Short-term effect of reclamation on numbers and distribution of waterfowl at Højer, Danish Wadden Sea

Korttidseffekten på ande- og vadefugles fordeling og antal ved bygningen af det fremskudte dige ved Højer

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In the summer of 1980, a new dike enclosed 11 km^2 of saltmarsh and mud flats in the south eastern part of the Danish Wadden Sea. The effect of the dike is analyzed on the basis of the abundance and distribution of waders and ducks during the migration periods. The analysis comprised ground censuses in the reclaimed and adjacent areas, aerial censuses in the whole Danish Wadden Sea, observations of the high tide movements in relation to time of high tide, and the flight lines to roosts at the dike.
The bird fauna has changed drastically in the reclaimed area and the nearby tidal flats. Eight out of twelve wader species decreased by 85% in this area and all important duck species by 60%. Aerial censuses showed that the change in distribution for some species can be traced in most of Listerdyb tidal basin. Judging from the pattern of the high tide migration, the changes can be assumed to be due to shorter feeding times for the decreasing species.

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Introduction

The importance of the Wadden Sea for the West European flyway of waders and ducks is outlined recently by Smit & Wolff (1981).

Thousands of waders and ducks rest during migration in the southern part of the Danish Wadden Sea at Højer. This area had a large salt marsh and still has extensive tidal flats which offer the birds good opportunities for foraging and resting. Most waders feed on the tidal flats and use the marsh as a roosting place, when the sea covers the tidal flats during high tide. The ducks forage and rest on the water, though some species also feed on the marsh.

In 1977 it was decided to build a new dike from Emmerlev Klev, in the north, across the Danish-German border, to the Hindenburg Dam in the south (Fig. 1). In autumn 1979, construction of the new dike started on the Danish side. The area was enclosed in May 1980. In April 1981 the construc-

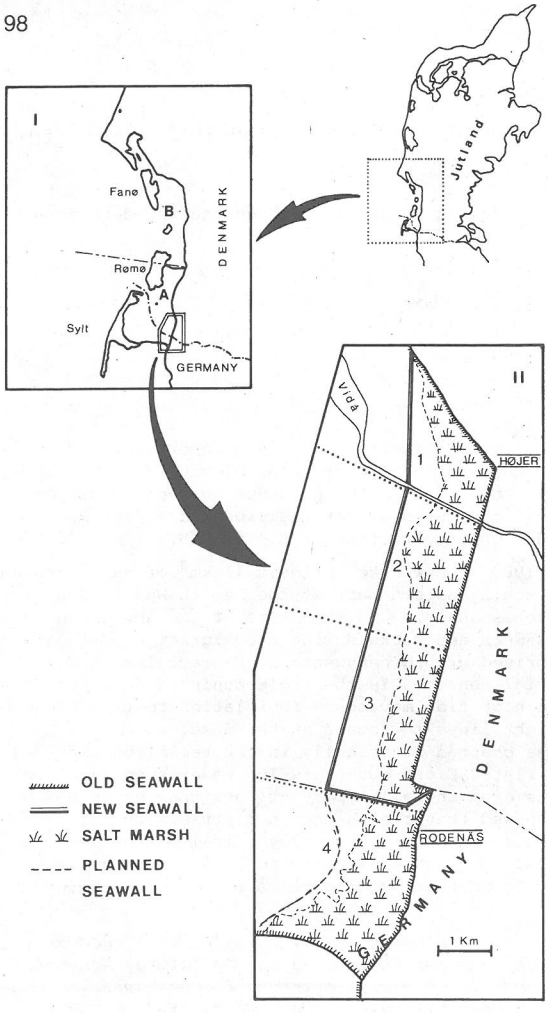

Fig. 1. Location of the study area. Map I shows the Danish Wadden Sea with sections A and B used for this study. Map II shows the situation at Højer, where the new dike has been built on the Danish side. The salt-marsh and tidal flats have been divided into four sectors. *Undersøgelsesområdets placering. På kort I er vist opdelingen af Vadehavet i områderne A og B. På kort II er vist placeringen af det fremskudte dige ved Højer. Marsken og det inderste af vaden er opdelt i fire områder. Signaturforklaring fra oven: Gammelt dige; nyt dige; strandeng; nyt tysk dige (opført 1981).*

tion started on the German side, and was finished in October 1981. This report compares the former numbers and distributions at high tide of migratory waders and ducks in the reclaimed area at Højer (Fig. 1, II) and in most of the tidal area of Lister Dyb (cf. Fig. 6), with those in the first year after construction of the Danish dike, and before the start of the German one.

Wader movements at high tide have been studied to some degree, as they reflect the birds' feeding time in the area.

It must be emphasized that the short-term effect of the reclamation does not necessarily suggest the effect over a number of years. Only a continuous study can reveal the full effect of the dike construction.

Study area

The area is situated at Højer in the south western part of Denmark (Fig 1). The old dike from Højer to the Danish-German border was built in 1861. In 1956 fascines were built in front of the dike to increase the sedimen-

Det fremskudte dige ved Højer set fra syd d. 1. september 1981.
Foto: Svend Tougaard.
The new sea-wall at Højer seen from south on 1 September 1981.

tation. This created a salt marsh which in 1979 covered an area of 800 ha on the Danish side.

On the German side the salt marsh covered about 400 ha, dominated by *Agrostis stolonifera* and *Festuca rubra*. Sheep grazing were less intensive on the Danish side than on the German side. The vegetation was therefore higher and in some parts dominated by *Spartina* sp. and *Aster tripolium*.

The inner parts of the tidal flats were very soft, and in the innermost part overgrown with *Salicornia europaea*. The mudflats are more sandy and firm in their seaward parts.

In front of the new dike an artificial beach was made. It consists of sand and is 100 m wide; at the inner part the beach is about one meter higher than the former level of the mudflat.

Between the dike and the old coastline about 300 ha of the former tidal flat remained. 50 ha of this area, just south of the river Vidå has been excavated, leaving some deep ponds. The rest of the tidal flat south of the river Vidå was covered with water during the autumn, winter and spring of 1980-81, but it dried out in the beginning of May 1981. The tidal flats in the north of the river Vidå have become dry since the dike building except for a small pond to the north.

Materials and Methods

To compare the number and distribution of birds before and after reclamation, data were collected up to October 1979, and from June 1980 to May 1981. Data from the main construction period were not used.

Data from three types of censuses were included in the study: Ground censuses in the areas at Højer and Rodenäs, aerial censuses in the Danish Wadden Sea and registrations of high water movements of waders at Højer.

Ground censuses and mapping of birds at high tide roosts were made three to four times per month in the areas of Højer and Rodenäs (Fig. 1, II) since July 1978. These censuses were made simultaneously on both the Danish and German sides.

Aerial censuses in the Danish Wadden Sea were conducted in 1965-1973 (Joensen 1974) and in 1978 (Meltofte 1980). In 1965-1973, ducks were counted in 28 aerial surveys, chiefly in autumn and late winter. In 1978, waders were counted at high tide in 16 aerial censuses, at least once a month with additional counts in spring and autumn. Original data from these early censuses have been used. For comparison, 10 aerial censuses in the Danish Wadden Sea were made at high tide after the reclamation.

High tide movements of waders were recorded in the autumn (August-October) of 1979 and 1980 to obtain information about time for feeding before and after the dike construction. Consequently waders flying to and from roosts were counted at 20 minute intervals four hours before to three hours after high tide. In 1979 these censuses were made in the northern part of section 3 (Fig. 1,II), and so were most censuses carried out in 1980.

Mean values for the most important species were calculated for the aerial censuses in the following way: Figures were used only from months where censuses were made both in the period prior to and after the reclamation. A monthly mean and a mean covering all months were calculated. For ducks and waders the figures represent 10 and 11 months respectively.

Calculations, expressed as percentages, have been used to compare the distribution on several occasions before and after the dike construction, mainly to eliminate annual fluctuations when data from only one year are used after the reclamation.

