Seriously Declining Trends in Migratory Waterbirds

Causes – Concerns – Consequence

Proceedings of the
International Workshop on
31 August 2006 in
Wilhelmshaven, Germany

Wadden Sea National Park of Lower Saxony
Common Wadden Sea Secretariat
Institute of Avian Research

WADDEN SEA ECOSYSTEM No. 23 – 2007

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Contents

Foreword

Huge flocks of migratory water birds are an impressive spectacle of the Wadden Sea's nature. The very high international responsibility for the conservation of migrating birds was one of the key arguments to build up a high conservation standard of this unique ecosystem throughout the three countries belonging to the Wadden Sea proper.

For more than 25 years the Trilateral Wadden Sea Cooperation has been a very successful example of international cooperation in European nature conservation.

Birds have played an important role in the Wadden Sea Cooperation since the very beginning. Furthermore, the trilateral bird monitoring work has provided an important scientific input in the trilateral conservation strategy and policy and, vice versa, strengthening the intensity and quality of bird counts in the Wadden Sea area and beyond, where they have been implemented already for decades.

Due to the trilateral harmonized counting and analysing programmes, we are now able to give a qualified assessment of the bird's population status. In the first years of the trilateral monitoring and assessment program (TMAP), the high nature conservation standard was reflected in relatively "satisfying" population trends indicating success in trilateral conservation work.

However, in recent years negative results indicate a change in the conservation status of several migrating species, and a different pattern of trend figures between the regions has been documented throughout the Wadden Sea.

What could be the main reasons for these changed patterns? Are the published trends up-to-date or fine-tuned enough? How do we have to deal with diverting results in the different parts of the Wadden Sea? Which scientific cooperation is needed to analyze and understand trends of migratory water birds in the Wadden Sea?

Climate change, economic pressure in high Arctic or African habitats, disturbance of water birds in the Wadden Sea staging sites, or insufficient amount of food in the Wadden Sea itself are main objectives on the agenda trying to explain these trends.

But, combining available scientific studies on these topics with the conservation issues and needs here in the Wadden Sea, to assess conservation options, is a challenge, and needs global thinking and local acting.

Discussing this in a scientific framework was the aim of a workshop organized by the National Park Administration of Lower Saxony, the Institute of Avian Research, and the Common Wadden Sea Secretariat in Wilhelmshaven on 31 August 2006.

The Wadden Sea National Park in Lower Saxony had its 20th anniversary in 2006. Bringing conservation, science and politics together was an important aim of this anniversary event.

I would like to thank all speakers, participants, and organizers of the workshop, which was very inspiring and brought a lot of input into scientific, monitoring and conservation work for the future. The trilateral bird monitoring has proved to present reliable up-to-date trends of bird numbers throughout the Wadden Sea, another "fruit" of successful trilateral Wadden Sea work.

These proceedings document all talks and publish the "Wilhelmshaven Declaration" with the main results. Hopefully, this is another important step towards further improvement of nature conservation work in the Wadden Sea – to fulfil the needs of the migratory birds today and in the future.

Peter Südbeck

National Park Lower Saxon Wadden Sea

Barnacle Geese foraging in Ballum Enge, Denmark (Photo: John Frikke)

Trends of Waterbird Populations in the International Wadden Sea 1987-2004: An Update

Jan Blew, Klaus Günther, Karsten Laursen, Marc van Roomen, Peter Südbeck, Kai Eskildsen and Petra Potel, Joint Monitoring Group of Migratory Birds in the Wadden Sea (JMMB)

1. Acknowledgements

This report would not have been possible without the help of a large number of people. First of all we want to mention the immense effort by the hundreds of ornithologists who participated in the waterbird counts in the Wadden Sea in the past decades. Many of them are volunteers and without their qualified help, production of a report like this would have been impossible. We hope that this report encourages all observers to keep on with their valuable census work!

Furthermore, we would like to thank all people who participated in the production of this report. Help during various stages of data processing and writing and draft-reading was received from Bettina Reineking (CWSS, Germany).

Erik van Winden (SOVON, The Netherlands) carried out the UINDEX and TrendSpotter calculations. Leo Soldaat (Central Bureau of Statistics, The Netherlands) helped along the way whenever questions arose with the programs TRIM, TrendSpotter or related statistical problems.

Financial support to analyse the data for this report was received from the Nationalpark Niedersächsisches Wattenmeer (Wilhelmshaven, Germany) and the Common Wadden Sea Secretariat (Wilhelmshaven, Germany).

The Common Wadden Sea Secretariat (CWSS) provided the necessary framework for the JMMB group. We would especially like to thank Bettina Reineking, secretary of the group, for her support during all stages of this report.

More information about the organisation of the counts as well as the regional coordinators in the four regions can be found in Blew *et al.*, (2005).

2. Introduction

The Wadden Sea constitutes one of the world's most important wetlands for migratory waterbirds. It is the single most important staging and moulting area and an important wintering area for waterbirds on the East Atlantic Flyway from the Arctic to South Africa. The Joint Monitoring of Migratory Birds (JMMB) program is carried out in

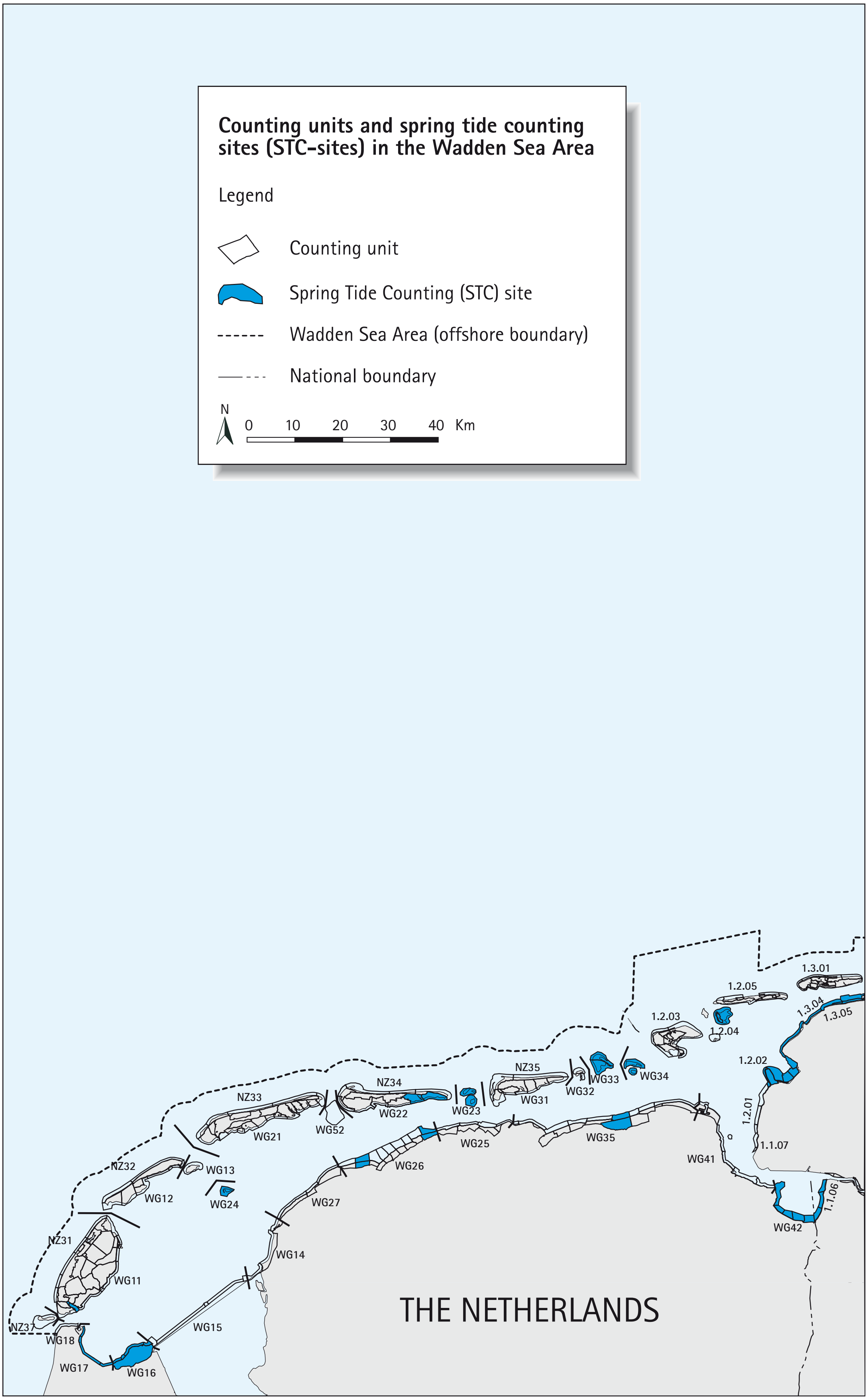
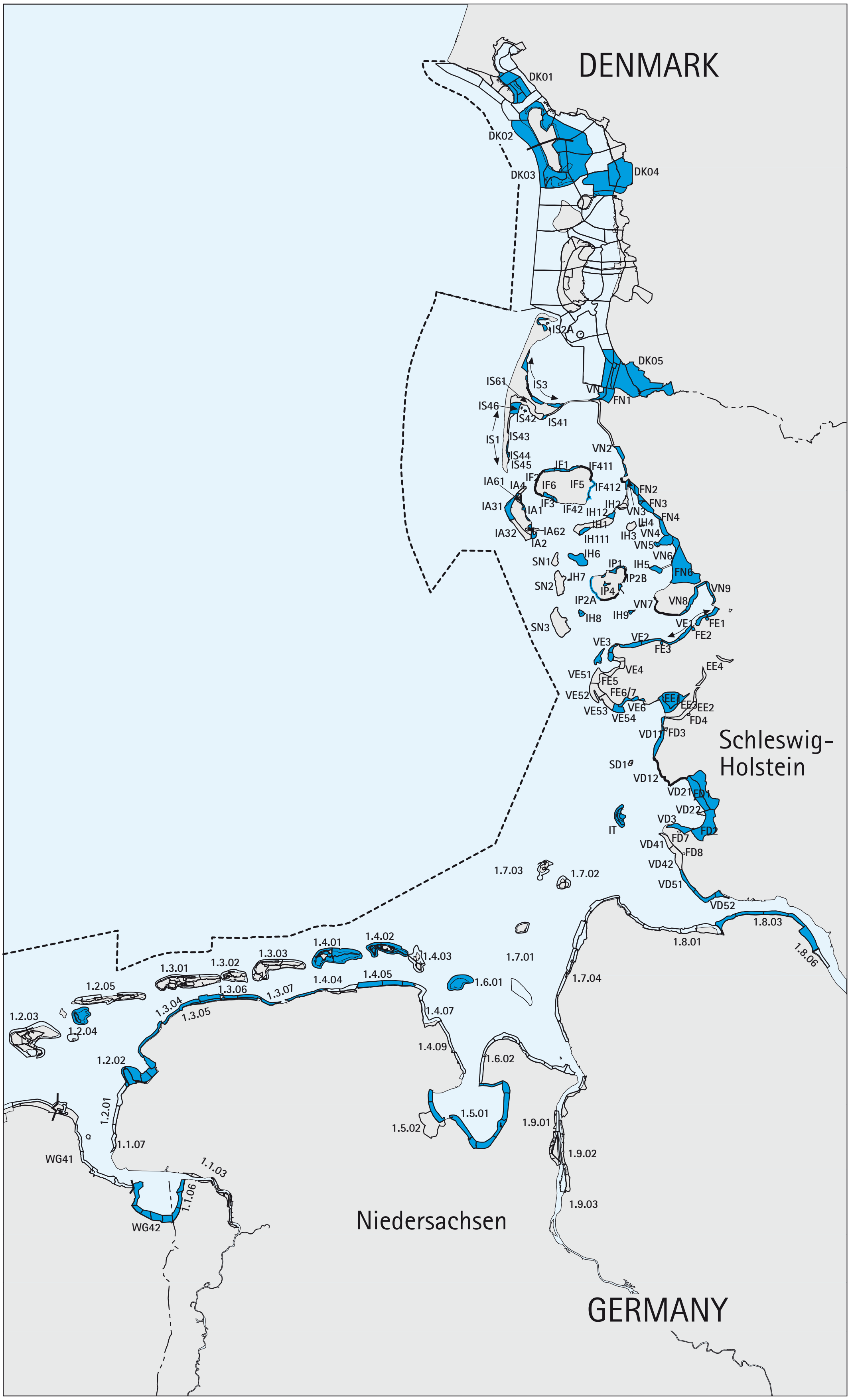


Figure 1: The Wadden Sea Cooperation Area, including delimitations of all counting units and spring tide counting sites (from: Blew *et al.* 2005)


DENMARK
Schleswig-Holstein
Niedersachsen
GERMANY

the framework of the Trilateral Monitoring and Assessment Program (TMAP), and constitutes a very ambitious internationally coordinated long-term monitoring program. It covers a large eco-region stretching from Den Helder in The Netherlands to Esbjerg in Denmark; regular ground counts for most species and areas plus aerial counts for others involves hundreds of volunteers. After Smit & Wolf (1981) provided a first overview on waterbird counting results, Meltofte *et al.*, (1994) compiled all data available for 1980-1991 and calculated maximum numbers and species distributions for the entire Wadden Sea; for the first time gap filling for missing counts was applied, thus providing estimates of the total waterbird numbers present in the Wadden Sea.

Two yearly reports followed, covering the seasons 1992/1993 (Rösner *et al.*, 1994) and 1993/1994 (Poot *et al.*, 1996). In the most recent report covering 1992-2000, for the first time trends were calculated for all relevant species for the entire Wadden Sea, accounting for missing counts within the calculations (Blew *et al.*, 2005). Those trend analyses for the period 1992-2000 have profited a great deal from a considerable improvement in amount and quality of migratory waterbird data as well as from the application of trend calculation software specifically tailored to the needs of time series data. Yet, the trends detected gave reason for concern: of the 34 species, for which the Wadden Sea represents a major staging and wintering area, 15 species (44%) showed significant decreases. In contrast, only three species (Cormorant *Phalacrocorax carbo sinensis*, Spoonbill *Platalea leucorodia* and Barnacle Goose *Branta leucopsis*) showed significant increases (Blew *et al.*, 2005). These results raised considerable concerns about the status of migratory waterbirds in the International Wadden Sea. In consequence, and due to the improved data exchange and analyses capacities of the four Wadden Sea regions, it was agreed to compile an update to calculate trends for the short-term period 1993/1994 - 2003/2004 and the long-term period 1987/1988 - 2003/2004. In addition to the analyses of the International Wadden Sea trends, now also trends for the different Wadden Sea regions – The Netherlands (NL), the federal states of Germany, Niedersachsen (Nds) and Schleswig-Holstein (SH), and Denmark (DK) – were calculated. While comparisons between trend calculation methods have been carried out, the trends presented here are calculated using UINDEX and TrendSpotter.

The scope of this report is to present trends of 34 waterbird species for the International Wadden Sea and the four regions - The Netherlands, the federal states of Germany, Niedersachsen and Schleswig-Holstein, and Denmark.

3. Material and methods

3.1 Counting program, site and species selection

Details of the "Joint Monitoring program of Migratory Birds in the Wadden Sea" are given in Blew *et al.* (2005). This program, consisting of international synchronous counts, spring-tide counts and aerial counts (only Common Shelduck and Common Eider), has been carried out by all Wadden Sea countries since 1992. Some differences between the countries' programs exist, due to different national approaches and older already existing counting programs, but these do not hamper the overall goal for calculating trends. Because many usable counting data before 1992 exist as well, it has been decided to include counts back to the season 1987/1988 in these analyses.

The area considered is the Wadden Sea Cooperation Area (Figure 1). This is, in general terms, the area seaward of the main dike (or, where the main dike is absent, the spring-high-tide-water line, and in the rivers, the brackish-water limit) up to 3 nautical miles from the baseline or the offshore boundaries of the Conservation Area (Essink *et al.*, 2005), some exceptions apply in the different regions (Blew *et al.*, 2005). The total area covers some 14,700 km², with 4,534 km² of tidal flats. A total of 559 different counting units exist in the Wadden Sea, where birds concentrate on high-tide roosts. Each country selected a set of spring tide counting sites, each consisting of 1 to 12 counting units, in which counts are carried out very frequently, preferably during every high tide - that is 24-25 counts a year. For this report, the original data, available at the smallest level have been used.

Thirty-four waterbird species are covered in this report. These are species which use the Wadden Sea as a staging, roosting or wintering area during one part of their yearly cycle with their entire flyway population or large parts of their flyway population. Species which only occur in low numbers or species which cannot be counted with sufficient representativeness have been excluded from the analyses (for a more detailed explanation see Rösner *et al.*, 1994).

