00

	Variable	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	lnECHOPTRK																							
2	TRACKQ																							
3	TRACKTYP																							
4	*lnSTT*																							
5	lnMVEL																							
6	lnVEL																							
7	lnMAXA																							
8	lnAREA																							
9	lnMMRANGE																							
10	*lnMINRANGE*																							
11	lnRANGE																							
12	BEARING																							
13	HEADING																							
14	TRACKDIS																							
15	lnMAXSEGMENT																							
16	*lnPERIMETER*																							
17	ORIENTAT																							
18	*lnELLIPSEMAJ*																							
19	*lnELLIPSEMIN*																							
20	lnELLIPSERAT																							
21	lnELONGATION																							
22	sqrtCOMPACTNE																							
23	*lnHEYWOOD*	1																						
24	*lnHYDRORADIU*	0.09	1																					
25	*lnWADDELDISK*	0.43	**0.94**	1																				
26	*lnMEANINTERC*	0.20	**0.90**	**0.88**	1																			
27	*lnMAXINTERCE*	**0.69**	**0.75**	**0.92**	**0.70**	1																		
28	*TYPEFACT*	**-0.81**	-0.05	-0.33	-0.15	-0.59	1																	
29	*lnCHORDX*	0.05	**0.77**	**0.72**	**0.68**	0.54	0.07	1																
30	lnCHORDY	0.07	**0.75**	**0.71**	**0.69**	0.57	0.03	0.29	1															
31	lnAVREFLECTI	-0.11	0.13	0.08	0.08	0.02	0.09	0.14	0.11	1														
32	lnMAXREFLECT	0.04	0.49	0.46	0.44	0.35	-0.02	0.39	0.39	**0.82**	1													
33	lnMINREFLECT	-0.35	-0.49	-0.56	-0.52	-0.53	0.26	-0.35	-0.39	0.30	-0.15	1												
34	lnSTDDEVREFL	0.08	0.35	0.34	0.31	0.28	-0.07	0.31	0.24	0.34	0.51	-0.24	1											
35	*sqrtRANGEREFL*	0.21	**0.69**	**0.70**	**0.65**	0.60	-0.16	0.53	0.54	0.40	**0.82**	-0.58	0.55	1										
36	lnWAVEHAVG	0.02	-0.13	-0.11	-0.13	-0.07	-0.04	-0.12	-0.09	-0.08	-0.16	0.04	-0.04	-0.18	1									
37	lnWAVEHMAX	0.02	-0.13	-0.11	-0.13	-0.06	-0.05	-0.12	-0.08	-0.08	-0.16	0.04	-0.04	-0.18	**1.00**	1								
38	WDIRAVG	-0.05	0.04	0.02	0.05	-0.01	0.04	0.03	0.02	0.02	0.04	-0.02	-0.01	0.05	-0.43	-0.44	1							
39	*WDIRMAX*	-0.05	-0.02	-0.04	-0.01	-0.05	0.05	0.02	-0.03	-0.01	-0.01	0.02	0.00	-0.02	-0.36	-0.36	**0.88**	1						
40	WLAVG	0.00	0.01	0.01	0.01	0.00	0.02	0.04	-0.01	0.07	0.09	-0.04	0.04	0.07	0.03	0.03	0.25	0.19	1					
41	*WLMAX*	0.00	0.00	0.00	0.01	-0.01	0.02	0.03	-0.01	0.07	0.09	-0.05	0.05	0.08	0.04	0.04	0.23	0.16	**0.99**	1				
42	*WLMIN*	0.00	0.01	0.01	0.01	0.00	0.02	0.04	-0.02	0.07	0.09	-0.03	0.04	0.07	0.02	0.02	0.28	0.22	**0.99**	**0.97**	1			
43	WINDDIR	0.00	0.07	0.07	0.05	0.05	-0.04	0.05	0.05	-0.02	0.00	-0.06	-0.03	0.02	0.07	0.08	0.46	0.36	0.12	0.13	0.11	1		
44	WVMS	0.05	-0.03	-0.01	-0.04	0.02	-0.05	-0.03	0.00	-0.04	-0.08	-0.04	0.00	-0.08	**0.79**	**0.79**	-0.56	-0.51	0.02	0.03	0.00	-0.03	1	
45	*WVMAXMS*	0.04	-0.04	-0.02	-0.04	0.01	-0.04	-0.04	0.00	-0.03	-0.07	-0.03	0.00	-0.07	**0.80**	**0.80**	-0.59	-0.54	0.04	0.05	0.02	-0.09	**0.98**	1