It became clear early in the period of the ground censuses that the German area, Rodenäs (Fig. 1, II) became a very important roosting place after reclamation of the Danish side. Only ground censuses were undertaken

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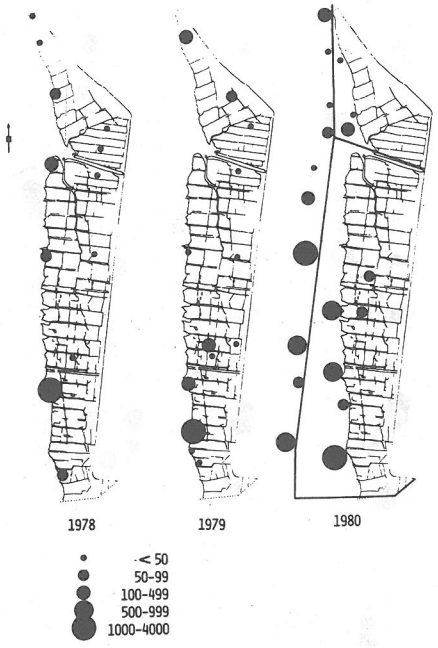
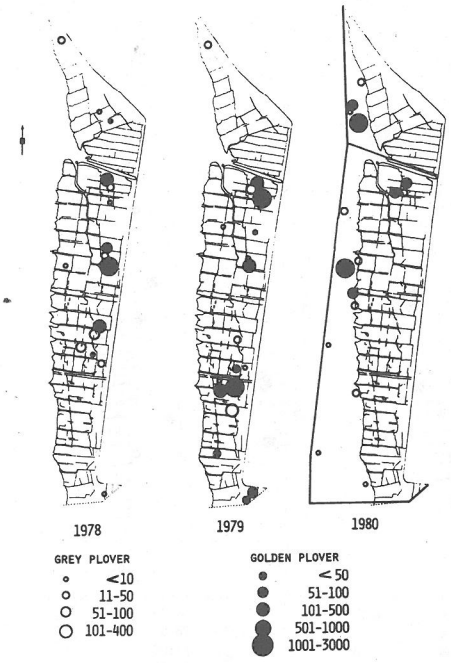
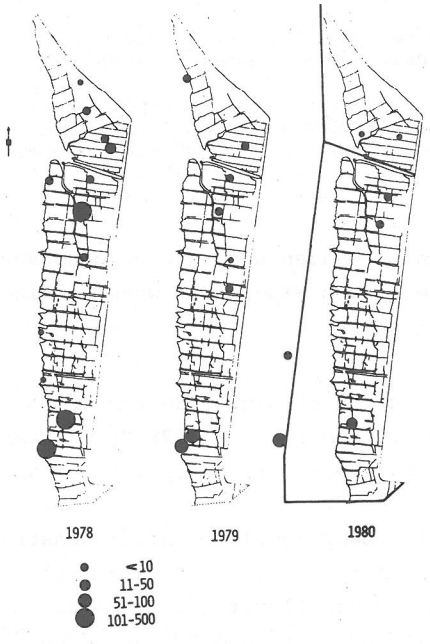


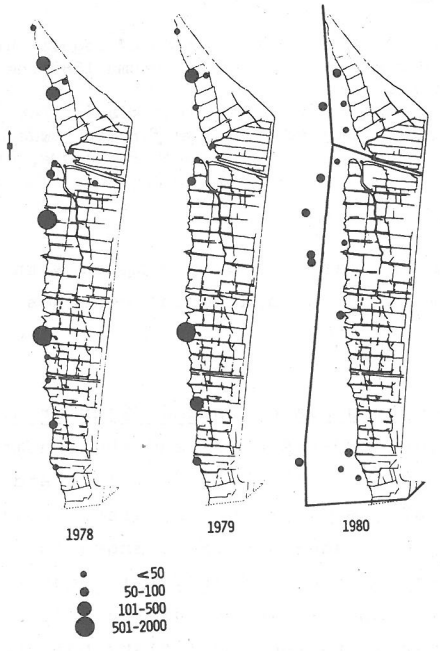
GREY PLOVER (PLUVIALIS SQUATAROLA) AND GOLDEN PLOVER (P. APRICARIA)



CURLEW (NUMENIUS ARQUATA)



BAR-TAILED GODWIT (LIMOSA LAPPONICA)



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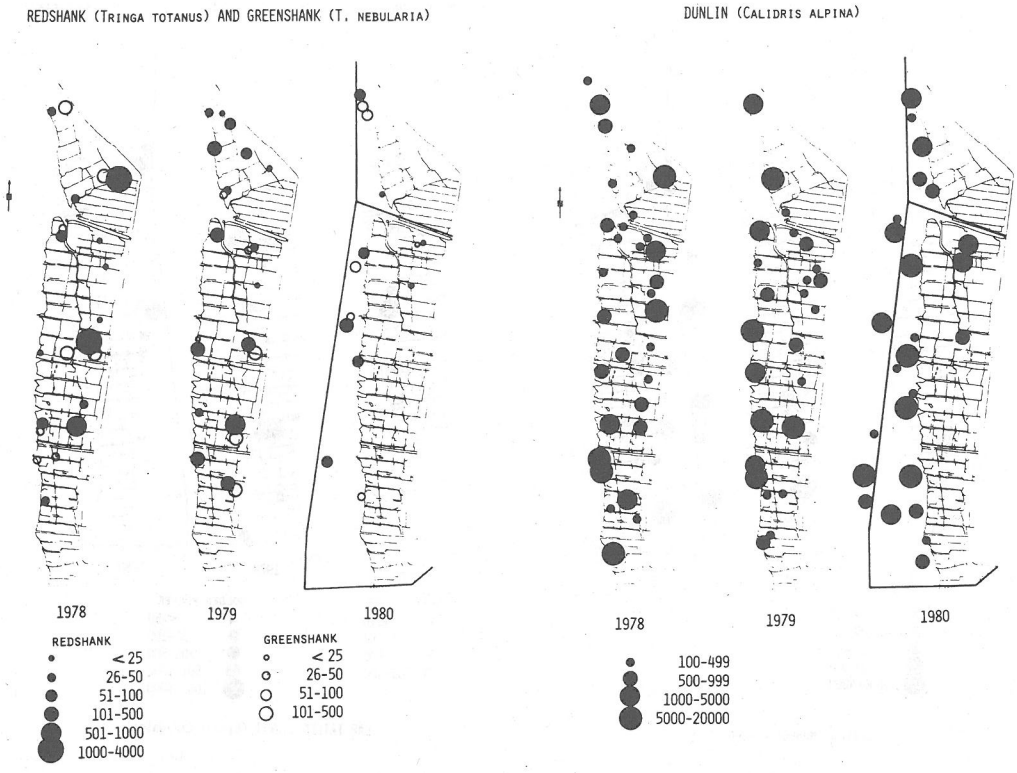


Fig. 2. Autumn distribution of regular high tide roosts with numbers of eight wader species in 1978-1980. In autumn 1980 the Danish dike was established, as shown in the figure.
Efterårsfordelingen af regelmæssigt benyttede højvandsrastepladser med angivelse af rastepladsernes størrelse for otte vadefuglearter. Fra oven mod højre: Strandskade, Strandhjejle & Hjejle, Stor Regnspove, Lille Kobbersneppe, Rødben & Hvidklire og Alm. Ryle. Det danske dige var bygget i efteråret 1980, hvilket er vist på figuren.

in this area, and to compare with the Danish Wadden Sea, ground censuses from Rodenäs and aerial censuses from the Danish Wadden Sea were combined.

Results

Roosting places in the Højer area. Distribution of high tide roosts for eight wader species and their numbers during the autumns 1978-80 are shown in Fig. 2. The maps from 1978 and 1979 show the distribution before, and 1980 the distribution, after reclamation.

All wader species changed most of their roosting places after construction of the dike (Fig. 2). Redshank *Tringa totanus*, Greenshank *T. nebularia*, Grey Plover *Pluvialis squatarola* and Golden Plover *P. apricaria* changed to the tidal flats between the old coastline and the new dike, while Dunlin *Calidris alpina*, Oystercatcher *Haematopus ostralegus*, Curlew *Numenius arquata* and Bar-tailed Godwit *Limosa lapponica* also established new roosts in front of the dike.

Tab. 1. Mean number of birds counted at ground censuses at high tide in the autumns 1978/79 and 1980 at Højer and Rodenäs.
Gennemsnitstal for landtællinger ved højvande efterårene 1978/79 og 1980 ved Højer og Rodenäs.