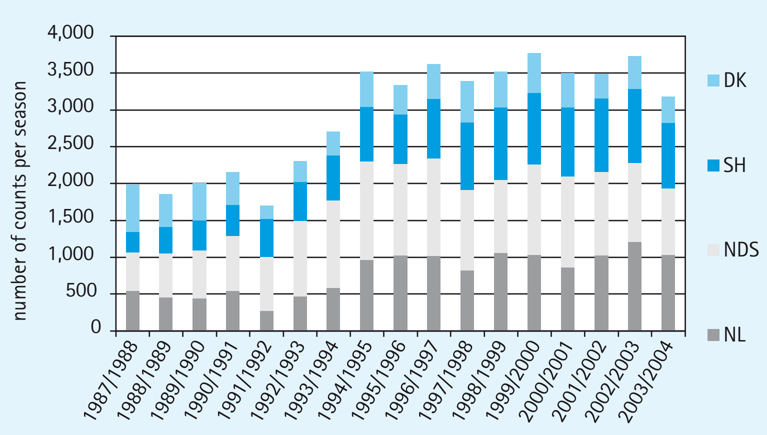


Figure 2: Number of counts per season

3.2 Counting effort

Counting effort is defined here using the parameter "counted counting units per time-unit". A total of almost 50,000 counts has been used for this analysis (Figure 2). It becomes clear that the counting effort has considerably improved beginning in the season 1992/1993. The slightly lower number of counts during the last season 2003/2004 may be due to the fact that some count results were not available at the time of data compilation. Counting effort is a first approach to describe the coverage of an area; however, several "unimportant" counting units might host only a few numbers of birds, thus a low counting effort may not reduce data quality, whereas the missing of one very important counting unit with many birds may have more serious implications. A counting coverage parameter stating the number or proportion of birds covered would be more appropriate, but this is currently not available.

3.3 Trend analysis

UINDEX (Bell, 1995) was used to account for missing values in the dataset. TrendSpotter was then applied to the complete dataset to calculate trends (Visser, 2004). The program UINDEX is able to take site- and month-factors and thus the phenology into account to impute missing values and to calculate index values; however, it does not give statistical parameters, above all no confidence limits for the modelled values (Underhill & Prys-Jones, 1994). Sites are grouped in four regional strata representing the four different "countries". The imputed monthly counts are added to yearly estimates for the respective "bird-years", covering the period from July to June of the following year.

The program TrendSpotter calculates so-called "flexible trends", particularly suitable for time series data with different periods of decreasing, stable or increasing trends, a common feature of migratory bird data (Visser 2004). A trend line calculated by TrendSpotter gives an intuitively accurate description of the population development. This trend line hardly deviates from a moving average or a smoothed trend line as calculated by a Generalized Additive Model (GAM). A useful characteristic of the TrendSpotter analysis is the calculation of confidence intervals for the differences between the trend level of the last year and each of the preceding years which is unique for flexible trend methods. This way trend estimates can be given for any recent period, as for example the last 10 and the last 17 years in the current analyses (Soldaat *et al.*, in prep.).

Since in former analyses a combination of TRIM and linear regression had been used to calculate trends (for details see Blew *et al.*, 2005), these calculations have been applied to the same dataset as well to be able to compare results between methods.

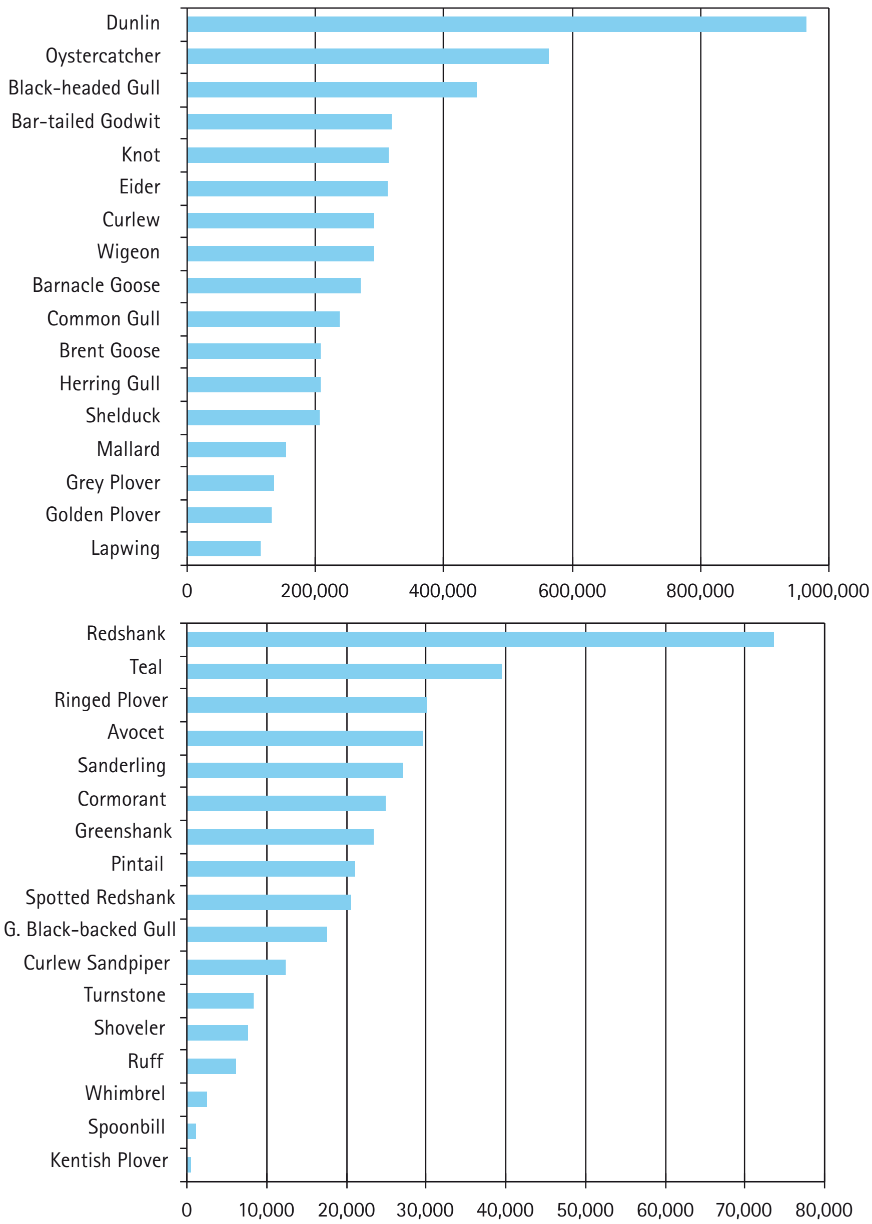
4. Results

4.1 Maximum estimates and proportions of flyway populations

Waterbird numbers in the Wadden Sea reach their maximum during the autumn and spring; lower numbers are present during the winter. The majority of those are migratory waterbird species breeding in the arctic, subarctic and boreal northern regions and wintering sometimes as far south as Africa. Of those, the Dunlin is the most numerous, reaching estimates of almost 1 million individuals in autumn during the last 10 years. It is followed by the Oystercatcher with some 550,000 birds and the Black-headed Gull with still some 450,000 birds (Figure 3).

Nine of 34 species utilize the Wadden Sea with more than 50% of their total population at some time in the yearly cycle; of these, the Brent Goose is present in the Wadden Sea with almost all birds of its population, as are some 70% of the species Barnacle Goose, Dunlin, Red Knot, Eurasian Curlew and Common Shelduck; still, Bar-tailed Godwit, Oystercatcher and Grey Plover are present with more than 50% of their flyway populations in the Wadden Sea. For an additional 14 species

Figure 3: Maximum estimates of 34 species in the International Wadden Sea (per species the average of the three maximum estimates between 1994/1995-2003/2004 is given). Scale on x-axis is different in both diagrams, with the high numbers in the upper, the low numbers in the lower figure.



between 10% and 50% of their flyway population are present. Of the remaining 11 species, all but Kentish Plover and Ruff fulfil the 1% criterion of international importance after Ramsar (Figure 4) (Wetlands International 2002).

4.2 Trends for the 10- and 17-year periods

The trends of the last 10 years in the Wadden Sea highlight recent developments in the Wadden Sea and also cover a period of excellent counting effort (see Figure 2). The trends of the 17-year period add information on long-term population development in the Wadden Sea. Trends for both periods may differ for some species; also, trends of the entire Wadden Sea differ for some species from those of the individual regions. For both the 10- and the 17-year period, 12 species are decreasing in the International Wadden Sea; however, this applies in part for different species. During the 10-year period, only six species were increasing, while for the 17-year period, eight species were increasing and further 11 species showed a stable pattern (Tables 1 and 2, Figures 5 and 6). A short description of these developments in the Wadden Sea and the four regions follows.

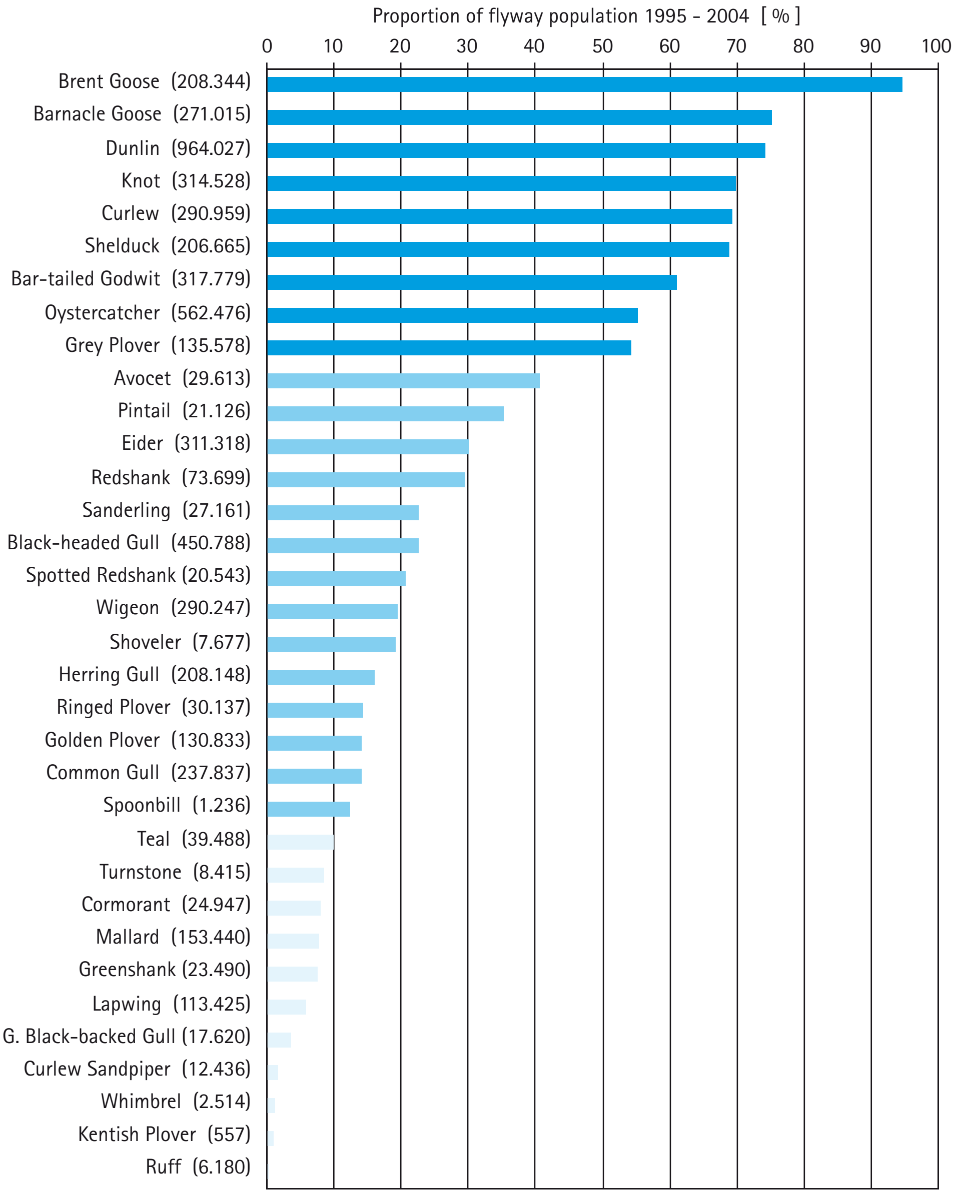


Figure 4: Proportions of flyway populations present in the Wadden Sea (numbers as in Figure 3), (flyway population estimates from Wetlands International 2002).

Table 1:
Trend categories for the 10- and 17-year periods for the International Wadden Sea and the four countries, calculated with TrendSpotter on yearly estimates, ranked after trend category and value: ++ strong increase; + moderate increase; 0 stable; - moderate decrease; -- strong decrease; F - uncertain.
(* Common Eider in italics, because results are from aerial counts only).

	Short-term 10-year trend 1995/1996 - 2003/2004					Long-term 17-year trend 1987/1988 - 2003/2004				
Species	**WS**	**DK**	**SH**	**NDS**	**NL**	**WS**	**DK**	**SH**	**NDS**	**NL**
Eurasian Spoonbill	**++**	++	++	++	++	**++**	++	++	++	++
Great Cormorant	**++**	+	++	++	++	**++**	++	++	++	++
Northern Pintail	**+**	F	0	+	+	**F**	F	0	F	+
Great Ringed Plover	**+**	++	+	+	+	**+**	+	+	0	+
Sanderling	**+**	+	F	0	++	**++**	+	++	0	++
Bar-tailed Godwit	**+**	F	-	0	+	**+**	-	-	0	+
Northern Shoveler	**0**	+	0	+	0	**0**	+	+	0	0
Common Shelduck	**0**	0	-	0	+	**-**	0	-	-	0
Barnacle Goose	**0**	F	0	0	+	**++**	++	+	+	+
Common Greenshank	**0**	+	-	0	F	**+**	+	-	0	+
Northern Lapwing	**0**	F	0	0	F	**0**	F	0	0	F
Eurasian Curlew	**0**	++	-	-	+	**0**	++	-	-	+
Common Gull	**0**	0	0	F	0	**0**	0	0	0	+
Dunlin	**0**	0	-	0	+	**0**	0	-	0	+
Black-headed Gull	**0**	0	-	0	0	**0**	0	-	0	0
Grey Plover	**0**	+	-	0	0	**+**	+	+	0	+
Whimbrel	**0**	F	F	-	F	**-**	F	F	--	++
Spotted Redshank	**0**	+	-	0	-	**0**	F	0	0	-
Common Redshank	**-**	++	-	-	0	**0**	+	0	-	+
Mallard	**-**	F	0	0	0	**-**	-	-	-	0
European Golden Plover	**-**	F	-	0	0	**-**	F	-	-	+
European Herring Gull	**-**	F	-	-	-	**-**	0	-	-	-
Eurasian Oystercatcher	**-**	0	-	-	-	**-**	+	-	-	-
Pied Avocet	**-**	-	-	0	-	**-**	-	-	0	-
Brent Goose	**-**	-	-	0	-	**-**	-	-	0	0
Great Black-backed Gull	**-**	F	-	-	F	**0**	0	0	-	0
Eurasian Wigeon	**-**	0	-	-	F	**0**	0	0	0	0
*Common Eider**	*-*	*F*	*-*	*F*	*F*	*-*	*F*	*-*	*F*	*F*
Red Knot	**-**	F	-	-	-	**-**	F	-	-	0
Ruff	**-**	F	-	F	0	**-**	--	-	F	0
Curlew Sandpiper	**F**	++	F	F	F	**F**	F	F	-	F
Common Teal	**F**	+	0	F	F	**F**	F	0	-	0
Ruddy Turnstone	**F**	++	0	F	0	**0**	++	0	F	0
Kentish Plover	**F**	+	0	F	F	**-**	F	0	--	F

Table 2:
Summary of trend categories for the 10- and 17-year periods in Table 1.

