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Using radar to obtain a quantitative description of summer bird movements in the Dutch coastal area.

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SUMMARY

During 1999, several feasibility studies on the creation of an airfield at an artificial island in the North Sea were carried out. One of the decisive questions was whether such a location would cause an increase in the bird strike probability. In order to obtain reliable three-dimensional bird density distributions, we have carried out monthly radar observations from the piers of IJmuiden protruding 2 km into the North Sea. We used a search and tracking radar and could observe medium-sized birds at up to 7 km distance.

The Dutch coastal area comprises both local bird movements and large-scale migration pathways. The last category consisted of broad front migration of birds crossing the coast on their way to or from Great Britain and leading line migration of birds following the coast, either over sea or over land. Since the different phenomena do not equally make up for differences between mainland and coastal areas, it is very important to differentiate between them.

At any time of the year staging gulls appeared to be very abundant. Therefore, in this paper we will isolate their local flying activity from migratory movements. Since they may have any direction they are sometimes hard to distinguish from both migration patterns. During June and July very little large-scale movements were recorded, whereas non-migrating gulls proved to be very abundant at times.

By considering the local and migratory movements quantitatively we attempt to assess the bird risk to potential aviation activities within the coastal zone.

Keywords: Radar, Visual, Flock Density, Local movements, Migration

1. INTRODUCTION

The need for quantitative research

The aviation boom of the past decades causes the Dutch government to consider expansion of the current airfield capacity. The narrow possibilities at the present-day Schiphol Airport immediately raise the question whether alternative locations would provide better chances in accommodating the increasing air traffic. As an alternative for expansion at Schiphol itself, expansion at an artificial island in the North Sea is considered.

During 1999 a variety of feasibility studies is carried out to support the decision about the North Sea island. Establishment of the bird strike risk is one of the research goals. Because of the nature of the bird movements in the coastal area of the province of Noord-Holland both a gradient in bird density from the coast to the sea onwards and a density gradient with altitude are expected. Moreover, these gradients are very site-specific, as will be explained in the following section. Bird strike risk is a function of kilograms rather than bird numbers aloft, and therefore not only numerical distribution but also the species distribution is important. This paper presents the first results of an investigation into the three-dimensional bird- and species distribution in the coastal area.

Bird movements

Three major types of bird movements occur in the Dutch coastal area. Broad front migration of birds crossing the coast, leading line migration of birds following the coast, either over sea or over land and local movements of ducks, waders, cormorants and gulls.

Large-scale migration mainly takes place during autumn and spring. In spring, birds between east and north to their breeding grounds and in autumn birds move between west and south to their wintering areas. The altitude of migration is highly dependent on weather conditions but may range from sea level up to 2500 metres altitude.

Some of the species migrating east- respectively westwards are hardly influenced by the coast. Their migratory path is more or less perpendicular to the coastline and no density gradient from the coast to the sea onward is to be expected. Since this movement may simultaneously occur over a width of several tens of kilometres, this phenomenon is called “broad front migration”.

However, due to a phenomenon called ‘leading line migration’ concentrations of migrant birds are especially high along the Dutch coastline. Many migrating birds tend to avoid surfaces that they cannot come down to for resting or feeding. As a result, those birds are led along the edges of their preferred habitat. In NW-Europe, where the continental and British coastlines form a funnel, many passerines migrating westward follow the coastline in SW-direction instead of immediately crossing the dangerous sea. The broad migration front somewhat curves off and the birds follow a rather narrow trajectory running parallel to the coastline.

In addition, some species of birds (waders, ducks, and geese) are dependent on estuaries and mud flats and thus choose migration pathways close to the shore. As a result, several migration pathways concentrate in the coastal area. The latter two phenomena should result in a decline of bird densities from the coast to the open sea, but no quantitative research has been carried out so far.