	Højer		Rodenäs	
	1978/79	1980	1978/79	1980
Gravand *Shelduck*	1100	900	850	1180
Gråand *Mallard*	1700	140	160	820
Krikand *Teal*	200	20	120	200
Pibeand *Wigeon*	800	550	370	5000
Spidsand *Pintail*	120	0	0	20
Ænder ialt - *Ducks total*	4000	1600	1500	7100
Strandskade *Oystercatcher*	360	400	600	1400
Vibe *Lapwing*	300	450	200	180
Stor Præstekrave *Ringed Plover*	0	60	0	170
Strandhjejle *Grey Plover*	200	70	70	40
Hjejle *Golden Plover*	200	150	50	30
Stor Regnspove *Curlew*	110	10	80	880
Ll. Kobbersneppe *Bar-tailed Godwit*	350	230	130	410
Rødben *Redshank*	600	120	200	300
Sortklire *Spotted Redshank*	30	10	30	30
Hvidklire *Greenshank*	230	210	80	20
Alm. Ryle *Dunlin*	27000	3000	12000	25000
Klyde *Avocet*	50	150	10	240
Vadefugle ialt - *Waders total*	29400	4900	13400	28500

Numbers and distribution of waders and ducks at Højer and Rodenäs. Figures from ground censuses made during high tide in the autumns of 1978-1980 at Højer and Rodenäs are shown in Tab. 1. The figures also include the area in front of the salt marshes or, in 1980, the dike itself.

The autumn number of waders at Højer decreased by about 85% from 1978/79 to 1980. The decrease involved most wader species, while three species increased. For all but one species the change in numbers tended to be the same in the Højer and Rodenäs areas. The exception was the Curlex which occurred in larger numbers in 1980 due to an increase at Rodenäs.

The autumn number of ducks at Højer decreased by 60% for all species after the dike construction. Mallard *Anas platyrhynchos* showed the greatest decrease, nearly 90%. Taking together the number of ducks in the Højer and Rodenäs areas, all species decreased in autumn 1980 except for Wigeon *Anas penelope*, which increased considerably at Rodenäs, and Shelduck *Tadorna tadorna* which increased very little.

In order to analyze the distribution of waders and ducks in the whole area from Højer to Rodenäs, it was divided into four sectors (Fig. 1, II).

After construction of the dike most birds were found in sector 4, i.e. in the German part (Rodenäs), while sector 3 contained only a small population of waders. This sector previously held the largest numbers.

Fig. 3 shows the distribution between the four sectors of the coast for five wader species in 1978 and 1980. Oystercatcher, Grey Plover, Redshank and Dunlin all showed an increase in sector 4 in 1980. The Ringed Plover *Charadrius hiaticula*, however, showed an increase in sector 1 the same year. Here the former tidal flats have dried out after reclamation and turned into a habitat apparently suitable for this species.

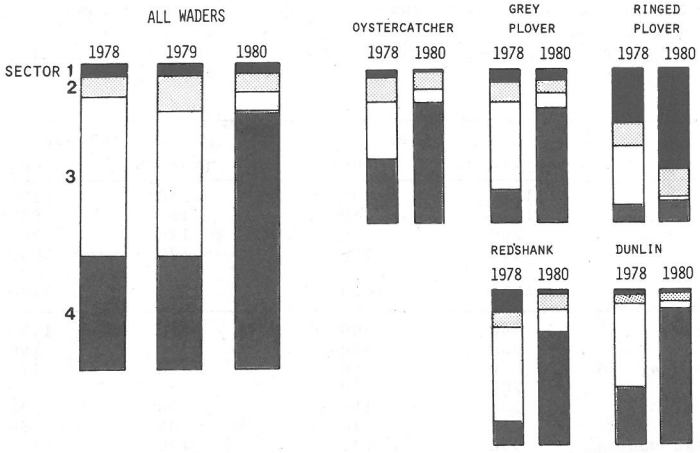


Fig. 3. The relative distribution of waders at high tide during the autumns 1978-80 in sections 1-4 recorded at ground censuses. Left, all waders shown together; right, five wader species in 1978 and 1980.
Fordelingen af vadefugle efterårene 1978-80 i områderne 1-4. Til venstre alle vadefugle vist samlet. Til højre er vist fem vadefuglearter i 1978 og 1980. Fra oven mod højre: Strandskade, Strandhjejle, Stor Præstekrave, Rødben og Alm. Ryle.

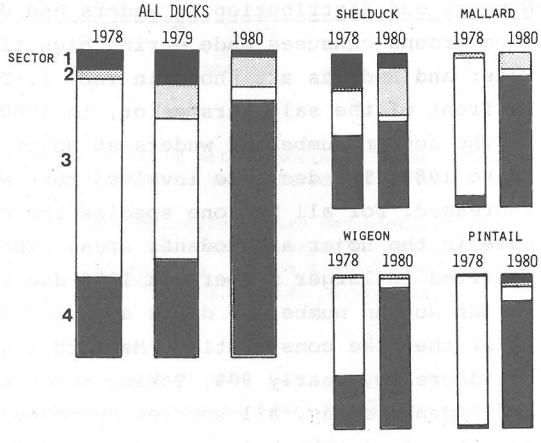


Fig. 4. Distribution of ducks at high tide during the autumns 1978-80 in sections 1-4 recorded at ground censuses. Left, all ducks shown together; right, four species in 1978 and 1980.
Fordelingen af andefugle efterårene 1978-80 i områderne 1-4. Til venstre er alle andefugle vist samlet. Til højre er vist fire arter i 1978 og 1980. Fra oven mod højre: Gravand, Gråand, Pibeand og Spidsand.

The distribution of ducks (Fig. 4) in the four sectors was very similar to that of the waders. For ducks, too, there was a great increase in sector 4 in 1980, but in sector 2 the numbers seem to have increased slightly. Thus the Mallard, Wigeon and Pintail *Anas acuta* showed an increase in sector 4, while Shelduck, apart from a small increase in that sector showed a greater increase in sector 2 (Fig. 4). Ponds were excavated in this sector, and most Shelducks were found here.

Whether the birds would use the area behind the new seawall has been the object of discussion. The percentage distribution of most waders and ducks in front of and behind the dike is shown in Fig. 5.

In total, 60% of the waders and 10% of the ducks stayed behind the dike during high tide in the autumn of 1980.

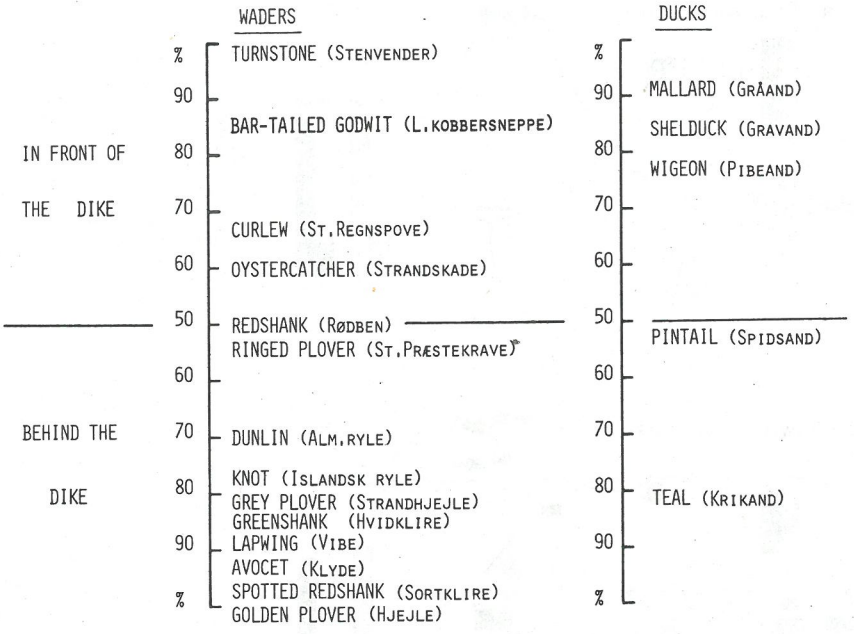


Fig. 5. Distribution (%) of waders and ducks at high tide in front of and behind the new dike, respectively, from mid July to late October 1980. Data from ground censuses. *Fordeling (%) af vadefugle og ænder foran og bagved det fremskudte dige ved højvande i perioden fra midten af juli til slutningen af oktober 1980.*