	Short-term 10-year trend 1995/1996 - 2003/2004					Long-term 17-year trend 1987/1988 - 2003/2004				
Trend category	**WS**	**DK**	**SH**	**NDS**	**NL**	**WS**	**DK**	**SH**	**NDS**	**NL**
Increase	**6**	14	3	5	10	**8**	12	7	3	15
Stable	**12**	6	9	14d	9	**11**	7	10	14	11
Decrease	**12**	2	19	8	6	**12**	5	15	13	4
Fluctuating / uncertain	**4**	12	3	7	9	**3**	10	2	4	4

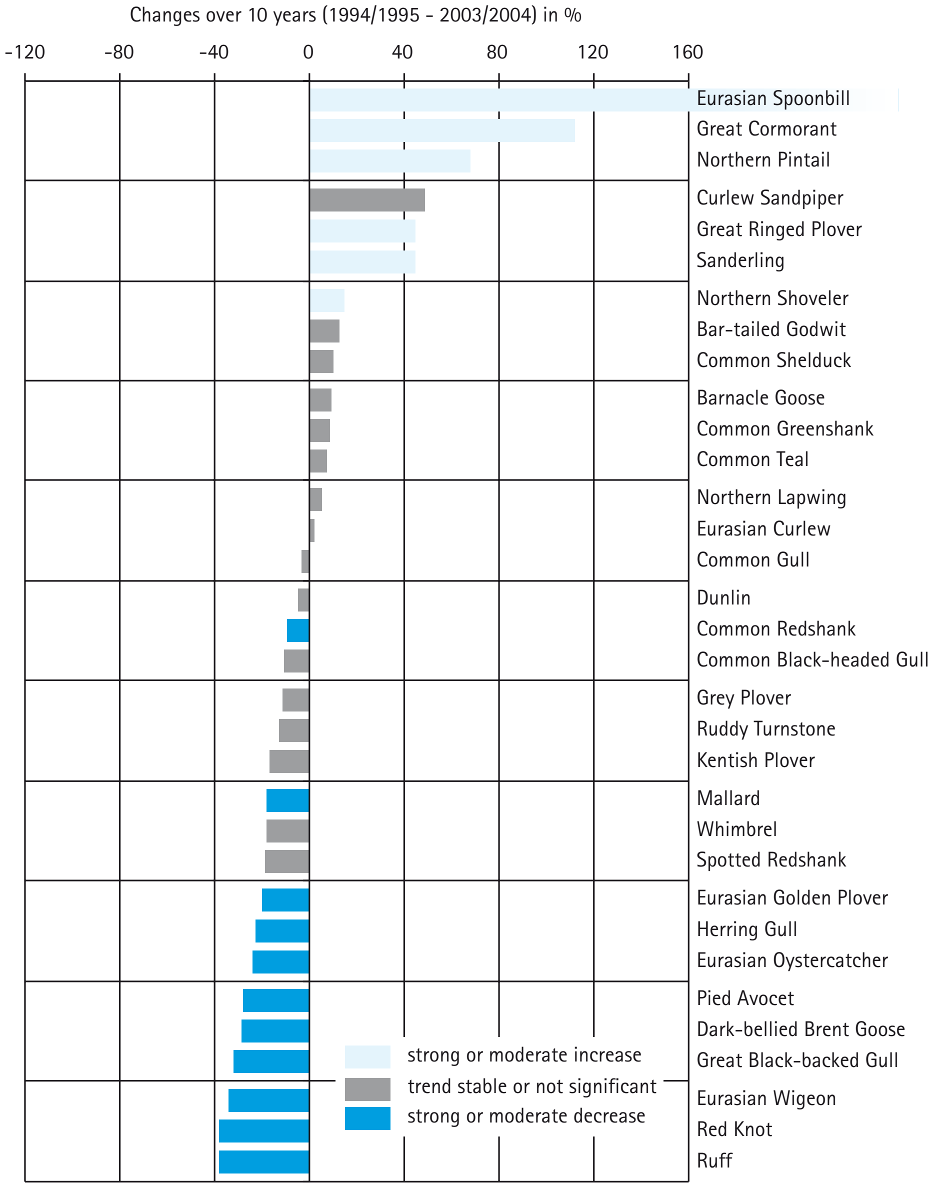


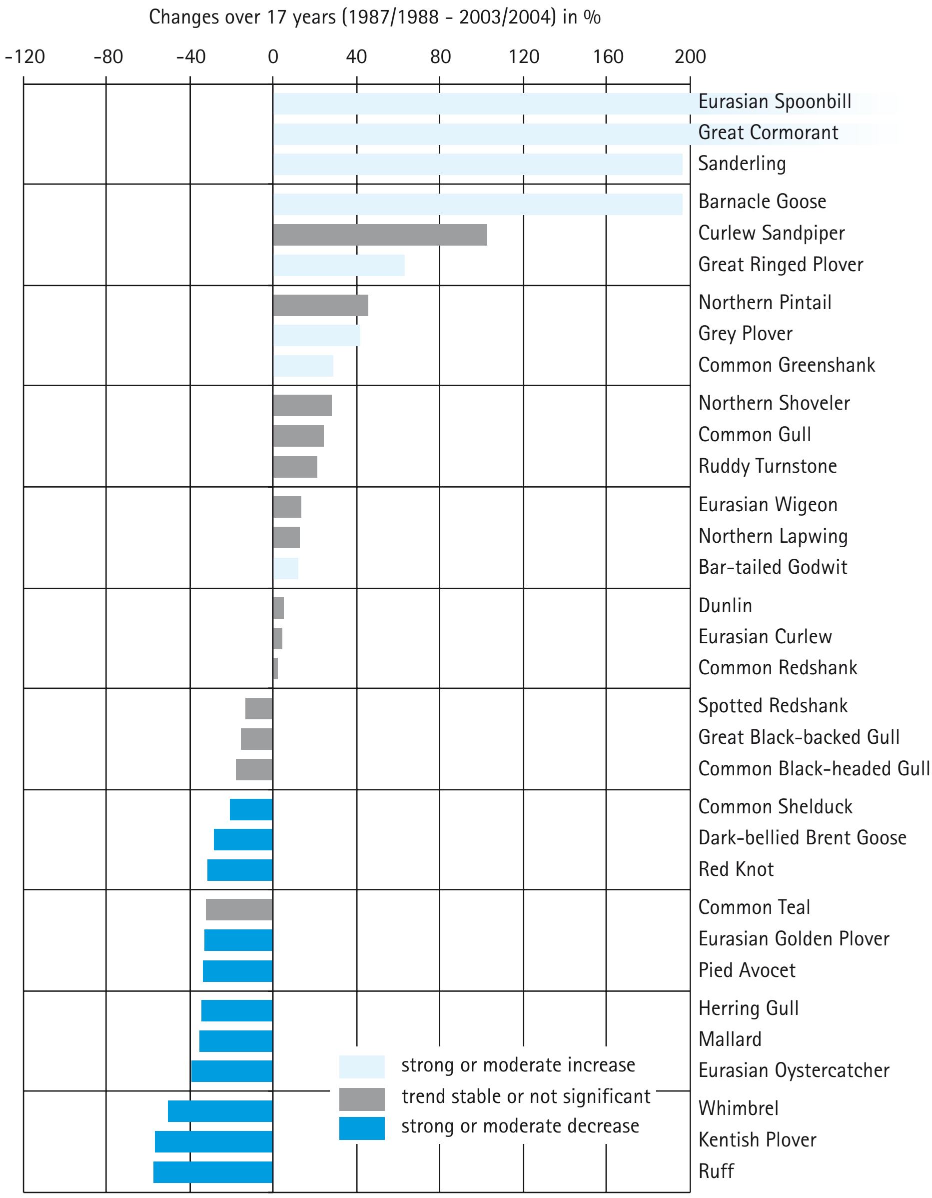
Figure 5: Trends calculated for the period 1994/1995–2003/2004 for the International Wadden Sea expressed as percentage change over the 17-year period, calculated with TrendSpotter on yearly estimates, ranked after trend value.

Increasing species

Five species show an increase for both the short- and long-term periods, respectively. Of these, the Cormorant has increased its flyway population; the Spoonbill – however with relatively small numbers - has enlarged its population size as well but also the distribution range of the breeding population, with many individuals spending the post-breeding period in northern parts of the Wadden Sea. The trends for Sanderling and Great Ringed Plover are increasing; for at least some parts of the Wadden Sea – *e.g.* Schleswig-Holstein – these increases might be affected by an improved counting effort in sandy habitats especially during the last ten years (see Blew *et al.*, 2005). The Bar-tailed Godwit also shows an increase during both periods, however, this appears exclusively in The Netherlands while it is decreasing in Schleswig-Holstein.

The trends of Barnacle Goose, Grey Plover and Common Greenshank were more or less stable during the last 10 years; their long-term increase over the 17-year period had occurred in the first half of that period. Of these, the Barnacle Goose flyway population has considerably increased during recent decades, maybe levelling off in recent years; the Greenshank shows increases in both periods in Denmark, but also decreases in Schleswig-Holstein. The overall increase of the Northern Pintail during the recent 10 years seems

Figure 6: Trends calculated for the period 1987/1988–2003/2004 for the International Wadden Sea expressed as percentage change over the 17-year period, calculated with TrendSpotter on yearly estimates, ranked after trend category and value.



to be occurring mainly in The Netherlands; it could be related to a re-distribution within NW-Europe, with fewer Pintails wintering in the UK and more on the Continent (Banks *et al.*, 2006).

Decreasing species

Of the nine species showing negative trends during both periods, both Brent Goose and Mallard show flyway population decreases (Wetlands International 2002); Eider, Oystercatcher, Knot and Herring Gull have in common that they are shellfish eating species, raising concern with regard to the status of their food source. For the Avocet, a decrease in both periods in all regions of the Wadden Sea with the exception of Niedersachsen is calculated. However, for this species, where in the Wadden Sea the breeding population is almost the same as the non-breeding population, the decrease does not appear in the breeding population (Koffijberg *et al.*, 2006); thus, this decrease might represent a decrease in the post-breeding period of this species, representing a lower proportion of moulting birds. The decreases of Golden Plover and Ruff appear in both periods in Schleswig-Holstein only; at least for the Golden Plover, an increase is registered for the long-term period in The Netherlands.

Wigeon, Common Redshank and Great Black-backed Gull decreased during the last 10 years, but were all stable in the 17-year period; of these,

	Short-term 10-year trend 1995/1996 - 2003/2004		Long-term 17-year trend 1987/1988 - 2003/2004	
Country	positive	negative	positive	negative
DK	10		7	1
SH		9	2	5
NDS	5	4	2	7
NL	8	1	11	1

Table 3: Deviations of the country trends from International Wadden Sea trends for the 10- and 17-year periods; deviations only given if both compared trend indications are different from "uncertain / fluctuating".

Wigeon and Great Black-backed Gull have seen an increase up to the mid-1990s, but have declined from those high numbers afterwards.

Both Kentish Plover and Whimbrel decreased over the long-term period, but show uncertain and stable trend estimates for the past 10 years. Both species, however, nowadays appear in low numbers and trends are hard to judge.

The Common Shelduck shows – according to land-based counts - a stable development during the past 10 years; the long-term trend is a decrease, which occurred mainly in the late 1980s (see also Meltofte *et al.*, 1994). In contrast, the numbers of Shelducks moulting in the Schleswig-Holstein part of the Wadden Sea, derived from aerial counts in July and August, show an increase up to the early 1990s and a more or less continuous decrease from then on; in turn, an increase in moulting Shelducks appears in the Dutch Wadden Sea, probably explaining the negative trend in Schleswig-Holstein (Kraan *et al.*, 2006).

Stable species

Seven species were stable in the 10- and 17-year periods. Of those, Curlew, Lapwing, Common and Black-headed Gull and Dunlin occur in the Wadden Sea in high numbers and with high proportions of their flyway populations, whereas the Shoveler and the Spotted Redshank are less numerous.

Country comparisons

Besides analyzing trends for the entire Wadden Sea, trends for the four countries have been calculated. Many country trends deviate from the Wadden Sea trends (Table 3). Denmark and The Netherlands have almost only positive deviations from the Wadden Sea trends, whereas most decreases occured in Schleswig-Holstein and Niedersachsen, where some species occur in very high numbers; thus, these trends may dominate the Wadden Sea trends. For the 10-year trends, four of the species decreasing in the Wadden Sea were stable in The Netherlands, whereas four of the species with stable trends in the Wadden Sea even increased in The Netherlands; in three of those latter cases, trends were decreasing in Schleswig-Holstein, leading to the overall stable situation. Denmark shows only positive deviations, most remarkably a strong increase of the Redshank, decreasing overall.

Of the 11 species decreasing in the Wadden Sea during the 17-year period, eight did not decrease in The Netherlands, and seven did not in Denmark. On the contrary, of the eight long-term increasing species in the Wadden Sea, only four were "stable" in Niedersachsen. In Niedersachsen, only three species showed an increase.

5. Discussion

This report represents an update on trend calculations compared to the report given by Blew *et al.*, (2005). Since then changes and modifications with regard to the analysis period and methods have taken place which shall be discussed in short.

In the previous report (Blew *et al.*, 2005), trends of 34 waterbird species in the International Wadden Sea had been calculated for the period 1992-2000, marking an advance in methodology and providing for the first time an assessment of those trends. In addition, the international synchronous mid-winter counts in January had been used to calculate mid-winter trends between 1980-2000. For this updated analysis presented here, the analysis periods have been expanded. More recent data up to 2003/2004 were included, and, since data quality and counting effort appeared to be good back to the late 1980s, data since 1987/1988 were also used for the analyses.

To analyze and assess population trends, different time periods may be looked at, preferably on a species specific level. Analysis periods should not be too short, since animal populations show yearly fluctuations. To follow up short-term and most recent population developments, trend calculation of the recent 5 to 10 years might be appropriate. In the United Kingdom, short-term trend analyses are used to trigger national alerts if species declines are more than 25% or 50%, respectively (Austin *et al.*, 2003, Atkinson *et al.*, 2006). Trend calculations of longer periods help to understand and to describe long-term developments in an ecosystem like the International Wadden Sea. In general, a long-term trend covering 17 years and a short-term trend covering the most recent 10 years both represent appropriate time intervals for trend analyses. Species specific approaches may choose to look at patterns of populations' developments common for some species and point at potential causes.

The current analyses show, that 12 out of 34 species are decreasing, both for long- and short-term trend estimates. The previous report covering the period 1992-2000, however, resulted in 15 species showing significant decrease, and an additional 7 species showing non-significant decreases (Blew *et al.*, 2005). Thus, differences for the two analysis periods exist and shall be explained.

Differences according to the analyses periods

Some changes in trends occur mainly because the interval of the trend analyses has changed. For instance, Shelduck (land-based counts) increased during 1992-2000. Since high numbers occurred before that time period, the 17-year trend of this species is now slightly decreasing. For most species, however, the opposite is true. Trends of Dunlin, Grey Plover, Bar-tailed Godwit and others have been declining during 1992-2000, but show higher estimates especially during the most recent years, in many cases also before 1992. Thus, considering the longer time period, trends of those species are now stable or even positive (see Annex - Grey Plover). While it appears that, according to the updated analyses, less birds seem to be declining, it is clear that the actualization of the results and above all the availability of longer time series enables us to give more precise and correct assessments of the populations' developments in the Wadden Sea as well as to do more justice to short-term population fluctuations during the long-term periods.

Differences according to the trend analysis method

Effects of calculating additional and independent country trends

Within the JMMB and after consultation with further experts from other institutions it has been agreed that the update of trend estimates shall treat countries as independent covariates during the analyses. Thus, instead of using data from the entire Wadden Sea to impute missing counts, now missing counts in one country are imputed exclusively with data from the same country. Climate, weather and food resources may influence the occurrence of birds in different regions of the Wadden Sea during different seasons. Thus, taking these regional developments into account, and not treating the entire Wadden Sea population as a whole, does more justice to the data. Choosing country as a covariate is a compromise, since country data are easy to separate. In the future it will be attempted to define a low number of ecologically related regions in the Wadden Sea to use as covariates.

Consequences of this modification are that, first of all, trends for the entire Wadden Sea might be slightly different, avoiding that imputing across countries potentially conceals regional trend developments. Secondly and more importantly, trends and trend figures for each country provide more insight into regional developments and might help to look at potential underlying reasons. Deviations in country trends compared to the Wadden Sea trend (see Tables 1 to 3) point to the fact that numerous trends in The Netherlands and Denmark are more positive than in the other regions of the Wadden Sea, as already reported by van Roomen *et al.*, (2005); this applies *e.g.* to the wader species Dunlin, Eurasian Curlew, Common Redshank, Eurasian Golden Plover and Ruff.

Effects of using different imputing and trend calculation methods

The important and reassuring result is that both methods - that is UINDEX for imputing and TrendSpotter for trend calculation (country as covariate) compared to TRIM for imputing and linear regression to calculate overall trends (no covariate) - yield highly comparable results. Of 33 species trends, 29 trends are the same; for Eider, this comparison has not been carried out. For three species, the UINDEX/TrendSpotter approach yields significant positive trends, while TRIM/linear regression yields non-significant positive trends; for one species, the first method yields a stable trend, while the latter method results in a significant decrease. It is concluded that the differences between methods are small and still may be influenced by the inclusion or non-inclusion of country as a covariate.