Birds foraging in the area and birds flying to and fro between foraging and resting sites occur at any time of the year. Especially during summer, gulls are very numerous in the North Sea coastal area. Some species are mainly seen foraging along the coastline and inland (Herring, Black-headed and Common Gull), others forage and rest at full sea (Great and Lesser Black-backed Gull, Kittiwake). Fishing-boats and other ships attract huge numbers of gulls. Large groups of gulls have been observed foraging at fronts between distinct water masses (Camphuysen & van Dijk 1983). Also for Cormorants, increasingly numerous all over the Netherlands, the North Sea coast functions as a foraging, sleeping, staging and breeding area.

From November until February the North Sea coastal waters serve as a wintering territory for divers, grebes, ducks and scoters. The lion's share of these birds is concentrated within 5 kilometres offshore. Not much is known about the flying habits of these groups of birds, in terms of frequency, covered distance and altitude.

In brief, those different types of bird movements make up for different spatial and seasonal bird distributions. It is clear that a numerical approach of bird numbers only will not suffice. In order to make comparisons with other areas possible, and to properly estimate seasonal effects on bird numbers, it will be necessary to assign all echoes to their accessory movements. However, from radar echoes itself no species information can be obtained. Leading line migration and broad front migration can generally be differentiated based on flight directions, but local movements may have any direction and are therefore likely to be mixed up with both types of migratory movements, and vice versa.

We suggest to consider the amount of the so-called 'local birds' a baseline number, on which, depending on the season, migratory bird numbers can be added. Naturally, the amount and species distribution of local birds is determined by the time of year as well.

Local movements occur throughout the year, but migration is confined to specific periods. In this paper we will isolate local movements by focussing on the summer months, when migration is considered to be very limited. The aim of this paper is to state and quantify the general properties of local bird movements in the North Sea coastal area.

MATERIAL & METHODS

<u>Location</u>

The measurements were carried out on a pier protruding 2 kilometres into the North Sea. The pier is situated in the province of Noord Holland, the Netherlands, 20 kilometres west of Amsterdam, close to the preferred location for an artificial island. The radar was placed at the far end of the pier, an ideal standing point to observe the bird density distribution from the coastline seaward. Depending on species, group size and orientation, bird presence could be detected at a distance of 3 to 10 kilometres from the radar, adding up with the length of the pier to a view of 5 to 12 kilometres off the coast and 3 to 10 kilometres inland. East of the research location bird densities above the dunes were studied. IJmuiden however is famous for its steelworks, which are situated north-east of the research location. The radar reflections of these industries made it impossible to view birds flying over that area up to considerable heights. Therefore over land, only bird movements south of the pier were detected. For detection of the echoes, the area was divided into three major areas: Sea, Dune and the shallow waters near the shore, herafter referred to as "Near Shore"