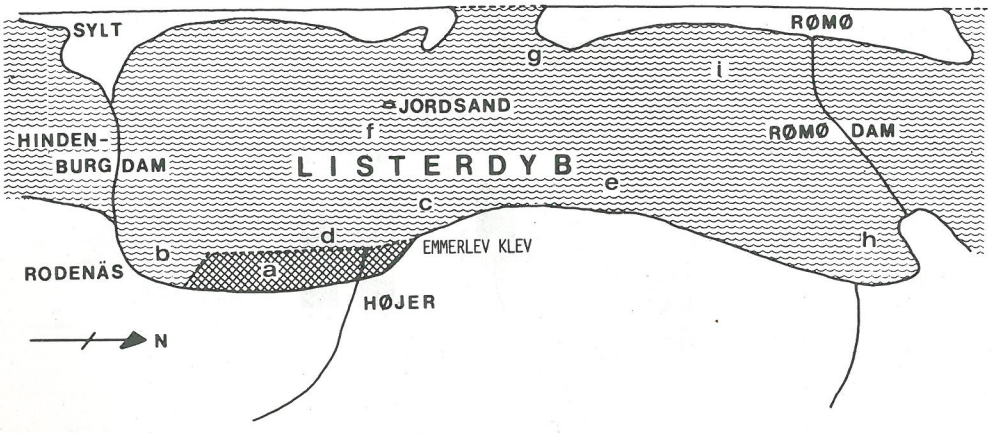


Fig. 6. Schematic map of the Listerdyb area (section A of Fig. 1) seen from the east. The cross-hatched area at Højer is the reclaimed area. Letters a-h refer to the aerial census areas (Tab. 2).
Kort over Listerdyb tidevandsområde. Det ternede område ved Højer viser det inddigede areal. a-h refererer til optællingsområder (Tab. 2).

Distribution in Listerdyb area. The Listerdyb tidal area is shown in Fig. 6. It is divided into nine census areas (a-i) covering the entire Danish part of Listerdyb including the Rodenäs area. The per cent distribution of five wader and three duck species at high tide before and after the

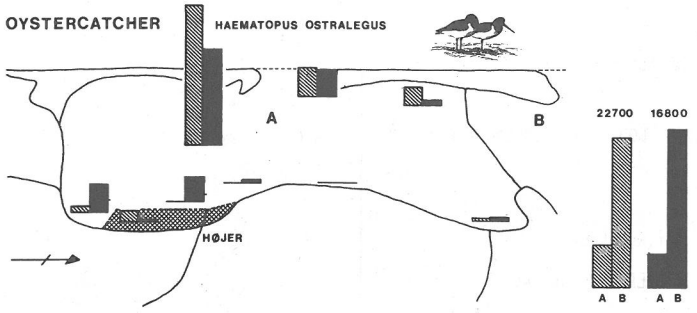
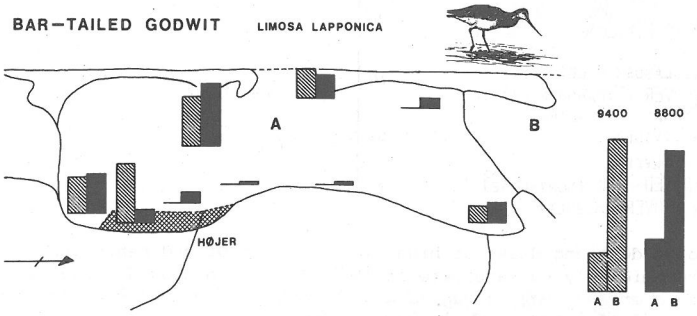


Fig. 7.



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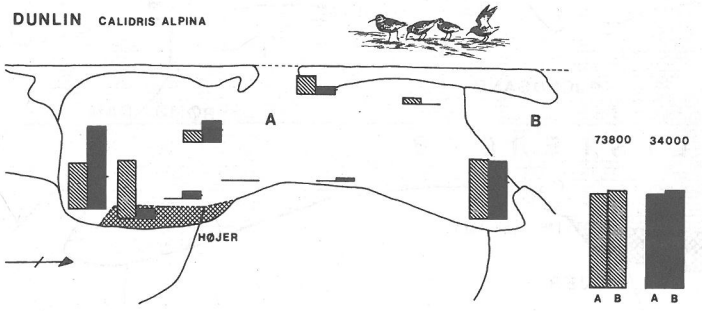

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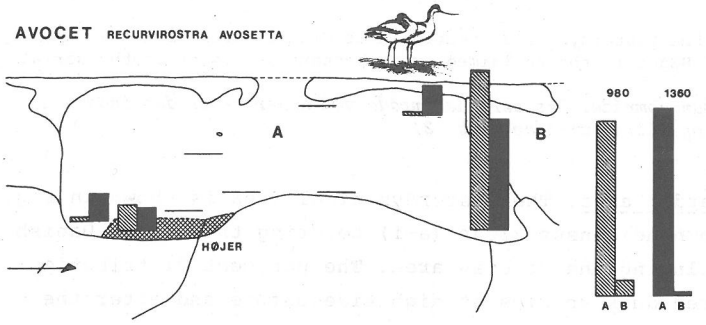
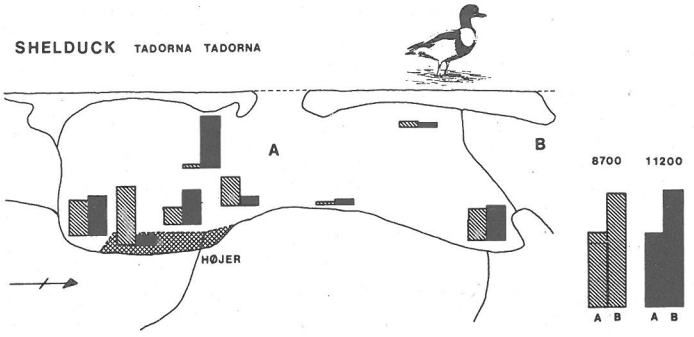


Fig. 10.



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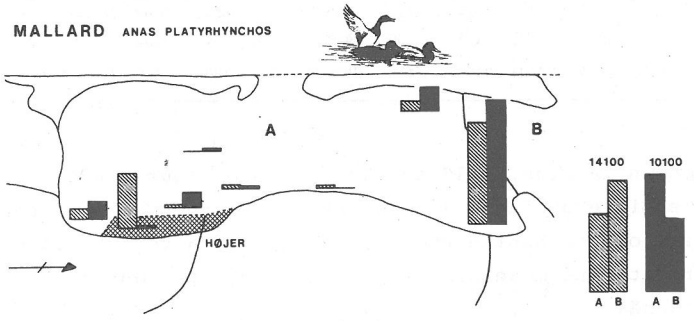

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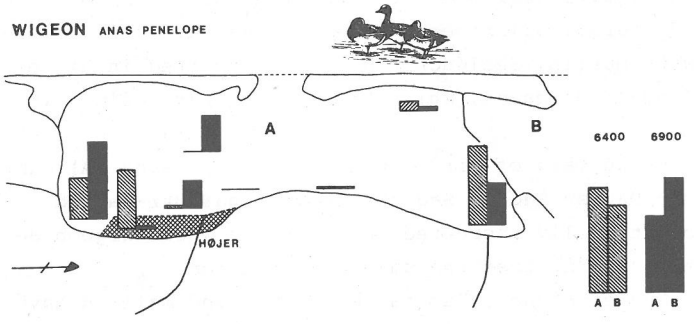


Fig. 13.

Fig. 7-13. Per cent distribution of four species of waders and three species of ducks in the Listerdyb area in the period before the Danish sea-wall construction (hatched) and after (black). To the right the columns show A) the percentage in the Listerdyb tide basin (the Danish part of Listerdyb area including the Rodenäs area) compared to B) the rest of the Danish Wadden Sea. The period before is hatched and the period after the dike construction is black. The mean numbers in the whole Danish Wadden Sea including Rodenäs area are given above the columns.
Søjlerne viser den procentvise fordeling af Strandskade, Lille Kobbersneppe, Alm. Ryle, Klyde, Gravand, Gråand og Pibeand før digebygningen (skraveret) og efter digebygningen (sort). Søjlerne til højre viser den procentvise fordeling af Strandskader i Listerdyb tidevandsområdet (A) sammenlignet med den øvrige del af det danske vadehav (B) før digebygningen (skraveret) og efter digebygningen (sort). Over søjlerne er angivet det gennemsnitlige antal fugle i Vadehavet i de to undersøgelsesperioder.