Conclusions

The process of updating trends for waterbirds in the Wadden Sea has seen some important improvements over the last 5 years, as there are: data collection in the individual countries as well as data exchange between the countries follows trilateral agreements and has become almost a standard routine; trend calculation methods have been agreed and discussed with experts from inside and outside the Wadden Sea; it also has been demonstrated, that at least for the methods applied so far, differences in the results due to the calculation methods are small to negligible. In the future, longer analyzing periods will further improve meaningfulness of the results.

The JMMB herewith presents the most recent results and trends and thus fulfills the monitoring requirements on the trilateral level as well as on the level of the EU Birds Directive.

According to these updated results, the situation of the 34 migratory waterbird species in the International Wadden Sea is still of much concern. While less species are decreasing than reported in the recent appraisal (Blew *et al.*, 2005), negative trends for the mussel-eating species and regionally different trends need to be further assessed. Especially for some of the most numerous species, declines still exist in some regions of the Wadden Sea. It seems desirable to conduct a more detailed analysis on regional trends potentially linked to habitat quality and availability as well as to different management regimes in the different countries.

The development of bird populations using the Wadden Sea as their most important stepping stone or wintering habitat in the non-breeding periods represents an important indicator of the quality of this ecosystem and the sustainability of its use. For some species the breeding period seems to be the driving force for population development, as is already known for the Dark-bellied Brent Goose and probably some other species (see Zöckler, 2007, this volume). For most species, however, habitat quality as well as food quality and availability in the Wadden Sea will be critical for their survival and fitness. While relationships between bivalves, their exploitation by fisheries and bird numbers have been demonstrated for the Red Knot (Gils *et al.*, 2006, Piersma, 2007, this volume), as well as Oystercatcher and Common Eider (Ens *et al.*, 2004), the effects, for example on Oystercatcher and Herring Gull, still need to be investigated, *e.g.* with regard to different management regimes in the Wadden Sea regions. The issue of climate change and the magnitude of potential changes may well influence habitat and food availability in the Wadden Sea (Bairlein & Exo, 2007, this volume). And lastly, disturbance both within the Wadden Sea or within other stepping stones of the East Atlantic Flyway has the potential to influence fitness of the waterbird species (*e.g.* Madsen, 2007, this volume). It will be the task of the research and protection institutions in the three countries to investigate the causal relationships and provide measures within regions or the entire International Wadden Sea.

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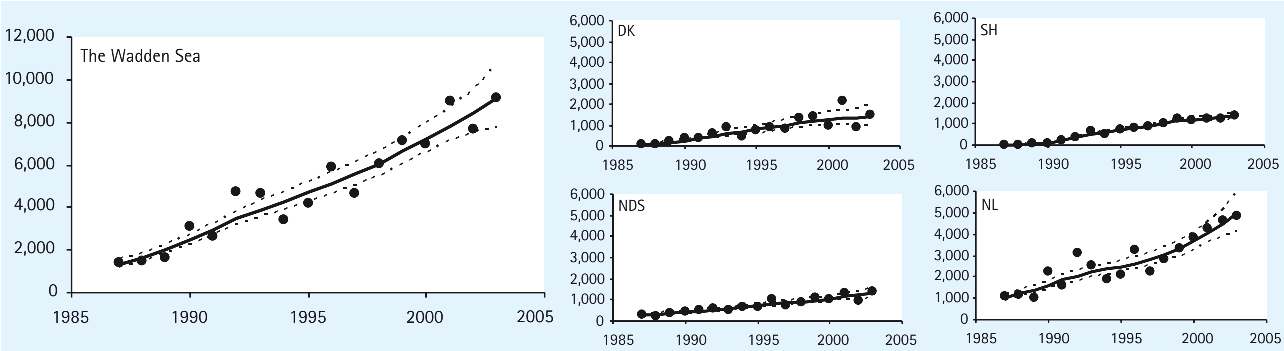
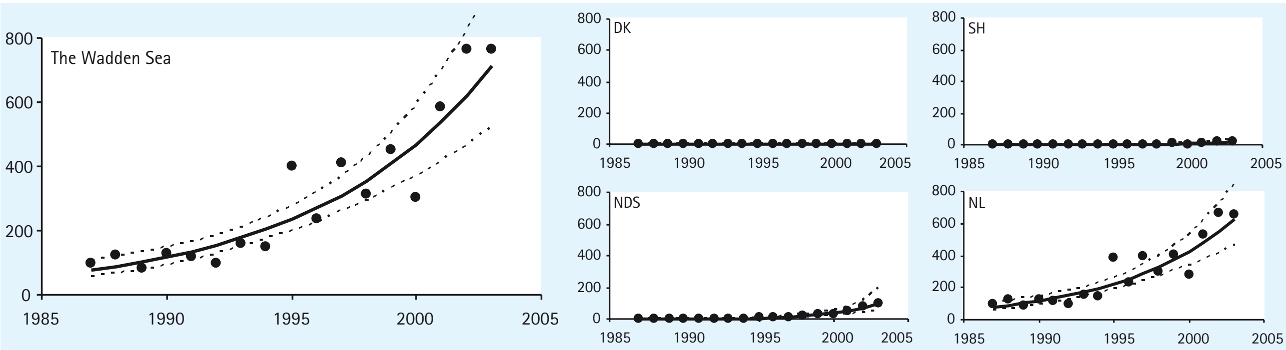
ANNEX – Trend figures of waterbird populations

Trends for the entire Wadden Sea, and for the 4 countries. Dots represent the individual estimates (monthly average numbers), solid lines the trend calculated by TrendSpotter, dotted lines the 95% confidence limits of the trend lines.