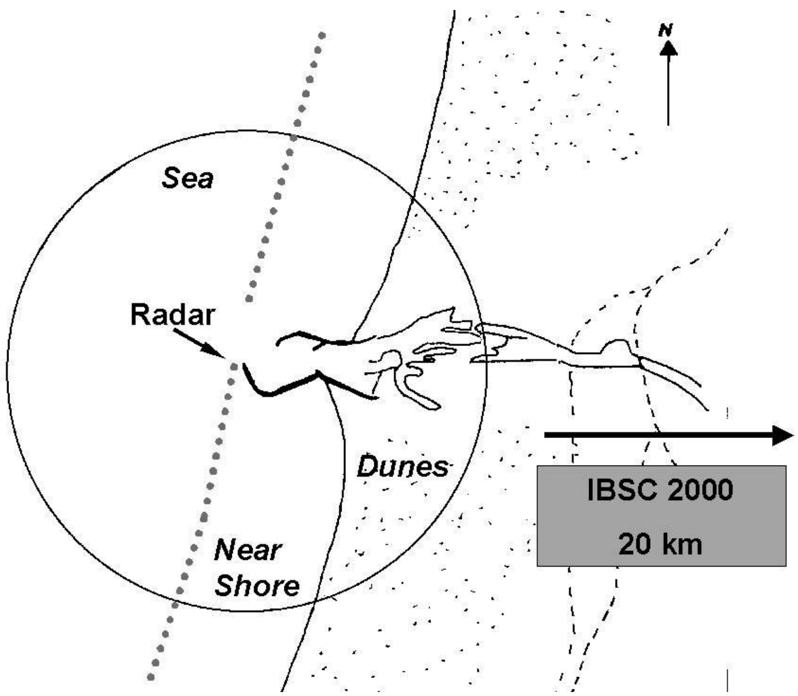


Figure 1: the research location

<u>Time</u>

This study is part of a year round study after bird intensities. The goal of this study is to establish the general properties of local movements in the area. Therefore the measurements of June and July 1999, the months with the least expected migration were selected. The measurements were carried out in week 24 and 28, from Monday until Friday continuously.

<u>Radar specifications</u>

The radar used in this study is a modified HSA MLU-Flycatcher. This is a monopulse Doppler radar with two antennas. The fan beam antenna is designed for making continuous scans to locate echoes, hence the name "search antenna". The pencil beam antenna is primarily designed to track single echoes ("track antenna") but has been modified so that it can be used to make scans as well. Both horizontal and vertical scans are possible. The radar has one 3-cm waveband transmitter that is used by both two antennas. Each antenna has its own receiver.

The fan beam has a vertical aperture of 18°, resulting in a maximal detection altitude of 1200m at 4km distance. The pencil-beam antenna has an aperture of 2.4°, resulting in a 300m beamwidth.

A video camera with 300mm lens is mounted parallel to the track antenna, so that during daytime tracked echoes could be identified. For additional echo identification purposes, an extra computer system is developed to record the Automatic Gain Control (AGC) signal. If one bird is tracked (see following section), the AGC signal roughly fluctuates with the wing beat pattern of the bird, thus allowing an approximate species identification (Blackwell & Houghton 1969; Bruderer 1971; Blackwell, Houghton and Wilmot 1974).

Tracking and scanning modes

In the basic function, a continuous scan is made with the search antenna. When an echo is located it can be selected manually and followed by the track antenna. As soon as the track antenna is activated, half of the total power available is send trough the track antenna. The rest is available for the search antenna and scanning goes on. As soon as the track is interrupted, all power is sent through the search antenna again.

Likewise the track antenna can be used to make scans. During vertical scans the track antenna “nods” between 0 and 85° elevation, in any desired azimuth. In the horizontal scan mode the track antenna scans the azimuth in any desired elevation. Al transmitter power is then available for the track antenna. Naturally, if echoes are tracked from these scans, the scan has to be interrupted. The first half of each hour was used for bird density measurements with the different scanning modes, which won’t be discussed in this paper.

Tracking of single echoes

The second half of each hour was spent tracking single echoes. Echoes were selected from the search radar image according to a standard procedure. On the image, four segments were assigned from which echoes were to be selected: one over land, two over sea within the 5 km- range and the fourth over sea, within the 5-10 km range. In each segment, for 60 seconds an attempt was made at tracking an echo. If this was successful, up to 5 echoes in the segment were tracked before viewing the next segment. Each track was to last 30 seconds. After 1 minute without successful tracks, the next segment was investigated. Segments were investigated in fixed order. If from the proceeding scans bird echoes at high altitudes were observed, part of the tracks were made from elevation scans in 284° and 194° azimuth (respectively perpendicular and parallel to the coastline). Any scanning method different from the standard procedure was noted.

During daylight, the boresight camera was used to determine bird species and group dimensions of each track. All flight paths were recorded with a frequency of 0.5 Hz, the corresponding AGC-signals with 50 Hz.

Video analysis

The PPI-image of the entire measurement was recorded on S-VHS video, time-lapse with 0.64 frames per second. For the analysis, the tapes were played back at 16 x real time. This provided a better look on movements and directions and offered the possibility to process many measurements in a short time. From the PPI image of the search antenna all occurring types of movements were scored on a nominal scale, which consisted of the 16 wind directions, “to the harbour”, “to a boat” and “without a specific direction”. For each observed direction, the instantaneous echo density was classified as 0-1, 2-5, 5-10, 10-20 and over 20 echo's per 4 km^2. Additionally, echo's which were obviously influenced by ships were independently scored as such.