Tab. 2. Mean numbers of four wader and three duck species counted at high tide during aerial surveys of the Wadden Sea.

Område / *Area*	År / *Year*	Strandskade *Oystercatcher* 1978 N	%	%	Strandskade *Oystercatcher* 1980/1981 N	%	%	Lille Kobbersneppe *Bar-tailed Godwit* 1978 N	%	%	Lille Kobbersneppe *Bar-tailed Godwit* 1980/1981 N	%	%	Almindelig Ryle *Dunlin* 1978 N	%	%	Almindelig Ryle *Dunlin* 1980/1981 N	%	%
a		337	7		48	2		580	31		160	7		10754	30		770	5	
b		139	3		410	15		355	19		502	21		8644	24		7289	44	
c		13	0		35	1		5	0		40	2		23	0		45	0	
d		0	0		366	13		0	0		150	6		0	0		720	4	
Sydøstlige Listerdyb *Southeastern Listerdyb*		489	10		859	31		940	50		852	36		19421	54		8824	53	
e		17	0		12	0		7	0		23	1		13	0		114	1	
f		3783	74		1397	50		492	26		788	33		1494	4		1791	11	
g		743	15		405	14		275	15		306	13		3282	9		745	4	
h		67	1		55	2		160	9		269	11		11179	31		5053	30	
i		9	0		95	3		0	0		120	5		653	2		197	1	
Øvrige Listerdyb *Rest of Listerdyb*		4619	90		1964	69		934	50		1506	64		16621	46		7900	47	
Listerdyb (section A)		5108	100	(23)	2823	100	(6)	1874	100	(20)	2358	100	(17)	36042	100	(49)	16724	100	(49)
Øvrige Vadehav (Section B) *Rest of Waddensea*		17545		(77)	14010		(83)	7483		(80)	6448		(73)	37762		(52)	17225		(51)
Hele danske Vadehav *Entire Danish Waddensea*		22653		(100)	16833		(100)	9357		(100)	8806		(100)	73804		(100)	33949		(100)

dike construction is shown in Figs. 7-13 and Tab. 2. The figures also show the numbers in the Listerdyb area (A), which covers the census areas a-i compared to the rest of the Danish Wadden Sea (B) and after the dike construction, together with the mean number per census in the entire Danish Wadden Sea and Rodenäs.

All species showed a decrease in the reclaimed area at Højer. After reclamation a higher proportion of birds was found in front of the new dike. Only Oystercatchers and Avocets *Recurvirostra avocetta* showed an increase in this part of Listerdyb area; all other species decreased. After reclamation Bar-tailed Godwit, Dunlin, Shelduck and Wigeon occurred in higher proportions at the island of Jordsand, while Mallard, in particular, increased at the Rømødam.

After reclamation, the numbers of birds in the Listerdyb area (A) compared to the rest of the Danish Wadden Sea (B) showed that Bar-tailed Godwit and Mallard proportionally increased in Listerdyb while Wigeon decreased. The other species maintained the same distribution.

The mean numbers of Oystercatcher, Bar-tailed Godwit and Mallard have decreased in the entire Danish Wadden Sea the year after reclamation. Avocet and Shelduck increased, while Bar-tailed Godwit and Wigeon were present in the same number.

Flight lines to high tide roosts at Højer. In the autumn of 1980, the flight lines of some abundant species to and from the roosts at Højer were recorded. During rising tide some Oystercatchers flew to the Højer area from the north. Other Oystercatchers from the tidal flats outside the dike walked in front of the tide-edge to feed, and gathered in roosts on the artificial beach in front of the dike, or in sub-roosts here and on some low sandbanks seaward of the beach (Fig. 14). A major part of the

Gennemsnitligt antal for fire vadefugle- og tre andefuglearter optalt fra fly i det danske vadehav ved højvande.

Klyde *Avocet*						Gravand *Shelduck*						Gråand *Mallard*						Pibeand *Wigeon*					
1978			1980/1981			1978			1980/1981			1978			1980/1981			1978			1980/1981		
N	%	%	N	%	%	N	%	%	N	%	%	N	%	%	N	%	%	N	%	%	N	%	%
122	14		156	12		1055	30		222	5		1702	29		64	1		1083	31		22	1	
21	2		192	14		829	24		946	21		225	4		573	9		780	22		1147	41	
0	0		0	0		511	15		238	5		179	3		125	2		7	0		4	0	
0	0		0	0		283	8		775	18		178	3		481	8		52	1		400	14	
143	16		348	26		2678	77		2181	50		2284	39		1243	20		1922	55		1573	57	
0	0		0	0		72	2		133	3		78	1		13	0		42	1		32	1	
0	0		0	0		72	2		1217	28		22	0		112	2		6	0		531	19	
0	0		0	0		-			-			-			-			-			-		
737	83		776	58		563	16		775	18		3177	55		4121	65		1391	41		572	22	
12	1		215	16		90	3		99	2		275	5		810	13		158	4		68	2	
749	84		991	74		797	23		2224	50		3552	61		5056	80		1597	45		1203	43	
892	100	(91)	1339	100	(98)	3475	100	(40)	4405	100	(39)	5836	100	(41)	6299	100	(62)	3519	100	(55)	2776	100	(40)
91		(9)	24		(2)	5251		(60)	6820		(61)	8280		(59)	3790		(38)	2924		(45)	4165		(60)
983		(100)	1363		(100)	8726		(100)	11225		(100)	14116		(100)	10089		(100)	6443		(100)	6941		(100)

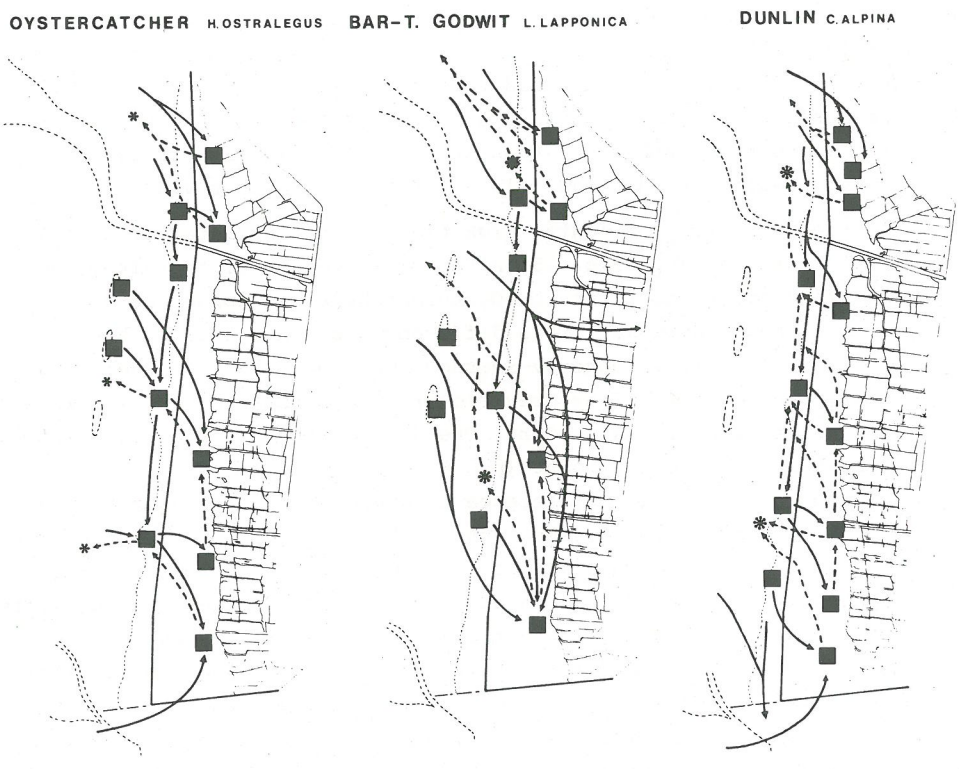


Fig. 14. Flight lines to and from roosting places at the Højer area, autumn 1980. Full line: flight lines to, and broken line: flight lines from the roosts. Squares indicate the main roosting places and asterisk show main foraging places shortly after high tide.

Trækruter til og fra højvandsrastepladser ved det fremskudte dige, efteråret 1980. Mod højre: Strandskade, Lille Kobbersneppe og Alm. Ryle. Optrukken linie viser tiltræk og stiplet linie fratræk fra rasteplads. Kvadrater viser de vigtigste rastepladser og stjerner de vigtigste fourageringssteder kort efter højvande.