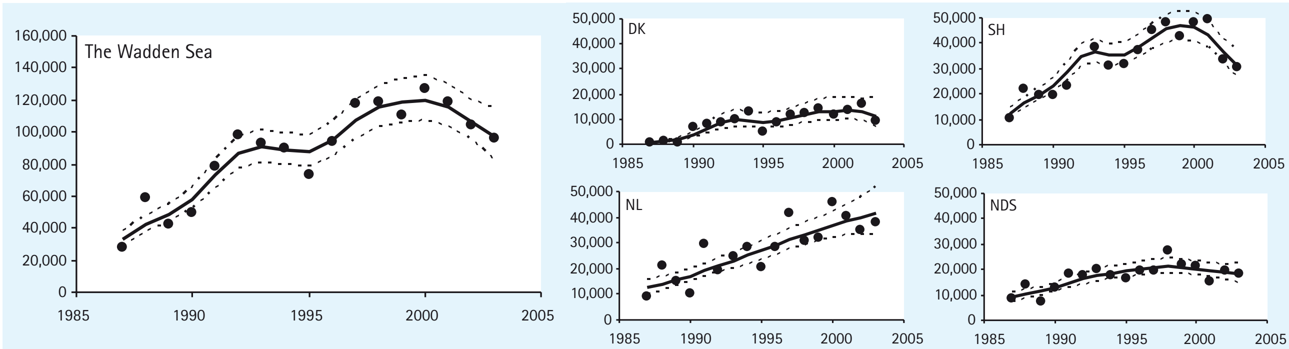
Great Cormorant



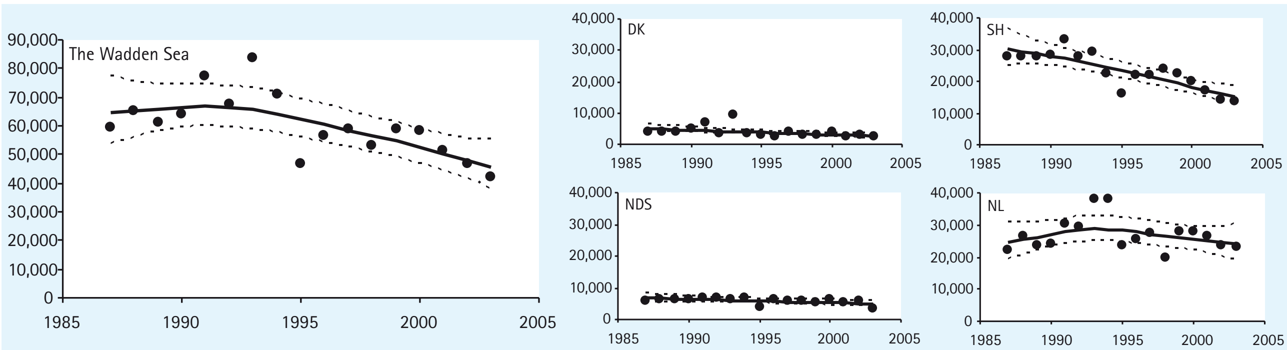
Eurasian Spoonbill



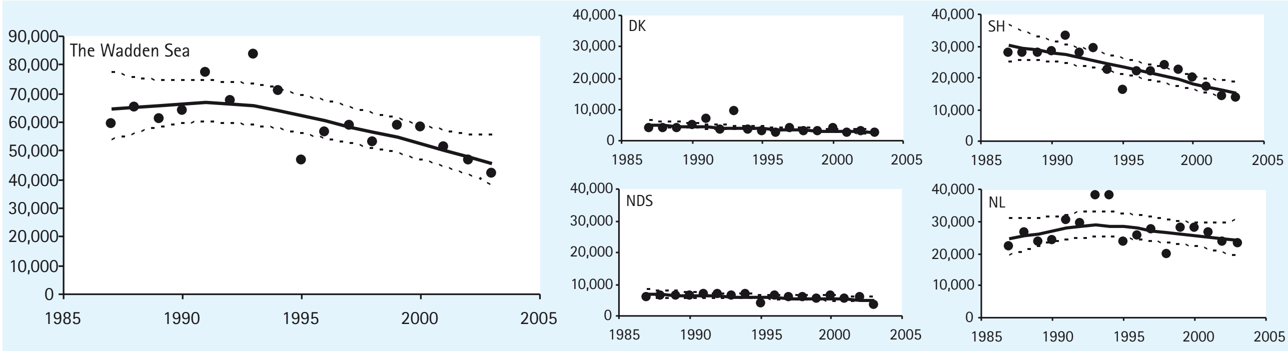
Barnacle Goose



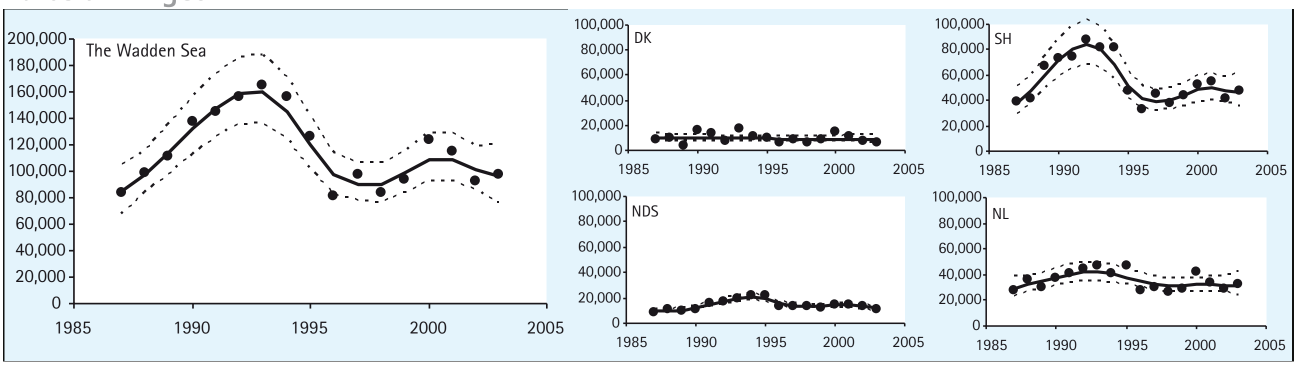
Brent Goose



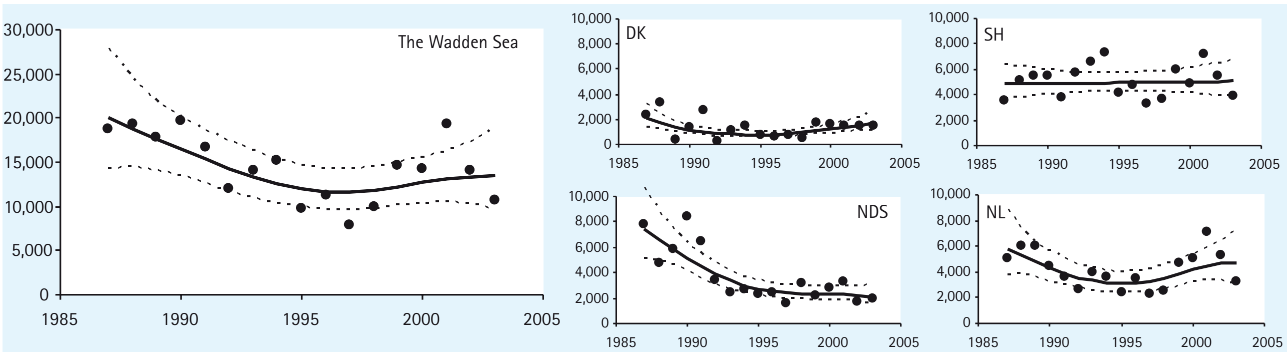
Common Shelduck



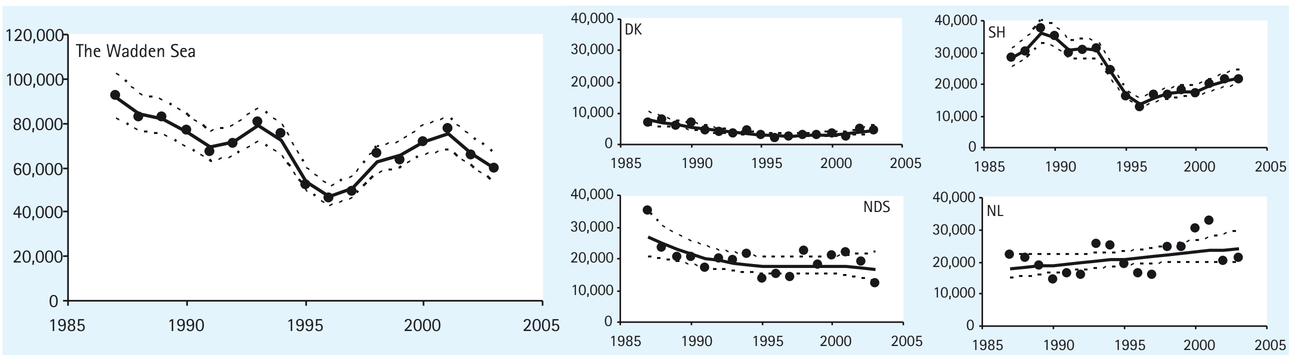
Eurasian Wigeon



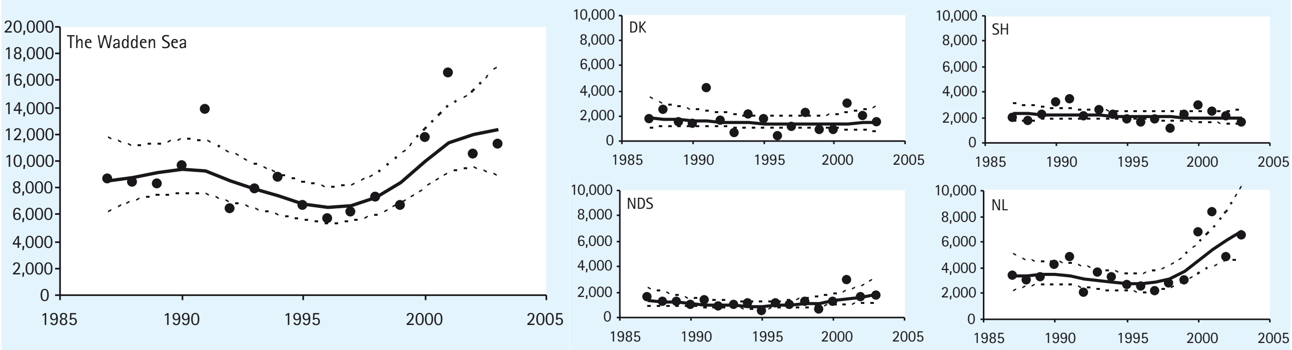
Common Teal



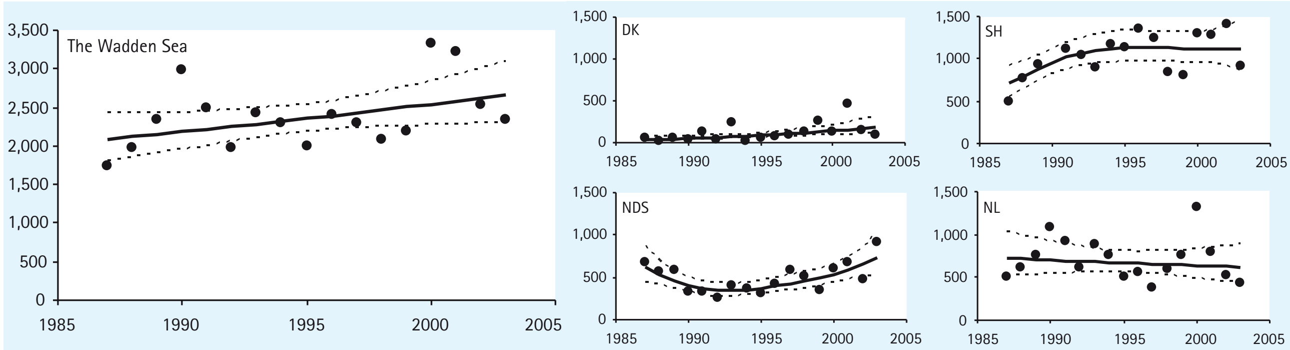
Mallard



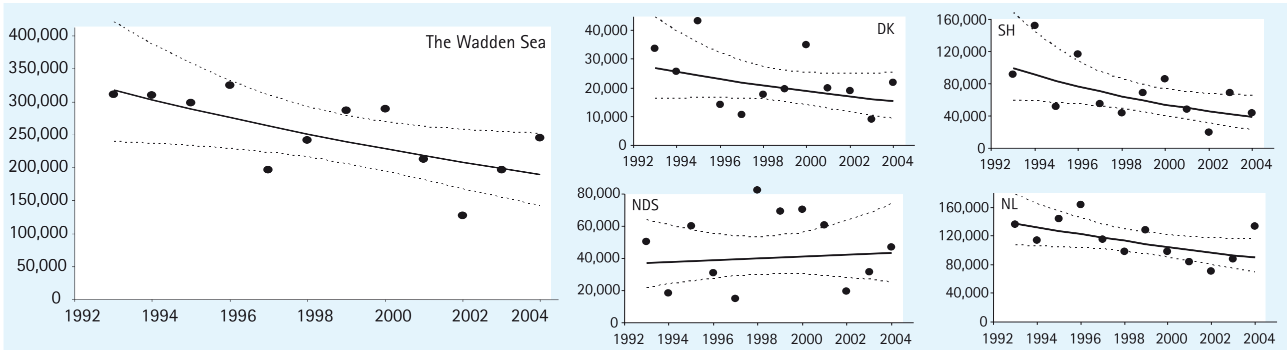
Northern Pintail



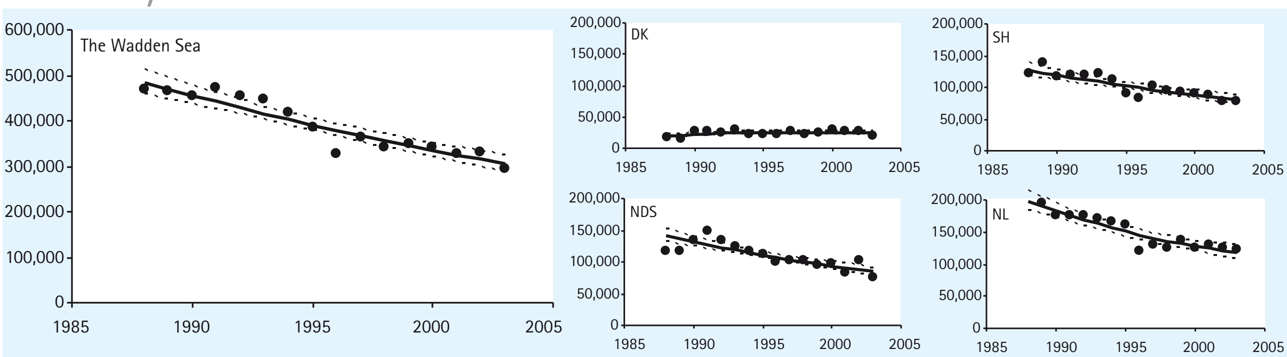
Northern Shoveler



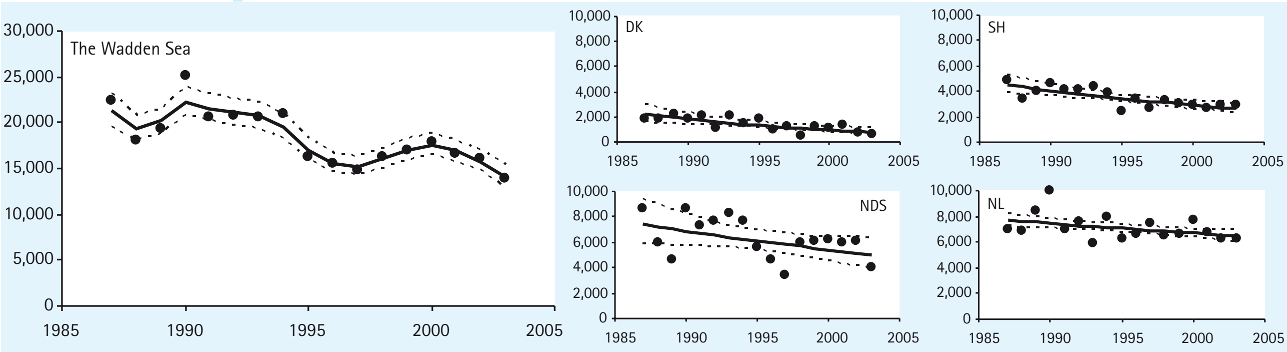
Common Eider (aerial counts in January / February 1993 - 2004)