Analysis

All tracks were analysed using MS Access, MS Excel, Santis (a shareware signal analysis tool) and Display_AGC, a signal analysis tool written in LabView.

The video data were used to analyse the directions and numerical distribution of radar echoes over the landscape with respect to time of day and tidal rhythms.

From the tracking sessions, mean wing beat pattern was established from all tracks where both the AGC-signal and visual species determination were available. These wing-beat patterns were used to assign species information to all other tracks. The resulting "composite" species information was used in further data analysis.

Using this composite species information the altitudes and the relative importance of the different species over the area were analysed.

RESULTS

General

The measurements were carried out from 14-06-1999 19:00h local time until 18-06-1999 08:45h and from 12-07-1999 19:00h until 16-07-1999 04:45h.

Numerical analysis of video data

Overall densities

In June, due to technical problems for 2 hours no video information was available. In July 5 hours of data are missing due to bad weather and 2 hours due to technical problems. This resulted in 84 hours of video data in June and 78 hours of video data in July 1999.

Echo densities were higher in June than in July. In both months, mean echo densities near the shore (from the beach until three km off-shore) were respectively1.5 and 2 times higher than densities at open sea (more than three km off-shore), which were again 4 and 9 times higher than echo densities measured above the dunes. See table 1. Echo densities were highly variable, ranging from 1 to 18 echoes per km^2.

Table 1: Overall means and standard deviations of echo densities over open sea, shore and dune in June and July.

	June		***July***	
	Mean	***st. dev***	***Mean***	***St. dev***
Open Sea	3	±3	2	±3
Shore	8	±4	4	±4
Dunes	1	±1	0.5	±0.5

Tables 2a, 2b: Mean share of the different types of movement patterns “No direction” and “with a clear direction”. “#” and “%” of hours are the number and percentages of hours when the specified movement pattern occurred. “Mean share” is the amount of echoes from of the specified movement pattern relative to the other patterns, averaged over the hours when this occurred. Note that, since the different movement patterns may or may not occur at the same moment, the percentages will not necessarily add up to 100%

2a: June

	Sea		***Near Shore***		***Dunes***	
	No direction	***Clear direction***	***No direction***	***Clear direction***	***No direction***	***Clear direction***
# of hours	85	35	92	58	59	16
% of hours	90	37	97	61	62	17
Mean share (%)	87	51	83	35	96	91

2b: July

	Sea		***Near Shore***		***Dunes***	
	No direction	***Clear direction***	***No direction***	***Clear direction***	***No direction***	***Clear direction***
# of hours	56	22	69	70	20	10
% of hours	72	28	88	90	26	13
Mean share (%)	89	59	70	33	98	95

Generally, echo numbers were dominated by numbers of “non-directed” movements. Both in June and July at sea movement patterns with “no direction” were observed 2_ times as often as echoes with a “clear direction”. Near the shore, “No direction” was scored 1_ times as often as “clear direction”. Above the dunes in June “no direction” occurred in 62% of the hours, versus 26% only in July. The amount of clearly directed echoes over the dunes was approximately equal in June and July: clearly directed echoes were found in 17% respectively 13% of the hours. (See row “% of hours” in table 2a) and 2b). Furthermore, whenever any movement pattern occurred, its relative amount to the total echo density of that hour, the so-called “share” of the movement, was estimated. The mean of those relative shares is presented in the last row of tables 2a) and 2b). Note that the “mean shares “ of both movements do not necessarily add up to 100 per cent, as the movement patterns do not necessarily occur simultaneously. Moreover, the deviation from 100 per cent, together with the number of hours that each movement was observed, indicates how often both movement patterns occurred. Mean shares of both “No direction” and “Clear direction” over the dunes were very high, indicating that both types of movements were exclusive. At open sea however, relative shares of both movement patterns were less high and near the shore, especially in July, mean shares add up to only slightly over 100 per cent, indicating that both directed and non-directed movements occurred simultaneously.