Oystercatcher population roosted outside the dike (Fig. 5). Normally the high tide covers most of the sandbanks, and the Oystercatchers moved to roosts on the beach which was seldom flooded. When this happened or when they were disturbed, the Oystercatcher crossed the dike.

On the falling tide, Oystercatchers started to feed from the roosts outside the dike. The birds roosting behind the dike crossed it, to the roosts or sub-roosts, and spread out on the tidal flats from these places.

Bar-tailed Godwits mostly flew to the area from the north and north-west. They formed sub-roosts both on the sandbanks and on the beach, and crossed the dike from these places (Fig. 14). But most of the Bar-tailed Godwits roosted outside the dike (Fig. 5). In some cases they crossed it without first resting outside.

When the water fell they crossed the dike and some of them started to feed outside the beach. Other Bar-tailed Godwits flew to feeding places far from and out of sight of the Højer area.

The Dunlins feeding on tidal flats in the Højer are left the feeding places rather early and flew south. Later, when the water rose, a movement came from the north and north-west, along the dike, crossing it in several places. Sub-roosts were formed outside the dike and when the water rose most of the Dunlins crossed the dike (Fig. 5). On the falling tide, the Dunlins crossed the dike and started to feed in the sourthern part, or flew to the north with stops at one or two sub-roosts before they started feeding on the tidal flats north of the river Vidå.

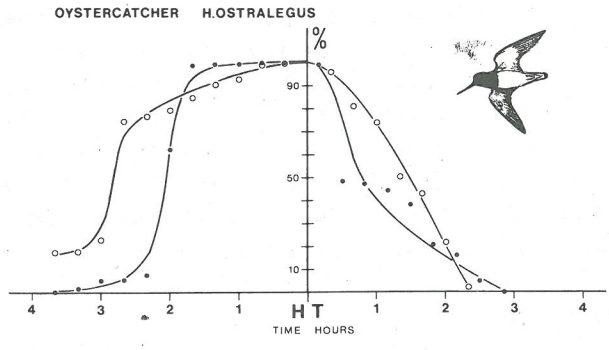
Timing of the high tide movements. High tide movements in relation to time of high water are shown in Fig. 15. After construction of the dike the mean time of movements to roost for Oystercatchers was three quarters of an hour later than previously. This difference is statistically significant ($p < 0.05$, $n = 12$; Kolmogorov-Smirnov two-sample test, Siegel 1956). In contrast, the mean times for Grey Plovers, Redshanks and Dunlins were about 1½-2 hours earlier than before. The differences for these species are also statistically significant ($p < 0.05$, $n = 12$).

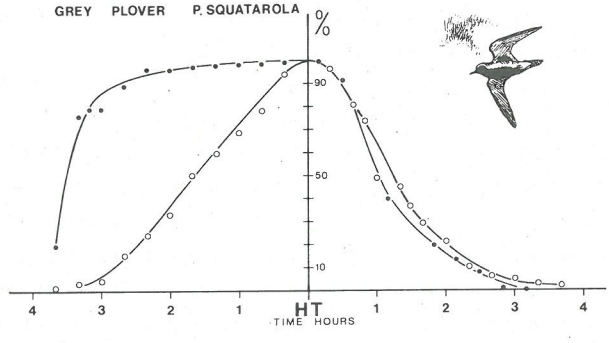
After high tide, no clear difference between the situations before and after the dike construction is apparent. Following the change, Oystercatchers seemed to leave the roosts three quarters of an hour earlier than before; Redshank and Dunlin seem to stay half an hour longer on the roosts. None of these differences are however statistically significant.

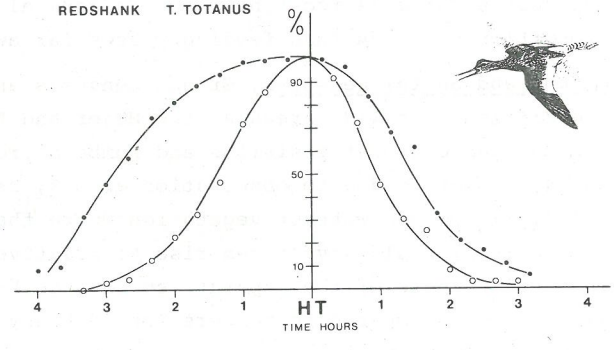
Previously, Oystercatchers left their feeding places when these became flooded and then flew right to the roosts. If, at that time, the Oystercatchers had followed the water's edge inwards they would have come to yet softer mud, on which they tend not to feed.

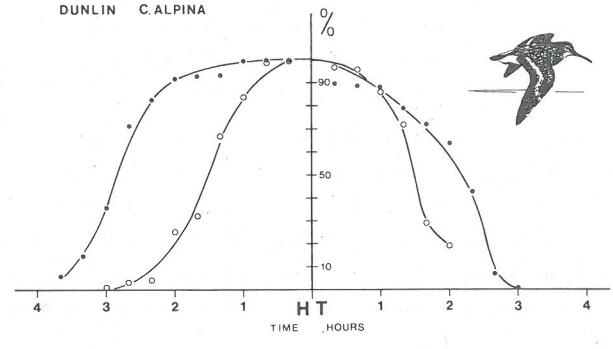
After construction of the dike the Oystercatchers walked in front of the ascending waterline, from the foraging areas to the sub-roosts or roosts, probably because of the now shorter distance between their feeding areas and roost-sites, and because the sediment is sandy and thus more suitable for foraging.

Fig. 15. High tide migration in relation to time before and after high tide (HT). Each point represents a mean of 6-11 recordings. The curves are cumulated to 100%. Circles: 1978/79; dots: 1980.
Tidsmæssig beskrivelse af tidevandstrækket før og efter tidspunktet for højvande (HT). Hvert punkt angiver et gennemsnit af 6-11 optællinger. Kurverne er summerede op til 100%. Fra oven: Strandskade, Strandhjejle, Rødben og Almindelig Ryle. Åbne cirkler: 1978/79; lukkede cirkler: 1980.









Grey Plovers, Redshanks and Dunlins changed their high tide movements in similar ways. In the Wadden Sea all these species tend to forage on soft substrates. Previously they moved while walking in front of the waterline to softer sediments, where they could still feed. After the building of the dike these species flew to roosting places, probably because of the longer distance involved. The roosts were situated chiefly at Rodenäs. In addition, the sediment became more sandy and less suitable to feed on for these species than before.

Discussion

High versus low water censuses. The birds counted at Højer were all at high water roosts and consisted of birds which foraged on tidal flats near Højer together with birds migrating to Højer from feeding grounds outside this area (Fig. 14).

Data from aerial censuses at low tide (Laursen, unpubl., Jepsen 1979) show that 80% of the waders feeding on the tidal flats outside the Højer area also roost there. After reclamation this proportion appears to have dropped to 75%. All ducks were present in the area both at low and high water, suggesting that they both feed and roost in the area. This means that the number of birds counted at high tide reflects the number of birds feeding in the area. The reason for using figures from high tide censuses is that most of the counts have been made at that time.

Zwarts (1976) and Goss-Custard (unpubl.) have found that foraging places near a suitable roosting place in general are visited by a higher proportion of birds than feeding places far away from the roosts.

Ground and aerial censuses. Ground censuses and plotting of flocks on maps are difficult in wide areas as the Højer and Rodenäs saltmarshes. However the changes of roost positions and numbers from 1978/79 to 1980 (Figs 3 and 4) cannot be due to observation errors, as in 1980 the birds were chiefly in places without vegetation where they could easily be seen, and consequently could have given rise to relatively high counts. Therefore, the 1980 numbers of the separate species on Højer saltmarshes (Tab. 1) may be too high, compared to numbers for 1978 and 1979.

Aerial censuses must be treated with some caution. Numbers may be incorrect, and some species, especially those in small numbers, may even be overlooked (Joensen 1974, Meltofte 1978). It is primarily the most numerous species which are suitable for aerial censuses, and consequently only these species are dealt with.

Roosts at Højer. After the dike construction new roosting possibilities became available on the new artificial beach in front of the dike. Behind the dike the former tidal flats were flooded initially, but it was still possible for waders to roost both here and near the old coastline. Furthermore, they could still roost on the saltmarshes. For ducks, the high water level may have offered good resting places.