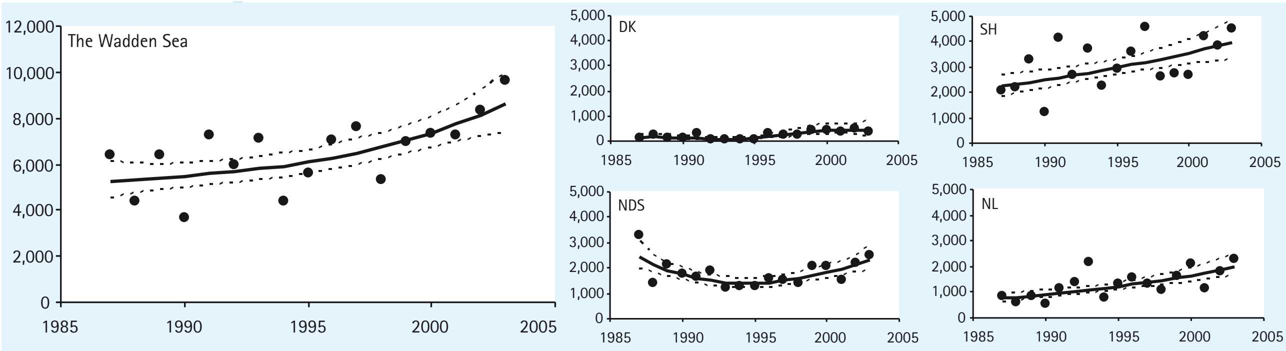
Eurasian Oystercatcher



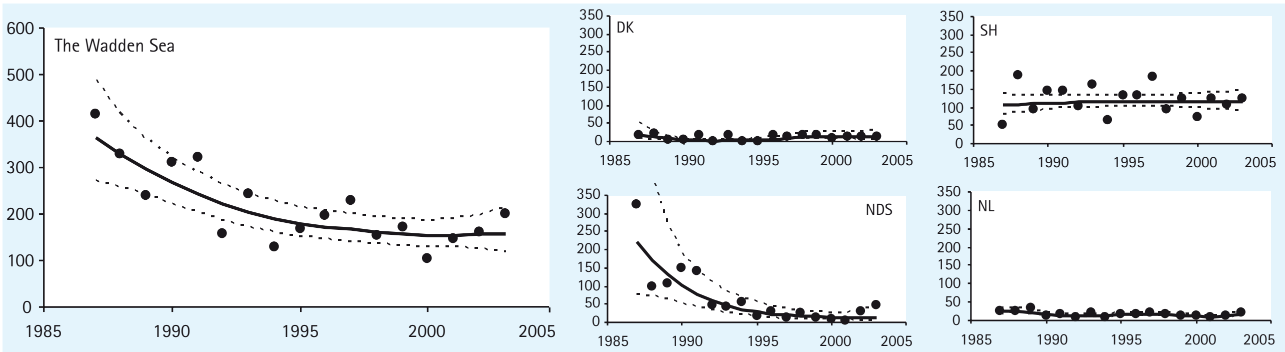
Pied Avocet



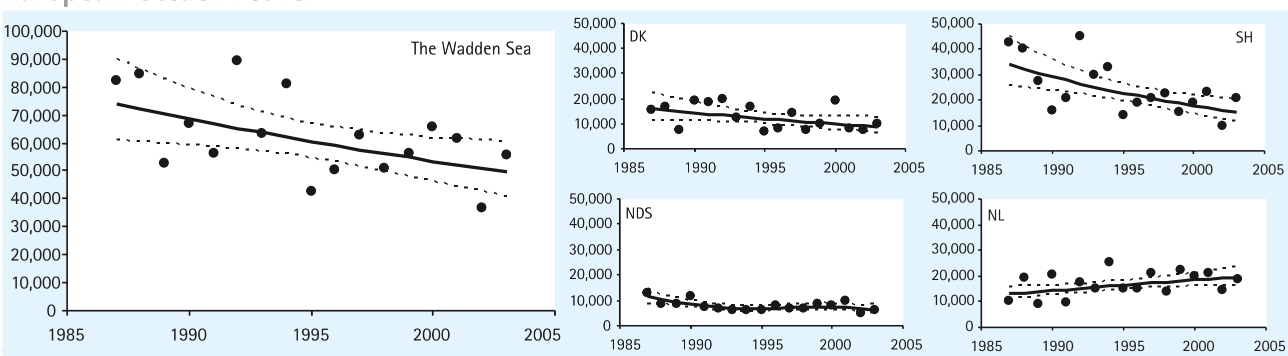
Great Ringed Plover



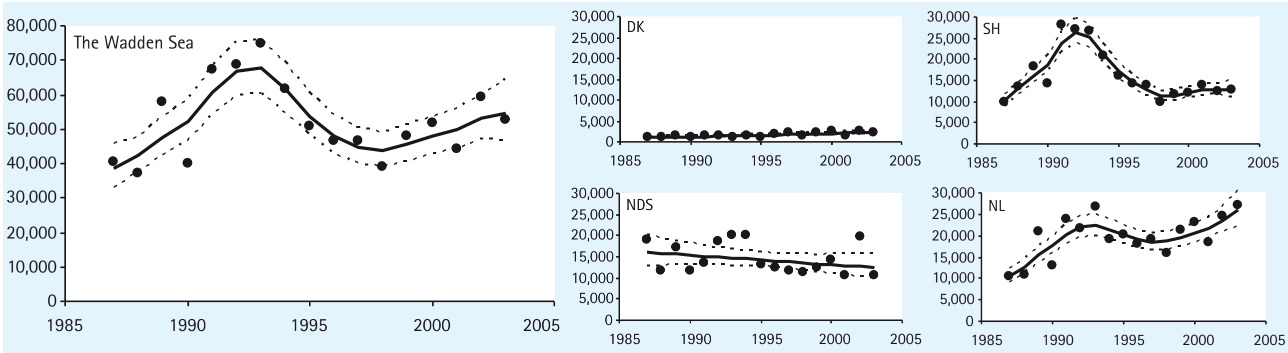
Kentish Plover



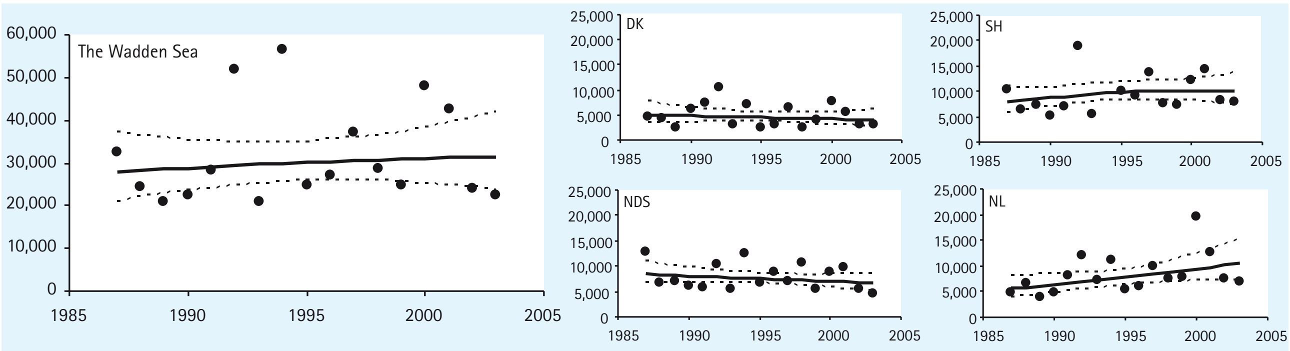
European Golden Plover



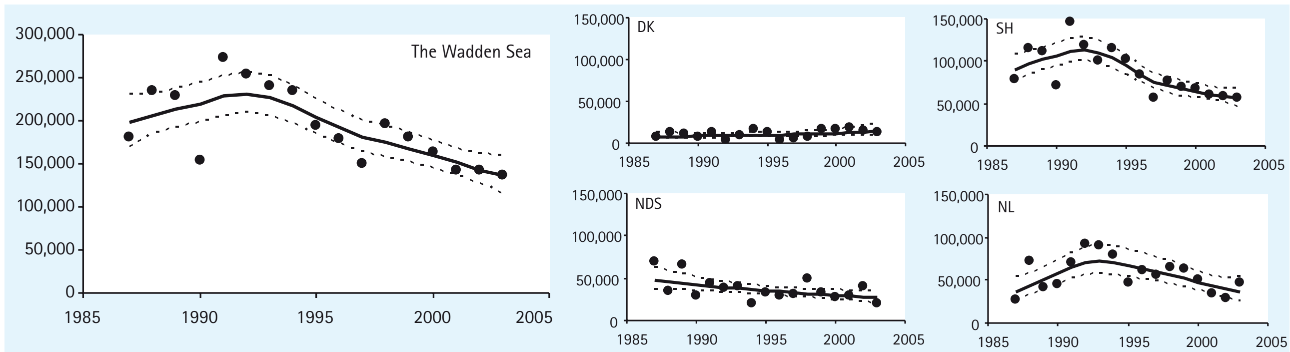
Grey Plover



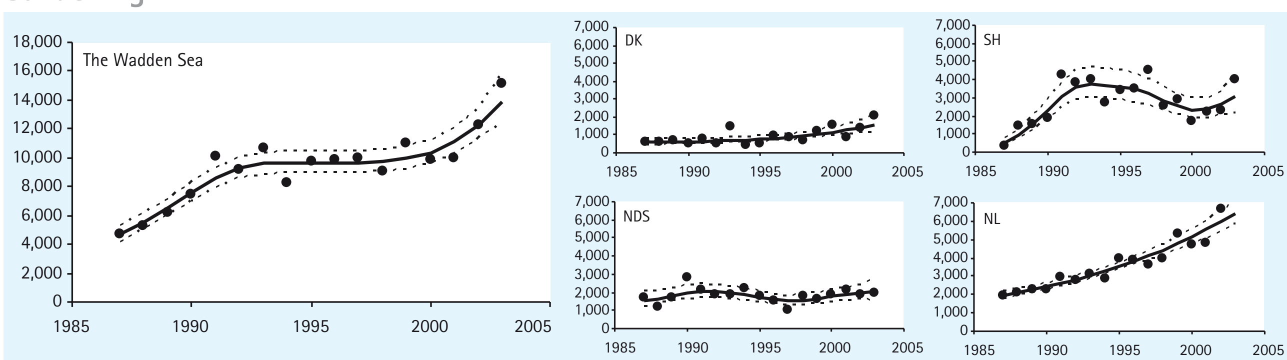
Northern Lapwing



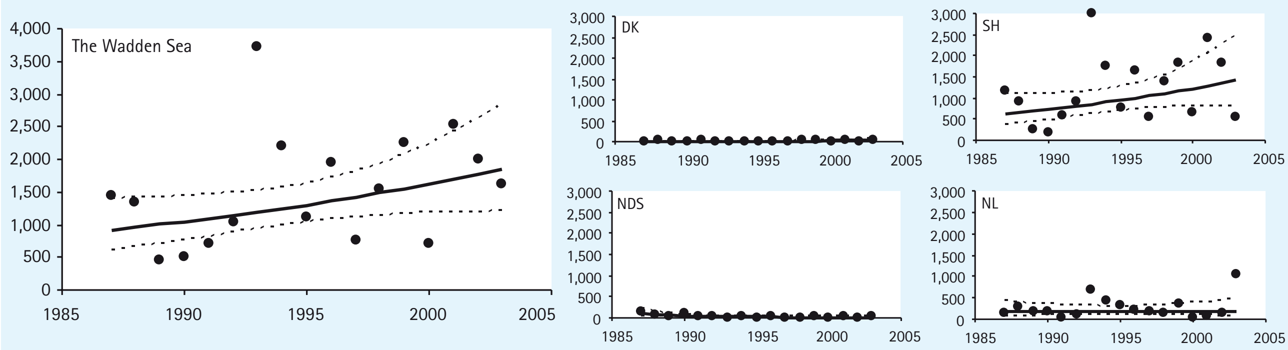
Red Knot



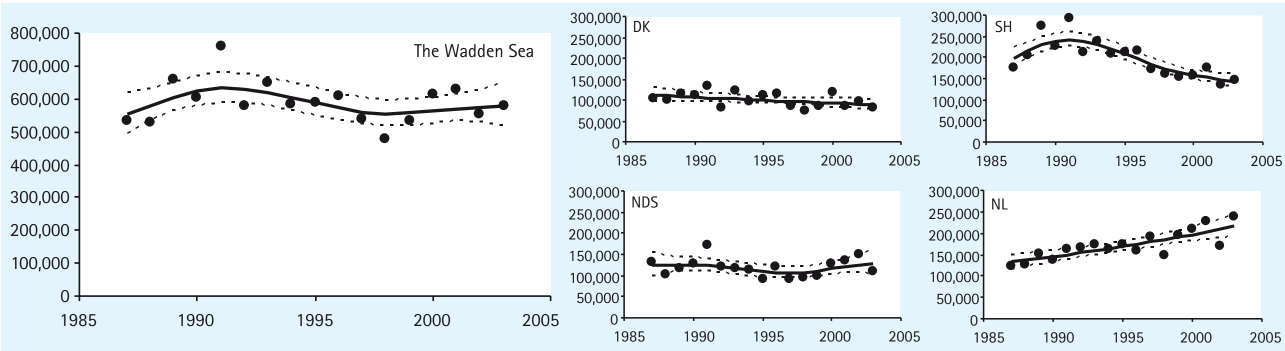
Sanderling



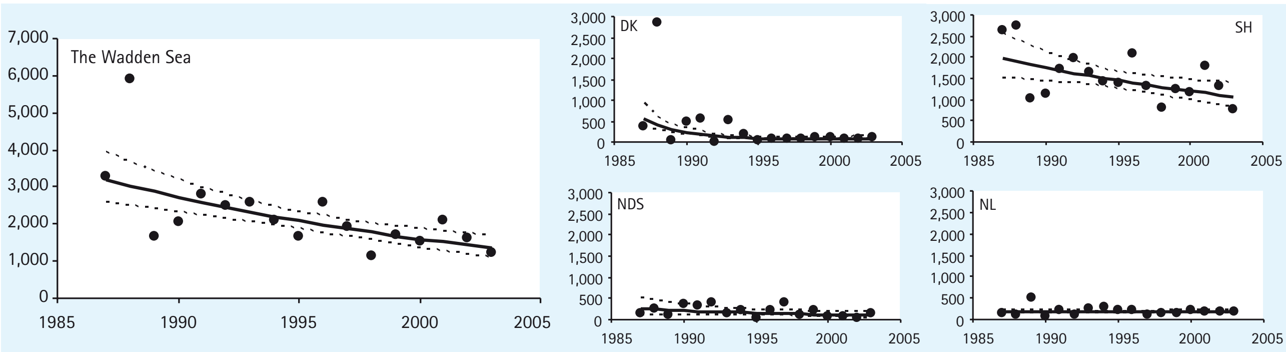
Curlew Sandpiper



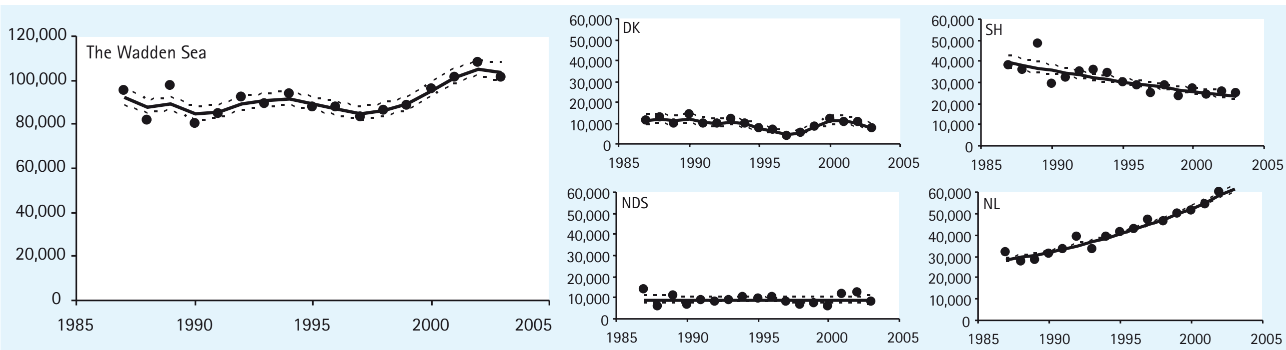
Dunlin



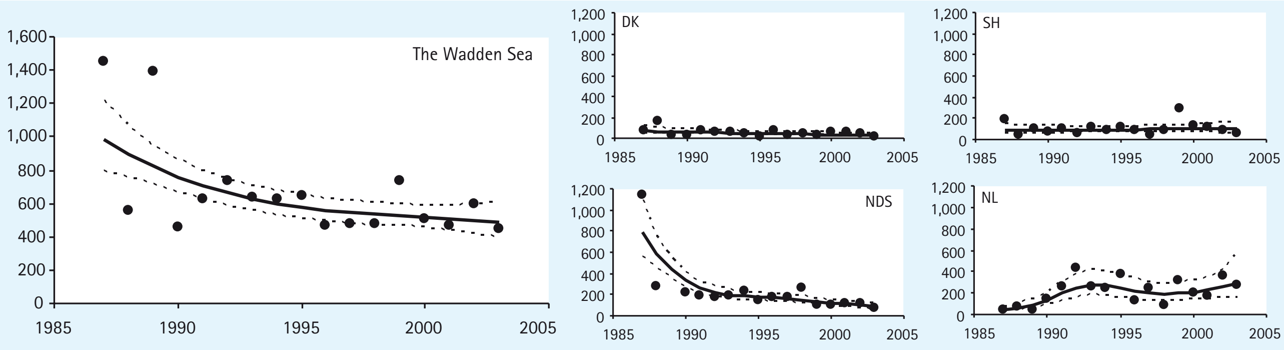
Ruff



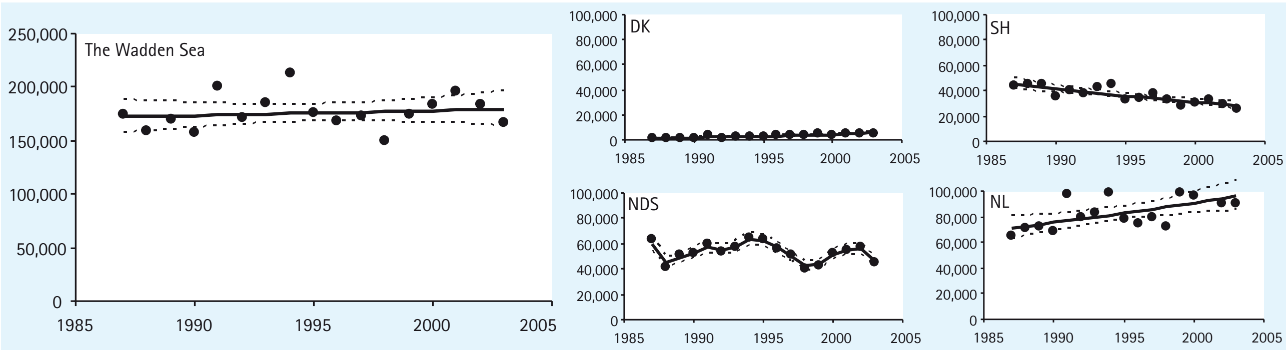
Bar-tailed Godwit



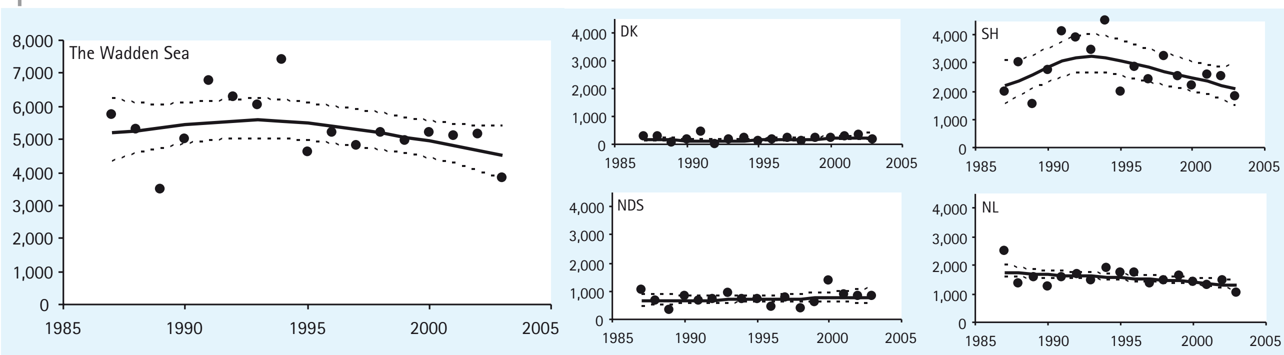
Whimbrel



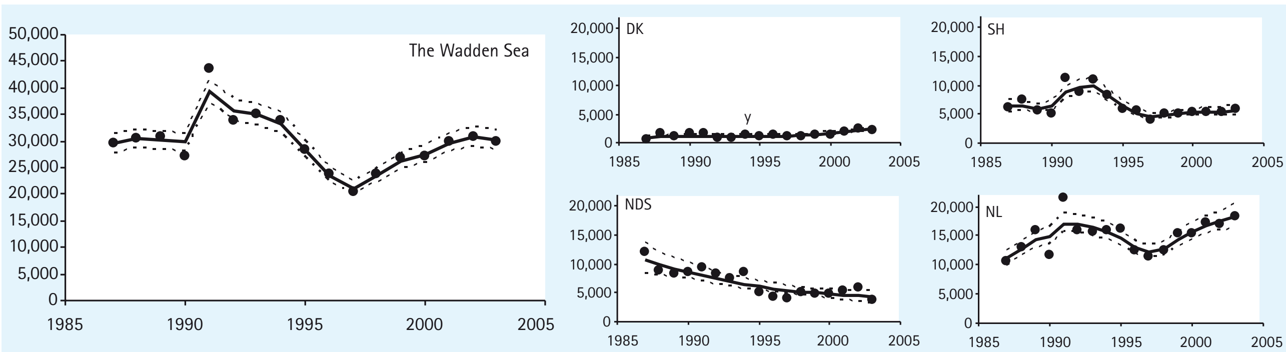
Eurasian Curlew



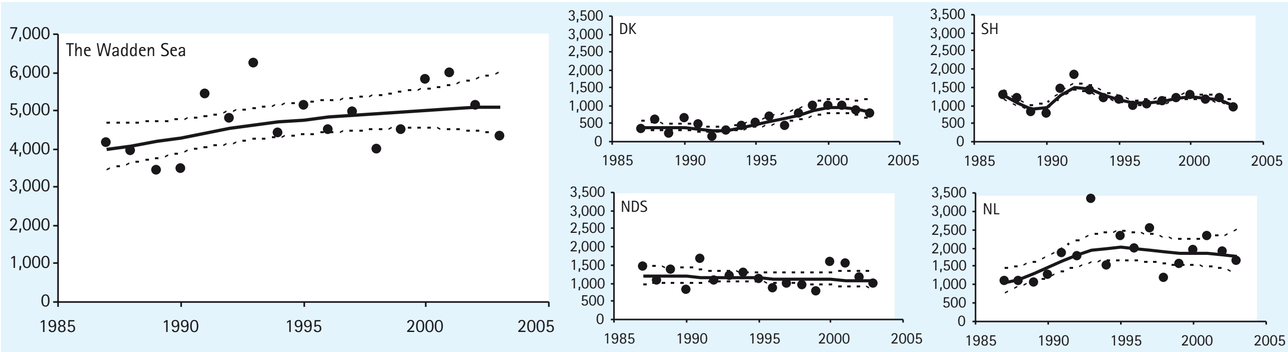
Spotted Redshank



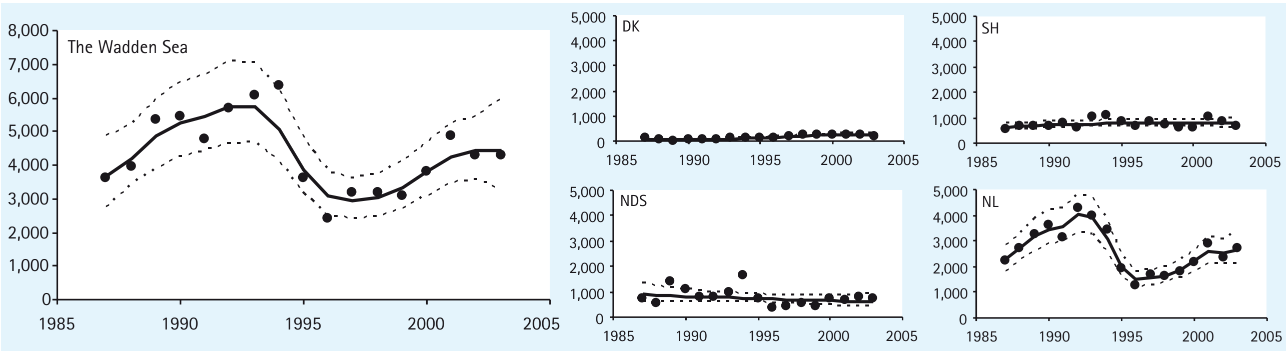
Common Redshank



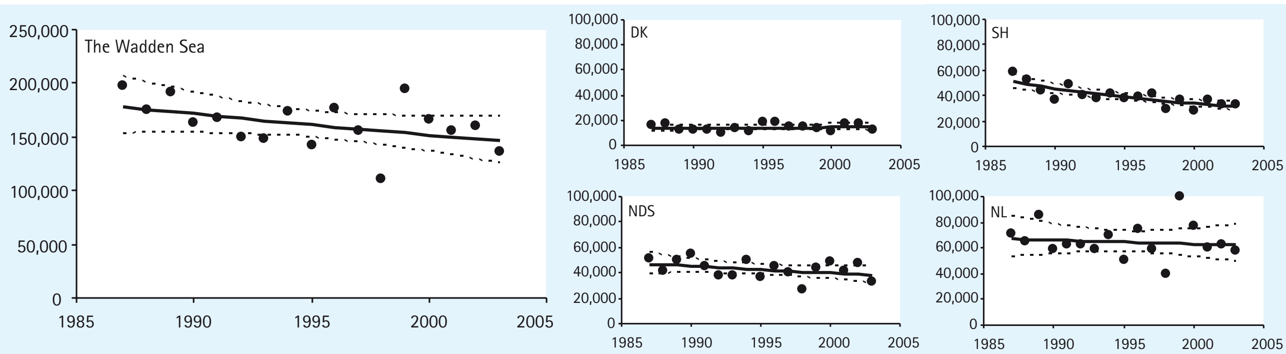
Common Greenshank



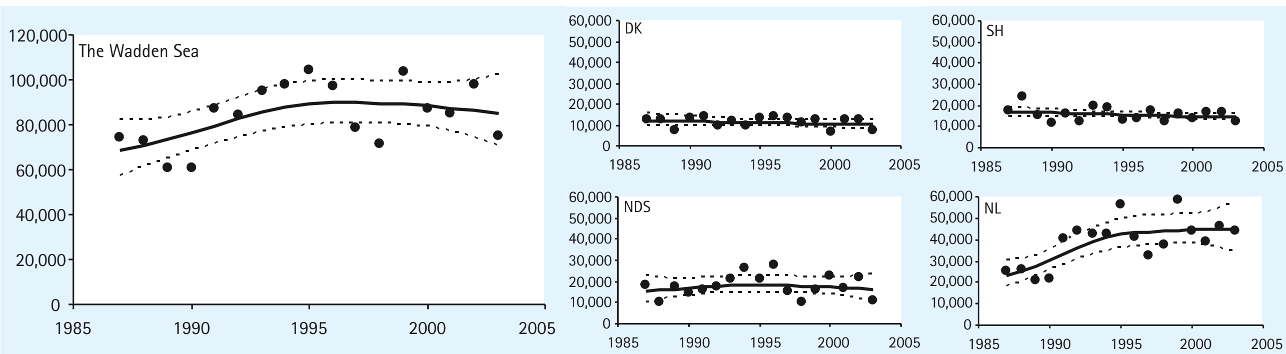
Ruddy Turnstone



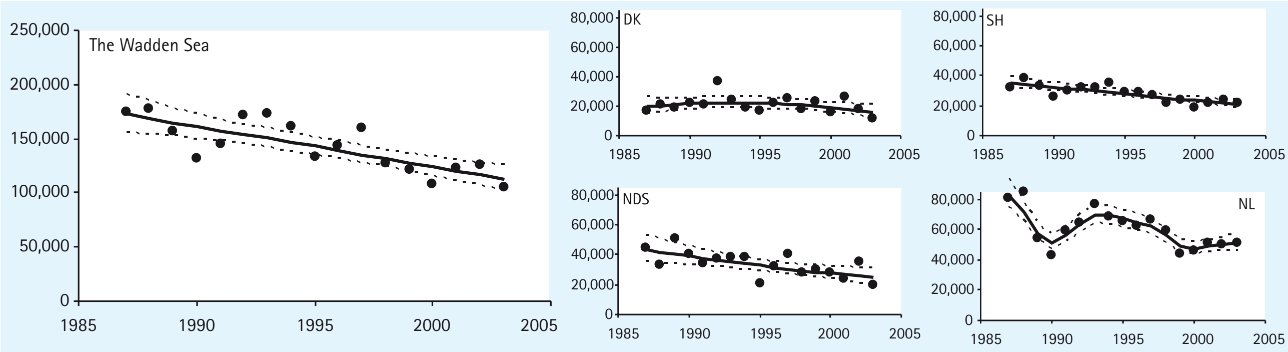
Black-headed Gull



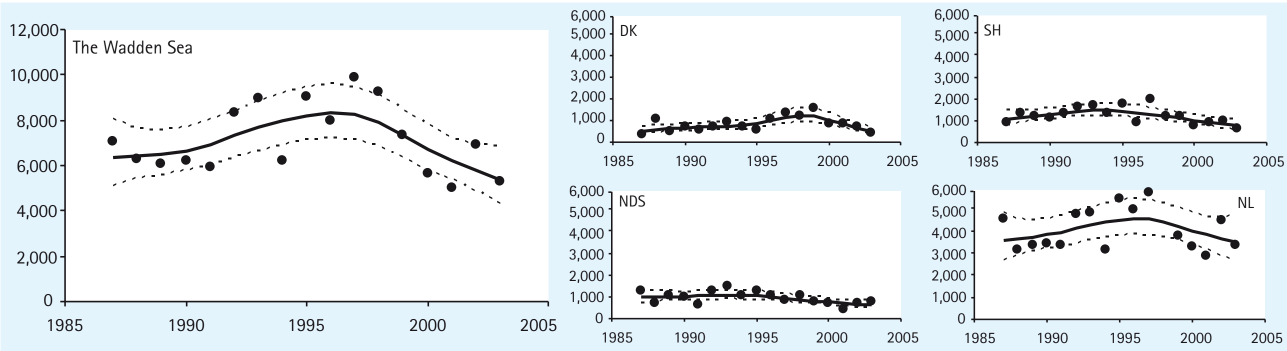
Common Gull



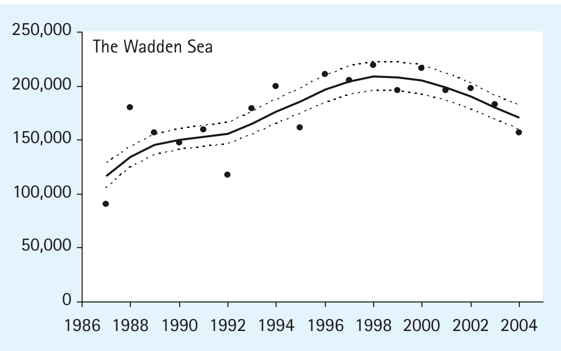
European Herring Gull



Great Black-backed Gull



Common Shelduck



Trend figures for Common Shelduck numbers moulting in the Schleswig-Holstein Wadden Sea. Aerial counts in July / August 1987 - 2006 (Kempf, 1997 - 2006).

Trends in Arctic Birds Migrating to the Wadden Sea

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1. Introduction

Declining waterbird populations are of major concern for conservation, and continue despite international efforts to halt the loss of biodiversity by 2010. Of the 34 species, for which the Wadden Sea is an essential stepping stone on their migration route, 12 species, equivalent to 35%, showed significant declining trends. An additional seven species are also declining, but not significantly (see Blew *et al.*, 2007, this volume). The reasons for the decline are not fully understood and could lie within the Wadden Sea or outside. Negative trends are prevailing in species feeding on mussels, such as the Oystercatcher (*Haematopus ostralegus*) or Red Knot (*Calidris canutus*), over those feeding on worms. Cockle dredging is believed to be a main factor explaining most of the losses among mussel feeders. However, to explain the widespread decline across all taxa and ecological guilds requires further explanations and the populations need to be considered in the flyway context (Boere, 2003; Boere and Stroud, 2006; Zöckler, 2005). The Arctic as the origin of many flyway populations migrating through and to the Wadden Sea will be looked at in more detail.

2. The significance of the Arctic region for Wadden Sea birds

A total of more than six million water birds regularly visit the Wadden Sea every year (Blew and Südbeck, 2005). More than half of these comprises of waders (3.46 million estimated), followed by ducks and geese with 2.29 million. The third largest group are the gulls with almost one million birds involved. Waders and ducks and geese primarily come from the North and mainly Arctic regions. The majority of these birds are migratory and more than 3.2 million birds (almost 2/3) originate from the Arctic, as defined by the Conservation of Arctic Flora and Fauna (CAFF,2001). They range in the East from Eastern Taimyr and sometimes beyond in Eastern Siberia as far as the Lena Delta and in the Western Arctic in NE Canada and NE Greenland.

Figure 1:
The Arctic region as defined by CAFF (2001), which also includes the Faroer Islands since 2005.

3. Major impacts in the Arctic

Climate change

Climate change is considered to be the biggest threat to Arctic biodiversity. The Arctic is warming 2.5 times faster than other regions on Earth with most of the increases occurring in the last 20 years (ACIA, 2005), which will accelerate the observed impacts on biodiversity and also the birds visiting the Wadden Sea. The differences in temperature vary considerably across the region (Figure 2) as well as between the seasons. The strongest increase has been noticed in the winter period, leading to earlier breaking of river ice and snow melt. Changing rainfall patterns additionally impact the regions differently. Some areas experienced a drying of the tundra in late spring and summer with adverse impacts on the rearing of chicks, depending on food from wet tundra soils. In eastern Siberia and Alaska permafrost thawing has lead to the decrease of tundra ponds in size and numbers over the last 30 years (Hinzman *et al.*, 2005). Data from other regions further west are not available. The European Arctic experienced an increase in precipitation and a cooling in the summer period as measured from Polar stations in the eastern Barents Sea, also with potentially adverse effects on the upbringing of the chicks.

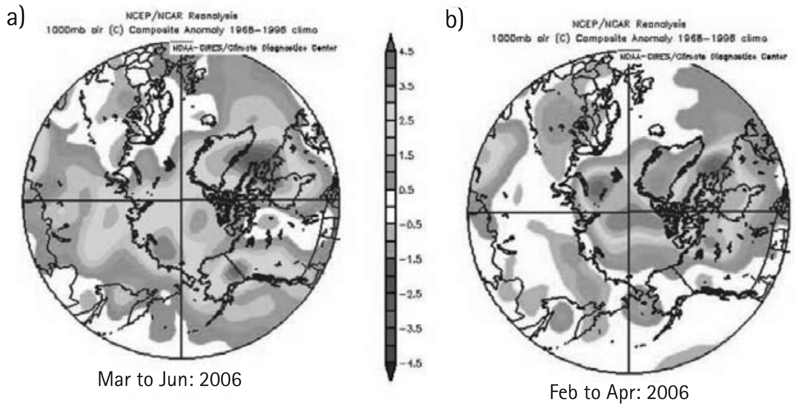


Figure 2: Near surface temperature anomalies (a) March – June 2005, (b) Feb – April 2006 relative to a 1968-1996 base period. The pattern for 2005 is similar to the patterns for 2000-2004 (Richter-Menge *et al.*, 2006)

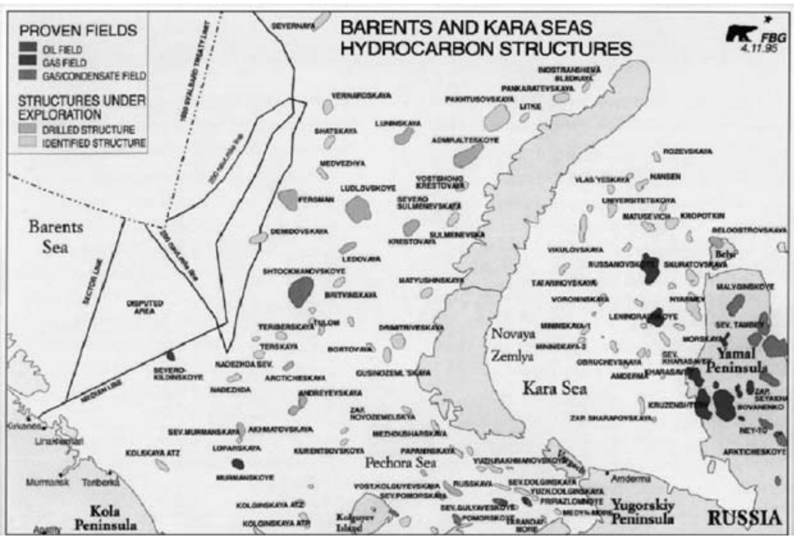
Oil and gas development and habitat fragmentation

Oil and gas exploration is the major industrial development in the region. It has increased and will continue to expand in the Arctic and in particular in the Russian Arctic (AMAP, in prep.). Figure 3 shows the distribution of oil and gas fields in the Barents Sea. Other mineral resources, such as tin, nickel and other heavy metals and coal will be increasingly extracted. But they all still act and impact on biodiversity at a local scale. The prospect of further development will likely enhance the impact on Arctic bird communities. However, at present the scale of development refers still only to a small fraction of the Arctic region.