<u>Ships</u>

The occurrence of bird-attractive ships and the numbers of echoes attracted by the ships were scored independently from the other movement patterns. That means that echoes scored to be attracted by ships may have been assigned to other movement patterns as well. The general range of attractiveness was 3 kilometres, the width of the path 500 metres. During 30 hours in June echoes to or from ships were observed. In July only in the beginning and the end of the measurement period echoes were recorded to be influenced by ships.

<u>No time-patterns</u>

The distribution of echo densities over time appears to be highly irregular. Especially in July sharp peaks could be observed, but neither in June nor in July patterns in time could be established. Peaks occurred both during day and night.

Density patterns at sea roughly follow density patterns near the shore. But echo densities over the dunes are low overall. Strikingly, in July the high densities in “directed echoes” coincide with the occurrence of “attractive” ships. For a closer look on the timing of bird densities see appendix A and B.

Individually tracked echoes

1338 tracks were recorded in June, 1216 in July. From the June session visual species information was obtained on 624 tracks (47%), in July on 544 tracks (45%), resulting in 14 resp. 10 observed bird species.

<u>Wing-beat patterns</u>

Tracks containing both a visual determination and an unambiguous AGC-pattern were used to assess species-specific wing-beat patterns. The resulting wing beat frequencies are depicted in table 3. These frequencies were used to assign species information to tracks without visual determination. Frequencies of the Common Scoter and the Oystercatcher were not used because of the small sample size. Gull species could not be differentiated.

Table 3: Mean wing beat frequencies of visually determined species. Data from June and July have been pooled. All frequencies are continuous, except for the Swift, which shows a discontinu wing beat pattern.

Species	***Nr***	***Mean***	***St. dev.***
Cormorant	14	4.4	0.7
Common Scoter	1	7.3	-
Oystercatcher	2	5.0	0.5
Lesser Black-backed Gull	111	3.0	0.3
Herring Gull	81	3.0	0.3
Black-headed Gull	3	3.1	0.3
Common Tern	7	3.4	0.7
Swift*	8	8.0	0.5

Species composition

Using these wing-beat frequencies, species information became available on 784 tracks in June (59%) and 864 tracks in July (71%). This composite species information is used in further analysis. Gulls were most abundant, of all identified tracks in June 89% dealt with Gulls, in July 79%. In June fair amounts of Swifts were around midnight during two nights, accounting for 4 % of all tracks. In July Shelduck and Cormorants were tracked frequently. See table 4.

Table 4: Visually identified species and number of tracks.

	June		***July***	
Species	***Nr***	***%***	***Nr***	***%***
Cormorant	14	2	56	6
Shelduck	4	1	73	8
Common Scoter	2	0	15	2
Duck sp.	7	1	11	1
Lapwing	10	1	1	0
Gull sp.	697	89	682	79
Swift	32	4	13	2
Starling	12	1	0	0
Other	4	0	10	1

Group size

During daytime, group sizes of tracked echoes were noted where possible. Table 5 shows median group sizes of the eight most tracked species. Cormorants and gulls appeared to fly singly most of the time, although some gull echoes were recorded to consist of several tens of birds. The number of swifts tracked during daylight was very small (7 in total) but they always flew single. Ducks typically appeared to fly in medium-size groups of 5-15 birds. The few records of Starlings and Lapwings all consisted of large groups.