In the spring of 1981 the diked area had low waterlevel, and dried out by the turn of April-May. This should have given reasonable resting prospects for ducks in their main migratory period, February and March, and for waders during the whole spring. Nevertheless they tended to rest on the undiked Rodenäs saltmarsh. This suggests that the majority of the birds, which had a choice between an embanked and an unembanked roost-site, preferred not to cross the dike or rest behind it. Most waders are sensitive to disturbances at roost-sites (Furness 1973), and disturbances in the Højer area could be a factor influencing the distribution of the birds.

Waders will generally not feed on roost-sites, though Dunlins often feed for part of the high tide period. The small number of Dunlins behind the dike could therefore be due to lack of prey after the reclamation. Meanwhile, unpublished data from bottom samples from the spring of 1980 in the area behind the dike, showed that one third of the previous *Hydrobia ulva* and *Corophium volutator* remained. Thus the profitability of foraging may have fallen (Goss-Custard 1977), and this, together with the physical barrier, may be reasons for the low number of birds.

Different species showed different tendencies to cross the dike (Fig. 5), and this to some degree depends on what substrate each species prefers while feeding (Bushe 1980). Turnstone *Arenarea interpres*, Bar-tailed Godwit, Curlew and Oystercatcher preferred to rest outside the dike, where the new, sandy artificial beach was a suitable resting place. These species foraged chiefly on sandy flats, whereas Dunlin, Greenshank, Grey Plover and Golden Plover preferred to rest behind the dike where the flats are soft and muddy. Also for ducks the distribution depends on their feeding habits. On tidal flats, Mallard and Shelduck forage on bottom fauna, Wigeon on vegetation, Pintail and especially Teal *Anas crecca* feed at the edges of the salt-marsh on vegetable matter (Smit & Wolff 1981).

Distribution of waders and ducks. It may be useful to establish some criteria as a basis for the evaluation of observations. The effect can be examined from changes in numbers or per cent distribution on areas of different extension, starting from the reclaimed area itself. I: The reclaimed area (the Højer area). II: the local area (the Højer area, together with Rodenäs and the area in front of the dike). III: the regional area (The Listerdyb basin), and finally IV: the entire Danish Wadden Sea.

The record of effects of the reclamation may be biased for several reasons, the most serious one being changes in the size of the whole population over the years compared, so that a change in the recorded local population may reflect either a change in general abundance over the years compared, or a local change.

If the dike had a negative effect on numbers and distribution and the total number of birds in the population remained the same, lower figures than before would be expected after the dike building both in per cent and in absolute numbers in each area from I to IV.

In case the total number of birds has decreased over the years, the density of birds might decrease, even if the percentage of birds in the diked area was higher than before. So even if the dike building had a negative effect the distribution pattern might possibly have remained constant, not withstanding a change in absolute numbers. If the total number of birds increased over the years, local decreases in per cent as well as numbers would suggest a negative effect.

Using these lines of guidance, Tab. 2 and Figs 7-13 show that all species, except the Avocet, decreased in the Højer area (I). The Avocet decreased slightly in percentage, but increased in numbers. Most other species showed clear decreases both in numbers and percentage. At Højer, Rodenäs and the area in front of the dike (area II) the Oystercatcher increased in numbers and percentage, while Bar-tailed Godwit, Dunlin, Shelduck, Mallard and Wigeon decreased both in numbers and percentage. Extending the area under consideration to include Listerdyb (area III), the data show that Shelduck, Mallard, Dunlin and Bar-tailed Godwit increased both in numbers and percentage, after construction of the dike. Wigeon decreased in number and percentage in the Listerdyb tidal area. Considering the whole Danish Wadden Sea (area IV) only the Wigeon increased. Thus negative changes are limited to the Listerdyb area.

Factors other than the dike construction at Højer may have influenced the number and distribtution of the species: e.g. local changes in food supplies between the years, as suggested for the Wigeon at Jordsand (see below). It was supposed that species using mainly soft sediments would be most affected, because the dike enclosed these parts of the tidal flats. It was thus expected that the Avocet would have been negatively affected, but surprisingly its numbers remained steady on a whole year basis (Fig. 10) or increased if only the autumn was considered (Tab. 1). The reason may be that the population in the Højer and Rodenäs areas is a breeding one, and that it is more attached to a place as such than a migrating population would be. A small fraction of the Avecets from Højer seems to have moved, and there has been an increase at Rodenäs. Gram (1981) found an increase in the total local breeding population during recent years.

The Wigeon also reacted in an apparently unexpected way (Fig. 13). It decreased noticably at the Rømødam, whereas there was a marked increase at Jordsand. This change may be due to an increase in vegetation on the tidal flats around Jordsand, especially an increase of *Zostera* sp. and *Ulva* sp. Previously these plants were very scarce during autumn but in recent years they have become widespread (P. Uhd Jepsen, pers. comm.).

Waders and ducks seem to react to a reclamation which changes their feeding conditions already by the next migratory season. Evans (1979) found that a reclamation of 260 ha in England was followed by a reduction in numbers of Shelduck (the only duck species examined), Curlew, Grey Plover, Bar-tailed Godwit, Redshank and Dunlin; the last four species declining more than 60%. Joyes et al. (1976) found that the number of migrato-

ry waders was reduced by 90% after a construction which removed a flat from tidal influence. Inside a reclaimed area the fauna often changes gradually from salt to freshwater conditions. This might favour dabbling ducks, while the waders will decline. Oystercatcher, Ringed and Golden Plovers and Avocet are expected to be least affected (Eerden et al. 1979, Prop & Eerden 1981). These species have also maintained their numbers at Højer.

High tide movements. The timing of high tide movements does not necessarily reflect the feeding time of waders. Some species, especially the larger ones, may rest in the middle of the low water period or at its end (Tubbs & Tubbs 1981). In 1980, Oystercatchers stopped to feed two hours before flying to their roosts, while other species, e.g. Dunlin, Grey Plover and Redshank, still feed at that time, or even later. For the last species at least, the feeding time seems to be restricted by the tide. No data for feeding time are available before the dike construction, so a comparison was not possible.

Goss-Custard et al. (1977a) found that the arrival time of waders to roosts in relation to time of high tide reflects their feeding condition. Evans (1979) also found that the probable reason for a decline in wader numbers after a reclamation was a reduction in time available for feeding.

Conclusions

About 10% of the tidal flats at Højer have been reclaimed, but these comprise 90% of the mud flats. Beukema (1976) found in Holland that the biomass on mud flats was 200 g/m^2, against values of 50 g/m^2 for sandy mud, and 5 g/m^2 on sand. This means that the reduction in the potential food is much larger than the reduction of the area suggests. Gram (1980) calculated that the secondary biomass will be reduced by about 75%. This figure corresponds very well with the reduction in waders (80%) and ducks (60%). The sediment, the slope and the invertebrate fauna of the tidal falts in front of the dike may change as a result of the reclamation. One or more of these factors can affect the feeding prospects for the birds (Goss-Custard et al. 1977b, Evans et al. 1979). Available evidence suggests that waders adjust their autumn numbers to the carrying capacity of the area (Evans 1979, Goss-Custard 1979) and that the best areas are occupied first (Zwarts 1976, Goss-Custard et al. 1977b). This probably means that in the Listerdyb, waders and perhaps even ducks, which formerly fed on the tidal flats outside Højer, now have to feed on secondary feeding grounds, or that they migrate through the Danish Wadden Sea without staging, because suitable feeding grounds were already occupied by other birds. Biological evidence of the effect of the new dike is partly given from the result of the high tide movements. Oystercatchers, which increased in the area, and which foraged on sandy flats, have taken advantage of better feeding and roosting conditions in front of the dike. Grey Plovers, Redshanks and the Dunlins, in contrast, which prefer to feed

in muddy areas, all decreased and had 1½ hour less time on the feeding grounds per tidal cycle after the dike construction.

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Dansk resumé: Korttidseffekten på ande- og vadefugles fordeling og antal ved bygningen af det fremskudte dige ved Højer.

Bygningen af det fremskudte dige fra Emmerlev Klev til den dansk-tyske grænse blev påbegyndt i oktober 1979. Diget stod i sin ydre skikkelse færdigt i sommeren 1980. Det inddigede areal er på ca. 1100 ha, hvoraf 800 ha var gammelt forland og 400 ha vadeflade. Området husede en kystfuglefauna, der placerede det blandt internationalt værdifulde områder for en række arter af vadefugle, ænder og terner. Inddigningen blev derfor fulgt med stor interesse.