Changes in predation

Possibly changes observed in the prey predator relationship can be related to climate changes in the Arctic. These might be a reflection of two processes noted in the Arctic. First, since 1990, the trapping and hunting of Arctic Foxes (*Alopex lagopus*) was no longer subsidised and has lead to changes in the predator abundance and composition (Klokov, in litt.). Secondly, across the Arctic changes in the natural fluctuations of the lemming cycles, the prime prey of predators, have been observed (Soloviev and Tomkovich, 2004), which might have been the consequence of climate change or triggered indirectly due to subtle changes in the vegetation.

Figure 3: Oil and gas development in the Barents and Kara Sea area (Gavrilov, in prep.)



4. Waterbird monitoring in the Arctic

Compared to many temperate regions there are only few stations, where water birds are regularly monitored on their Arctic breeding grounds. The following selected sites represent a selection where beside the physical and chemical parameters biodiversity and in particular breeding waterbirds have been monitored

Zackenberg, Greenland

Zackenberg is a remote place in NE Greenland. The very comprehensive monitoring program started in 1996 with the establishment of the Bio Basis Programme at the Zackenberg Station in NE Greenland (Meltofte and Berg, 2003). The trends of the six waders monitored between 1996 and 2005 are mostly stable. Only the Ringed Plover (*Charadrius hiaticula*) showed a slight decline in recent years (Meltofte, 2006). Without including the high values for 2005, the Red Knot also shows a slight decline over the past ten years (Thorup and Meltofte, 2005).

Taimyr, Russia

On the Taimyr Peninsula the monitoring of breeding birds started in the 1990s, when scientists from the West joined Russian expeditions into the pristine and remote wilderness. In 1997, the Willem Barents Station was established by the Dutch government and monitoring was carried out

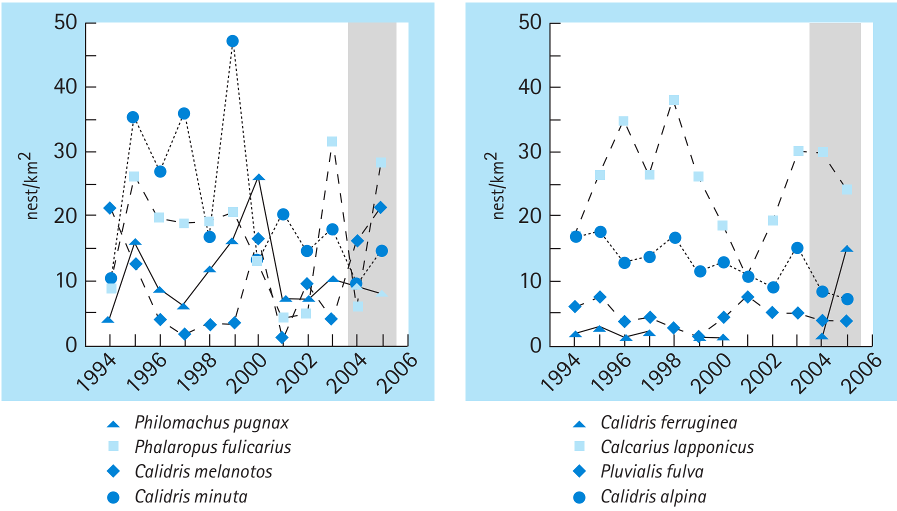


Figure 4: Trends of selected waders and Lapland Bunting (*Calcarius lapponicus*) breeding in Eastern Taimyr on a tundra terrace between 1994 and 2005 (Soloviev *et al.*, 2006).

irregularly since, but geese, waders and predators, such as Polar Foxes were monitored almost annually. Another monitoring programme has been implemented in Eastern Taimyr in 1994, on the edge of the East Atlantic flyway. This monitoring scheme has been established in a framework of scientific cooperation between the National Park Schleswig-Holsteinisches Wattenmeer and the State Nature Reserve Taimyrsky Working Group on waders (CIS) and the Arctic Expeditions of the Russian Academy of Sciences. This programme is to date looking back on more than 12 years of monitoring data on waders and breeding conditions. For the Wadden Sea the data are less relevant, as most of the populations migrate through Central Asia. No clear trends were noticed as yet with many populations fluctuating in between years according to local climate variability and the abundance of lemmings. However, interestingly, the density of Dunlin (*Calidris alpina*) and Pectoral Sandpiper (*Calidris melanotos*) seem to gradually decline (see Figure 4, Soloviev *et al.*, 2006).

Kolguev

Much further west and part of the East Atlantic flyway including the Wadden Sea area, the Island of Kolguev is located in the southeast shelf zone of the Barents Sea at 69° N and around 50° E. The 75 km long and 60 km wide island is special in several aspects. Firstly, it is free of any rodents, and secondly, possibly related to that, the island is the most densely populated place in the Russian or entire Arctic for geese. In addition the island is hardly populated by humans leaving huge areas of pristine wilderness for the geese. The recent oil and gas development has as yet only little impact on the bird population. The island has experienced an exceptional increase in the breeding Barnacle Goose populations, which ultimately influenced the breeding behaviour of other birds. In 2006, a German-Russian expedition, including the author, visited the island to study the waterbirds on the island. The research follows on from the surveys and investigations of the mid 1990s when Morozov and Syroechkovski (2004) studied the eastern part of the island. The two expeditions and survey results provide a further opportunity for comparisons and indications of some trends (see Table 1). For some species, in particular most of the waders, all of them migrating to the Wadden Sea, these trends show sharp declines. These trends require confirmation and further monitoring to verify the declining trend and whether the reasons are within the Arctic or a reflection of changes in the wintering areas in the Wadden Sea.

The Flyway approach

Population changes of waterbirds in the Wadden Sea can only be seen in the context of the entire flyway. Hardly any population stays in the Wadden Sea all year and most use the Wadden Sea as major stop over or wintering site. The Wadden Sea is an important stop over site for most of the Arctic

Table 1:
Trends of selected waterbirds breeding on Kolguev island and wintering or stopping over in the Wadden Sea, based on Morozov and Syroechkovski (2004) and Kondratiev *et al.* (in prep.), – = declining, –– = > 50%, + = increasing, ++ = >50%*pairs/10 km², **= pairs/km², except for Barnacle Geese (*Branta leucopsis*), with total estimates for the island in *italics*.