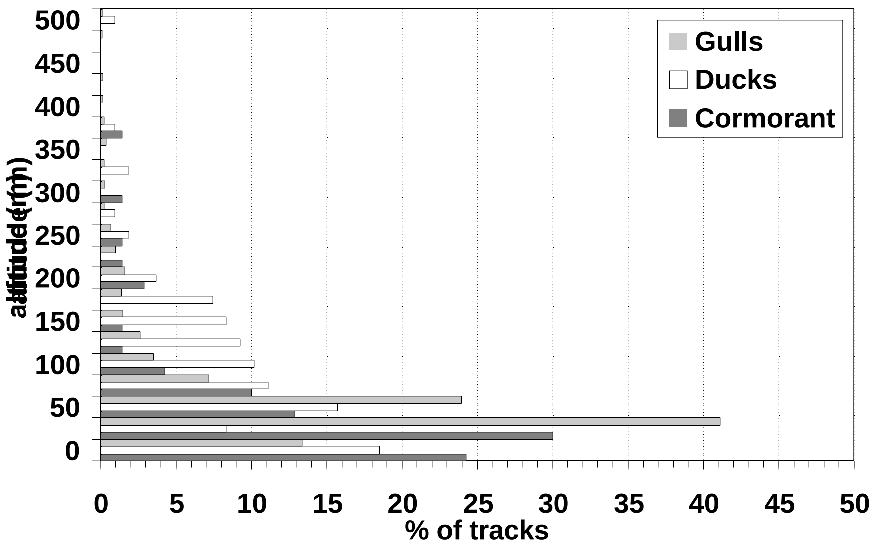
Table 5: Median group size of visually identified tracks.

Species	***June***	***July***
Cormorant	1	1
Shelduck	8	15
Common Scoter	6	5
Duck sp.	6	13
Lapwing	50	
Gull sp.	1	1
Swift	1	1
Starling	50	

Altitude distribution

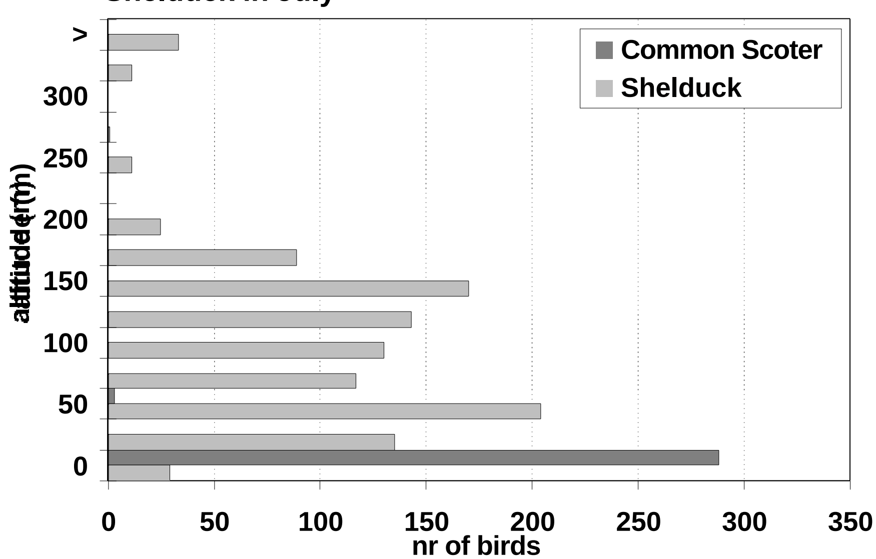
The vast majority of birds flew at low altitudes, see graph 1. The bulk of the Gulls flew below 25 metres, very few Gulls flew higher than 75 metres. The same holds true for Cormorants. Numbers of the third abundant species group, ducks, were much more evenly distributed up to 175 metres altitude.

Graph 1: Altitude distribution of Gulls, Ducks and Cormorants in June and July



In graph 2 the altitude distribution of ducks is differentiated to Common Scoter and Shelduck. Since Shelduck and Common Scoter usually fly in groups, we present number of birds instead of number of tracks. Nearly all ducks at sea level were Common Scoters, all ducks at higher altitudes were Shelduck.