Resultaterne af undersøgelser over digets påvirkning af ande- og vadefugles fordeling og antal ét år efter digets opførelse præsenteres her. Undersøgelsen omhandler antal og fordeling af rastende ande- og vadefugle ved højvande på Højer forland samt på vaden ud for dette, samt i Listerdyb og det øvrige danske vadehavsområde før og efter bygningen af det fremskudte dige. 3-4 månedlige registreringer blev udført fra land både før og efter digebygningen på forlandet ud for Højer og Rodenäs samt på de tilstødende vadestrækninger (Fig. 1 II). Desuden er der foretaget optællinger fra flyvemaskine i hele det danske vadehavsområde, inklusiv det inddigede område. Andefugle blev således optalt i perioden 1963-1975 og vadefugle i 1978. Efter bygningen af diget er begge artsgrupper optalt ca. en gang om måneden.

Vadefuglenes tidevandsbestemte træk mellem fouragerings- og rastepladser er beskrevet tidsmæssigt før og efter digebygningen. Dette træk afspejler i nogen grad, hvor lang tid vadefuglene har til at søge føde. Endelig er vadefuglenes indflyvning til og udflyvning fra rastepladserne beskrevet for efteråret 1980.

Det skal nævnes, at vadearealet bag det fremskudte dige i efteråret 1980 var vanddækket. Vandet forblev i området hele vinteren og forsvandt som følge af fordampning i slutningen af april og begyndelsen af maj 1981.

Placeringen af højvandsrastepladser for en række vadefuglearter om efteråret er vist på Fig. 2. Kortene viser generelt, at alle arter har flyttet deres rastepladser mod vest fra det gamle forland og dets kystlinie til vadefladen mellem forlandet og diget og ud foran diget. Desuden viser en del arter opsplitning af de rastende flokke. Landtællinger af rastende fugle ved højvande på Højer og Rodenäs forland (Tab. 1) viser, at antallet af ænder ved Højer er faldet 60% fra 1978/79 til 1980. Slåes andefuglearterne sammen for Højer og Rodenäs viser de alle en nedgang med undtagelse af Pibeand, der i 1980 er steget betydeligt på det da endnu uinddigede forland ved Rodenäs.

Antallet af vadefugle ved Højer faldt med ca. 85% fra 1978/79 til 1980. De fleste vadefuglearter gik tilbage: Hjejle, Strandhjejle, Stor Regnspove, Lille Kobbersneppe, Rødben, Sortklire, Hvidklire og Alm. Ryle, medens Strandskade, Vibe, Stor Præstekrave og Klyde gik frem. Betragtes de to områder under ét, viser arterne de samme tendenser i hele området som ved Højer. Stor Regnspove er dog en undtagelse; den er steget i antal ved Rodenäs i 1980.

I Fig. 3 og 4 vises fordelingen af nogle talrige vade- og andefuglearter ud for Højer og Rodenäs. Området er til dette formål opdelt i 4 zoner (se Fig. 1 II). Det fremgår, at der er sket en omrokering. Zonerne 1-3 har mistet en væsentlig del af deres fugle, derimod er der sket en forøgelse af fuglene i zone 4, ved det dengang uinddigede Rodenäs forland. Stor Præstekrave har dog øget sin andel i zone 1, i modsætning til de øvrige arter. Det skyldes, at området nord for Vidåen er blevet så tørt, at denne arts specielle krav til levested midlertidigt er opfyldt her. Gravanden er steget i område 2. Det er netop det område, hvor der er gravet klæg til beklædning af diget. Disse klæggrave dækker ca. 50 ha og er det eneste område bag diget, der har været konstant vanddækket siden inddigningen. Bortset fra de to fremhævede arter viser de øvrige ande- og vadefuglearter en tydelig procentvis tilbagegang i det inddigede område og en tilsvarende stigning på det uinddigede tyske forland.

Fordelingen foran og bagved det fremskudte dige er vist på Fig. 5. Denne fordeling er af særlig interesse for en senere indretning af det inddigede areal, da den viser, hvilke arter man kan forvente, der vil bruge den nye kog. For ænderne fremgår det, at kun 10% (i middel ca. 200) raster bag diget. Gråand og Gravand foretrækker at ligge foran diget, Spidsand fordeler sig ligeligt på begge sider af diget, hvorimod Krikand foretrækker at opholde sig bag dette. Det forholdsvis lave antal kan dog delvis skyldes færdsel i byggeperioden, samt jagt i den nye kog. For vadefuglenes vedkommende foretrækker Stenvender, Lille Kobbersneppe og Strandskade at opholde sig foran diget, mens Alm. Ryle, Strandhjejle, Hvidklire, Vibe, Klyde, Sortklire og Hjejle træffes hyppigere bag diget. For samtlige vadefuglearter har 68% (ca. 4000) i gennemsnit rastet bag diget.

Resultaterne af flytællinger i den danske del af Listerdyb tidevandsområde og landtællinger i det tyske område Rodenäs før og efter bygningen af det fremskudte dige fremgår af Fig. 7-13 og Tab. 2. Sammenligningerne viser, at samtlige arter er gået tilbage i det inddigede område. Tages den sydøstlige del af Listerdyb tidevandsområde under ét (det inddigede areal, vaden foran diget samt Rodenäs området), viser Strandskade og Klyde en fremgang efter digets bygning. Strandskaderne har åbenbart nydt godt af de sandede arealer foran det nye dige. Fuglen raster der og strækningen mellem rastepladserne og fourageringsstederne er kortere nu end tidligere. Stigningen i antallet af Klyder må hænge sammen med, at det er ynglefugle og derfor mindre tilbøjelige til at flytte end rastende arter. Klyderne har i de seneste år op til digebygningen været i fremgang, og det er givetvis denne fremgang, der fortsat har fundet sted, og som afspejles i tallene. Klyderne har dog haft forringet yngleresultat efter bygningen af diget på grund af for tørre bundforhold (Gram 1981).

De øvrige arter Gravand, Gråand, Pibeand, Lille Kobbersneppe og Alm. Ryle er alle gået tilbage i den sydøstlige del af Listerdyb tidevandsområde.

Betragtes hele Listerdyb tidevandsområde samlet har Gravand, Gråand, Lille Kobbersneppe og Alm. Ryle hverken vist antalsmæssige eller procentvise tilbagegange. Deres fordeling er imidlertid blevet ændret, således at de nu opholder sig i den nordlige og vestlige del. Betragtes hele det danske Vadehavsområde, kan tilbagegangen for Pibeand ikke længere spores.

Undersøgelser af vadefuglenes tidevandstræk (Fig. 15) viser, at Strandskaderne i 1980 trak ca. 1 time senere til rastepladserne bag diget end tidligere. Rødben, Strandhjejle og Alm. Ryle forlod derimod fourageringspladserne 2½ til 3 timer tidligere i 1980 end tidligere.

Strandskaderne har foran diget egnede rastepladser nær fourageringsområdet på den ydre sandblandede vade. Ved stigende vand går de foran vandlinjen, stadig fouragerende, ind til rastepladserne. Tidligere fløj de fra fourageringsområderne til rastepladserne, da de ved at gå foran vandlinjen ville passere uegnede slikholdige vader.

Rødben, Strandhjejle og Alm. Ryle fouragerer nu på en vade, der ligger lavere, og som derfor bliver tidligere dækket af vand ved flod, og som også bliver blottet senere. Dette, sammen med at disse arter nu raster længere væk, ved Rodenäs, bevirker, at de flyver direkte til rastepladsen fra vadefladen, når denne overskylles af tidevandet. Tidligere gik disse arter ved stigende vand fouragerende til rastepladserne. Herved kom de ind til en højereliggende og mere slikholdig vade, som var velegnet til fouragering. Diget med dets nye forland og kogen bag det ligger nu på denne bløde slikvade.

Beregninger viser, at til trods for, at det inddigede område samt diget med forland kun udgør 10% af vadefladen, dækker det over 75% af føden i området, da det ligger på den mest produktive del af vadefladen. Dette stemmer ganske godt overens med, at ænderne er gået 60% tilbage i området og vadefuglene tilsvarende er reduceret med 80%.

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