Graph 2: Altitude distribution of Common Scoter and Shelduck in July



Flight directions

Flight directions of the 5 most tracked species were investigated. Both in June and July overall flight directions of Gulls were slightly but significantly bimodal, roughly towards ENE and WNW. Also Cormorants in July showed a bimodal distribution of flight directions, towards NNE and SSW. Shelduck and Common Scoters in July headed NNE and N respectively. No preferred flight direction was found for Swifts. See Table 6.

Table 6: Overall flight directions of the 5 most tracked species. A second direction is given whenever a bimodal distribution was found.

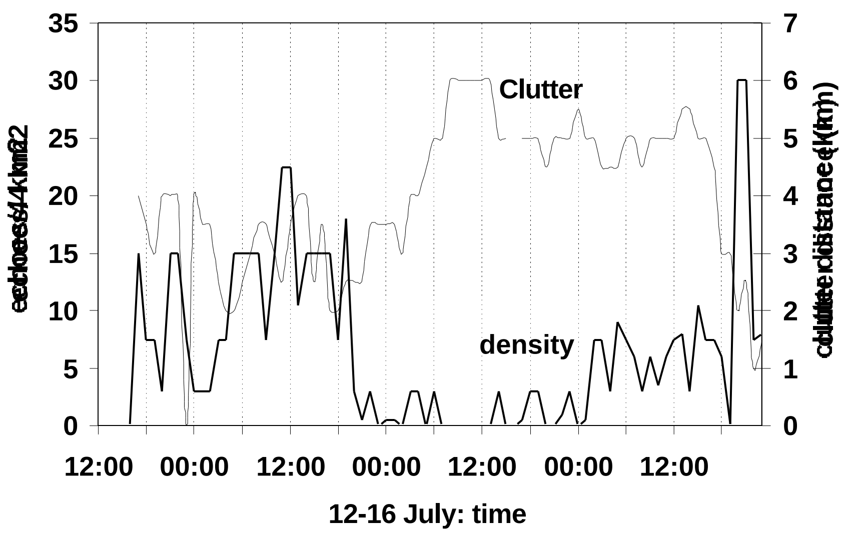
Species	***Month***	***Day / Night***	***Direction***				
			1st	***2nd***	***vector***	***N***	***Sign.***
Cormorant	June	D + N	-	-	-	14	-
Cormorant	July	D + N	17°	197°	0,35	56	***
Gull	June	D	71°	251°	0,3	563	***
Gull		N	217°	-	0,29	134	***
Gull	July	D	109°		0,27	503	***
Gull		N	56°	236°	0,27	179	***
Swift	June	N	-	-	-	32	-
Swift	July	N	-	-	-	13	-
Shelduck	July	D	22°	-	0,87	73	***
Common Scoter	July	D	3°	-	0,71	15	***

DISCUSSION

Densities above the dunes are very low compared to the densities over near the shore and at open sea. This effect is partly artificial. The dunes and the hotels near the beach hinder measurements at altitudes below 25 metres. From the results of the tracks we found that over sea a large proportion of the birds actually flew below 25 metres altitude. This effect however will not make up for the tenfold difference as observed, so bird numbers over the dunes will indeed be smaller than near the shore.

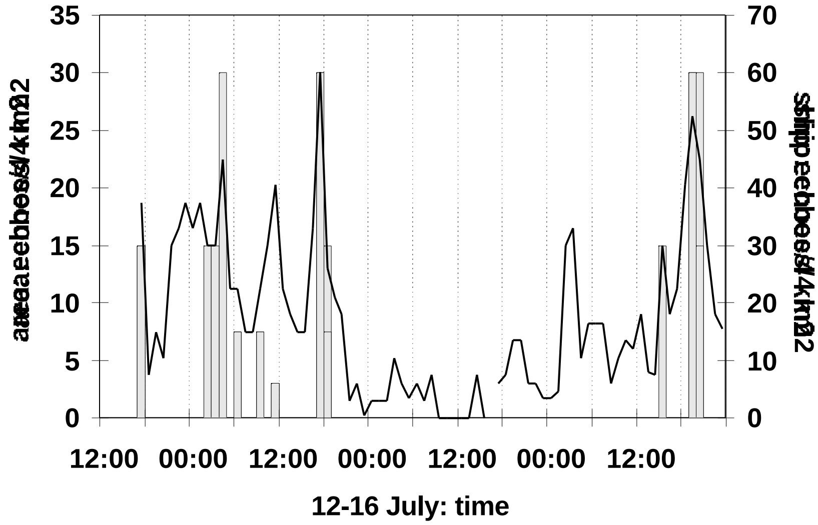
Overall echo densities appeared to be higher in June than in July. Part of this difference is explained by the weather. During two days in June the wind was very strong. From visual observations it seemed that less birds were actually flying during strong winds. Moreover, the resulting waves cluttered the radar images, deteriorating the view on bird movements. See also graph 3. Furthermore, it is well possible that actual bird numbers in the area were larger in June than in July. A large colony of Lesser Black-Backed Gulls is nearby. In June, this colony may have caused a concentration of gulls in the area but in July most of the gulls of this colony will have spread out over the North Sea area more evenly. (Spaans 1998)

Graph 3: Total echo densities and clutter distance, July



Also, the occurrence of “attractive ships” seems to influence echo densities strongly. Even if only densities of clearly directed echoes are concerned, which are specifically not heading for ships, striking similarities are observed between the occurrence of attractive ships and peak echo densities. In graph 4 densities of the clearly directed echoes and the occurrence of “attractive ships” are presented.

Graph 4: Clearly directed echoes and the occurrence of ships. The line presents the number of clearly directed echo's (left axis), the bars represents the echo densities attracted by ships (right axis).



CONCLUSION

The presupposed domination of local movements during summer months holds out. A firm 80-90 per cent of all individually tracked echoes concerns Gulls, and the weak, largely bimodal direction of the gulls does not support any migration pattern. In June, the remaining 10 per cent of the tracks concerned mainly Cormorants and Swifts. No preferred direction was found for Swifts, and the two preferred directions of the Cormorants roughly follow the coastline north- and southward, also suggesting that these movements are of local rather than migratory origin. In July, relatively large numbers of tracks of Shelduck going north, presumably heading for their moulting areas in the Wadden Sea (Camphuysen & Van Dijk 1983), were recorded

Echo numbers above the shallow waters at the shore are clearly higher than further out at sea. The vast majority of echoes are gulls, which usually fly singly. We found no general difference in species distribution or group size between dune, shore and sea. Only during one evening and the subsequent morning in July considerable numbers of Shelduck, flying in groups of 15 individuals, passed along the shore. In earlier experiments with the same type of radar it was proven that the possibility to observe birds hardly decreases within 5 km from the radar, the range we used for analysis. Thus we state that the mean bird density at the shore will be at least 8 ±4 birds per Km_, and at sea 3 ±3 birds per Km_. This decline in bird density from the coast to the sea onward corresponds with counts performed from small aeroplanes (H. Baptist, pers. comm.)

Lensink ***et al.*** (this conference) estimate the daily average bird numbers aloft between 2-7 birds per Km_ at an inland site. Since many species at their inland site are smaller than the gulls and ducks at the shore, and echo numbers relate to flocks rather than individuals, the bird mass density will be considerably higher at the shore than at an inland site.

Remarkably, bird activity during daytime was not clearly different from bird activity at night. Due to this phenomenon, overall bird activity was probably higher during the summer months than in any other period, but those data are still in preparation. Some correlation exists between the occurrence of ships and the presence of large numbers of gulls in the area, but these ships alone will not explain the high densities.

Another striking phenomenon of the summer months is the altitude distribution. 55 per cent of all tracked gulls flew below 25 metres altitude and 75 per cent below 50 metres. Only Shelduck clearly flew higher, up till 200 metres altitude.

In conclusion, we state that local movements can lead to very high bird densities, but this bird mass is largely limited to the lowest air layers, during day as well as at night.

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