Kolguev	1994	2006	Trend
Dunlin *(Calidris alpina)*	**55	15-20	--
Little Stint *(Calidris minuta)*	**8.7	< 1	--
Turnstone *(Arenaria interpres)*	*16	2-5	--
Grey Plover *(Pluvialis squatarola)*	*46	40 – 44	0
Barnacle Goose *(Branta leucopsis)*	20,000	70,000+	++
Bewick's Swan *(Cygnus bewickii)*	*3.7	2.6	-
Shorelark *(Eremophila alpestris)*	** 8-10	?	?

Figure 5: Important spring stop over sites (arrows) of Greater White-fronted Geese, as revealed through satellite transmitters on three geese. Migration routes as of early June 2006 (www.blessgans.de, accessed 5 June 2006; Kruckenberg, in prep.).

species, which refuel energy levels for continuing migration to more southern latitudes. For some species the Wadden Sea is the final destination and they spend most of the winter in that area. The various stops along the migration route can impact the population in many different ways. In this respect each population has to be considered differently.

The example of the Arctic breeding Greater White-fronted Goose *(Anser albifrons)* highlights the diversity of potential impacts at different stations along the flyway and the difficulty of the threat analyses. In spring 2006 five satellite transmitters were attached to selected geese and their migration has been followed throughout the year. During spring migration the data transmitted from the satellites revealed information of three geese on important stop over sites, which were previously unknown (see Figure 5). In addition, three of five geese were shot, illustrating the high hunting pressure on the species along the flyway.

Similar results relate to other Arctic species visiting the Wadden Sea and it is important to highlight the significance of impacts along the entire flyway in understanding changes in populations migrating between the Arctic and the Wadden Sea.

Origin of declining species

The Arctic region is the origin of most global flyways. The declining populations and the most numerous populations in the Wadden Sea derive from the Arctic region (see Figure 6).

Migratory pattern

The longer the flyway the more vulnerable the species is to obstacles along the migration route. Most long distance migrants originate in the Arctic. Figure 7 shows that with almost 50% declining and only 8% increasing wader populations, the long distance migrants are most affected by negative impacts along the entire flyway between the Arctic and the wintering grounds in Africa, Asia and Europe. Table 2 lists the declines by different flyways that similarly reflect the same trend.

Population trends in other flyways

Arctic waders and some geese are also declining in other flyways. For some of them comprehensive information is available. Others lack a flyway assessment. Table 2 summarises the present knowledge from different flyway regions, suggesting the decline to be a much wider phenomenon and not just restricted to the flyway connected with the Wadden Sea.

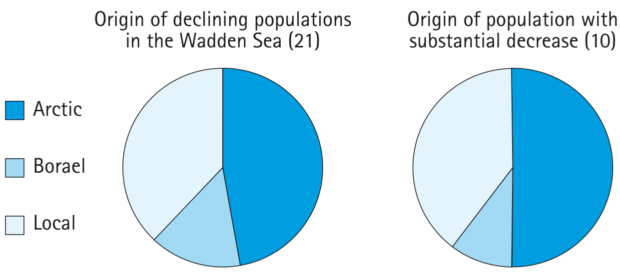


Figure 6: Origin of declining Wadden Sea waterbird populations by biome (Arctic, sub-arctic or boreal and local Wadden Sea breeders, based on Blew and Südbeck, 2005).

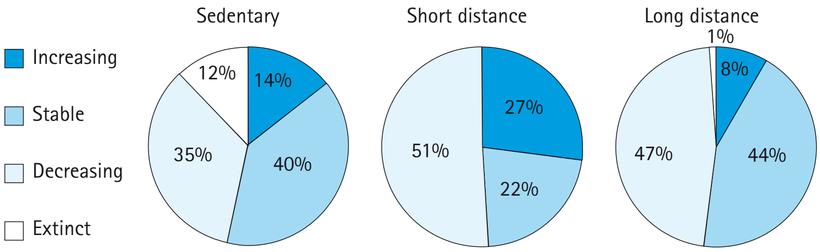


Figure 7: Trends in migratory wader populations in relation to their migratory behaviour (based on 204 wader populations globally, Zöckler *et al.*, 2003).

5. Trends in Arctic species

In the following, a few Arctic species are selected for a more detailed analysis of trends, as they are important visitors in the Wadden Sea in high numbers. In addition to the comprehensice data from the Wadden Sea (Blew and Südbeck 2005) there are also sufficient trend data available for many Arctic species through regular midwinter counts and other sources (Wetlands International, 2005) to complement the sparse data monitored within the Arctic region.

Brent Goose

The Dark-bellied Brent Goose *(Branta b. bernicla)* is a high Arctic breeding species, wintering almost exclusively in coastal salt marshes and mudflats with the majority of the population spending a considerable time in the Wadden Sea. Trend data goes back as far as 1956 (*e.g.* Ebbinge and Mauzurov, 2005). This population breeds from the Kara Sea islands west of Taimyr, across the Peninsula, East as far as the western Lena Delta (Ebbinge *et al.*, 1999; Syroechkovski *et al.*, 1998) with a tendency to expand, both east and west (Syroechkovski and Lappo, 1994; Syroechkovski *et al.*, 1998). Up to 1995 the population appeared to increase steadily, but despite its range expansion, since then, the population has experienced a gradual decline to below 200,000 birds up in 2004 (see Figure 8; Ebbinge 2004). Ebbinge and Mauzurov (2005) also noticed the decline coinciding with the disruption of the three-year lemming cycle in that period and a decline in goose productivity.

Bewick's Swan

Although the Bewick's Swan *(Cygnus bewickii)* does not migrate to the Wadden Sea but in neighbouring wetlands, it shares a large proportion of the same Arctic breeding ground as the Brent Goose and many waders (Mineyev, 1991), potentially reflecting the same or similar yet unknown issues impacting all these species in the Arctic. Figure 8 shows the population trend, which interestingly peaked at about the same time as the Brent Goose and declined in a similar pattern, indicating to changes happening within the Arctic environment rather than in the wintering areas (see also Figure 9). This overall declining trend of the entire population is also reflected in the trend data from the Kolguev population (see Table 1).

Author	Flyway Region	No. of populations	% declining
Morrison *et al.*, 2001	N America	35	80
Stroud *et al.*, 2004	African, Western Eurasian	70	43
Davidson, 2003	Central Asian	14	50
Stroud *et al.*, 2006;	East Asian Australian	55	89
Meltofte, 2006	East Greenland	6	17
Fox *et al.*, 2006	West Greenland	Greenland White-fronted Geese	30

Table 2: Population trends in Arctic flyways

Dunlin

The Dunlin *(Calidris alpina)* is the most common visitor in the Wadden Sea (Blew and Südbeck, 2005). The large majority of Dunlin migrating to the Wadden Sea, breed in the Scandinavian and Russian Arctic. The overall population trend, as measured in the wintering areas (Figure 10; Wetlands International, 2005) is not as clear as in the two previous species. Even within the Wadden Sea, the numbers vary to a great extent (see also Blew *et al.*, 2007, this volume). In addition, the total population might remain stable and only undergoes regional shifts, as recorded by Rehfisch *et al.* (2003) in the United Kingdom (UK). It is still unclear if the Wadden Sea population also shifted into other regions, such as the UK or elsewhere. The International Waterbird Count (IWC) counts do not suggest such a shift, other than within the Wadden Sea area. However, data generated from several Arctic sites and regions suggest an overall decline (see Figure 4 and Table 1).

Barnacle Goose

The Barnacle Goose *(Brant leucopsis)* is one of the few Arctic species visiting the Wadden Sea, which has been increasing for several decades (see Koffijberg and Günther, 2005). The increase is possibly still continuing, as the latest observations from the main breeding area on Kolguev Island revealed (Kondratiev *et al.*, in prep.). The Barnacle

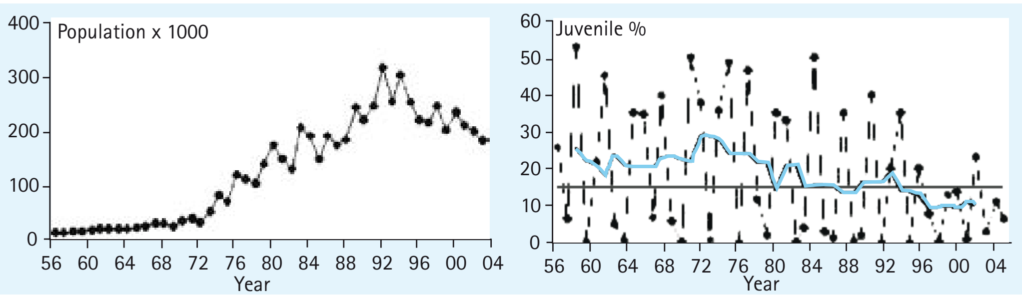


Figure 8: Population trend (left) and productivity (right) in the Dark-bellied Brent Goose as recorded from data from the Wadden Sea (Ebbinge, 2004, Koffijberg in lit.).

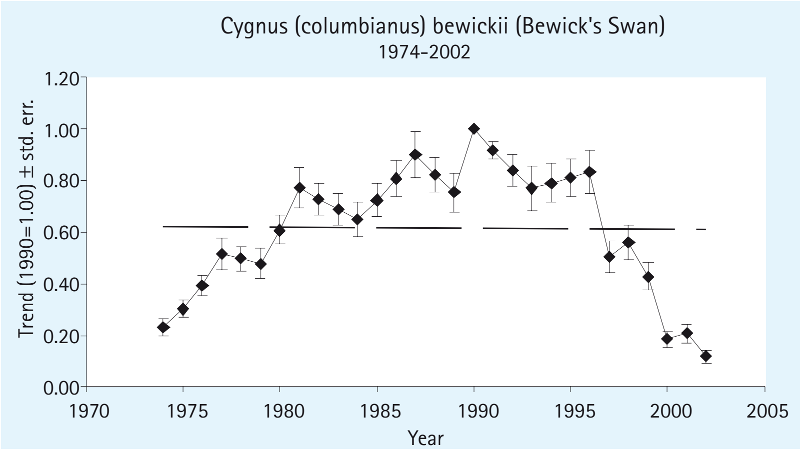


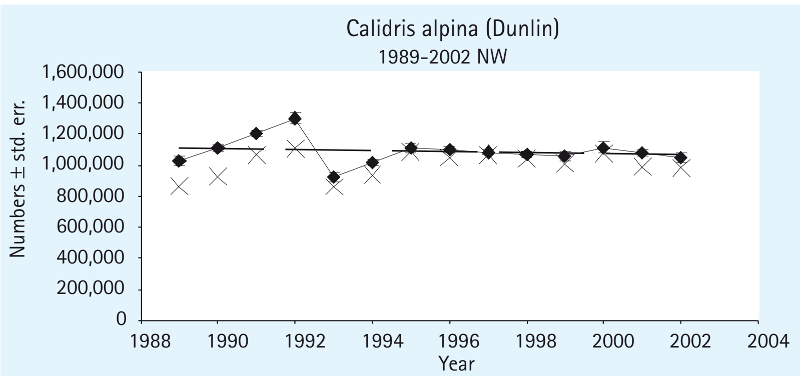
Figure 9: Population trend of Bewick's Swan recorded from IWC mid winter count sites in Western Europe over a period of almost 30 years (Wetlands International, 2005).

Goose was first recorded on Kolguev Island in 1989 (Ponomareva, 1995). Syroechkovski (1995) estimated the breeding population on Kolguev in 1994 at 1,000 pairs, which represents 30% of the total lowland proportion of the Russian Barents Sea population. In 2006, the total estimate of the population breeding in the Peshanka valley and delta on Kolguev only has been 35-40,000 pairs and the total island population is at least 70,000 but likely more than 100,000 pairs, representing almost the entire flyway population (Kondratiev *et al.*, in prep.). This extraordinary increase is also reflected in the westward range expansion and in the colonisation of non-arctic areas, such as Gotland (Ganter *et al.*, 1999).

Shorelark

The Shorelark *(Eremophila alpestris)* is among the Arctic passerine species regularly wintering along the Wadden Sea salt marshes. They are often neglected in the monitoring schemes and deserve a brief consideration. Already Gätke (1900) noticed changes in occurrence on the island of Helgoland as early as the mid 19th century, when birds only became regular visitors after 1857, reflecting a possible shift in distribution. In the 1920s, the species again declined on the North Sea coast and increased in inland habitats far from the known coastal habitats for the first time (Glutz and Bauer, 1985). Where these shifts came from and what triggered them is widely unknown. Busche (1980) estimated the total wintering population in Schleswig-Holsteins salt marshes at around 4,000 birds and Dierschke (1997) concluded for the total German North Sea coast an estimated 6,500 birds, but mentions a steady decline, which has been blamed on local impacts (Dierschke, 2003). The situation in the Arctic is largely unknown. However data from Finland already suggest a strong decline since monitoring started in the 1950s, when the total Finish population had been estimated at around 10,000 pairs. By 1983 it was already down to only 100 pairs and completely lost in 2005 (Glutz and Bauer, 1985; Hilden, 1987; Tolvanen, in litt.). Data from other regions are mostly not available and the situation on Kolguev in Russia does not indicate any changes (see Table 1).

Figure 10: Population trend of Dunlin, recorded from IWC mid winter count sites in Western Europe over a period of almost 30 years (Wetlands International, 2005).



Timing of decline

There is an obvious coincidence in the timing of some of the long term trends, showing population increases for many decades, but suddenly around the mid 1990s a decline. As shown in Figure 11 several species experienced a long term stable or increasing trend, like the Brent Goose and the Bewick's Swan with almost overlapping breeding distributions. Interestingly, the Greenland White-fronted Goose also started to decline only a few years later at the end of the 1990s, despite a completely different breeding area in Western Greenland. The wintering sites in Ireland and Scotland differ from the Wadden Sea. Apart of the Dunlin, displaying a slightly different trend pattern, all three listed waterbirds are grazing on tundra vegetation and salt marshes, indicating to global changes in the feeding habitats as potentially explaining the declines. Koffijberg and

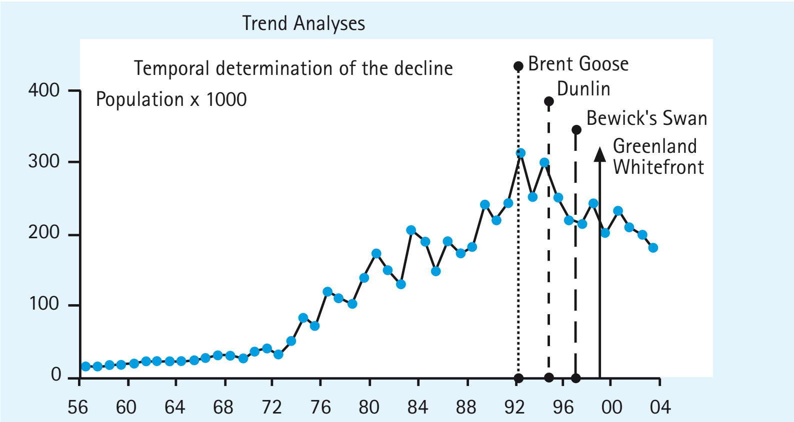


Figure 11: Timing of recent declines in selected Arctic species visiting the Wadden Sea, based on the trend for the Dark-bellied Brent Goose (blue dots), with Dunlin, Bewick's Swan and Greenland White-fronted Goose.

Günther (2005) observed a shift in grazing geese and a prolonged stay in the Wadden Sea area for the increasing Barnacle Geese, but a contraction of the Brent Geese feeding areas in the wintering area. Fox *et al.* (2006) also suspected amongst others inter-specific competition on the breeding grounds of White-fronted Geese in Greenland with the expanding Canada Geese *(Branta canadensis)*. The more widespread phenomenon requires further confirmation from other species and similar trends, but suggests a more globally acting factor, potentially varying between the species also in combination with other more local factors within the Arctic.

6. Discussion and conclusion

The Arctic region is changing dramatically and at a greater pace than any other region on Earth, due to global warming. There is strong evidence of these changes in the observations of physical and chemical environment of the Arctic, such as climate parameters, sea ice and hydrological features (ACIA 2005; Richter-Menge, *et al.* 2006). There are also first indications that biodiversity is equally and severely affected by these processes and point to changes in Arctic bird populations visiting the Wadden Sea.

The gradual decline of the Brent Goose is accompanied by the enormous increase of the Barnacle Goose. Both phenomena are not fully understood. Both species utilise salt marshes in the Wadden Sea and would encounter similar changes in population, were the real reasons for the decline to be seen in the Wadden Sea area. As suggested, the change in the salt marsh management with fewer sheep and higher plant growth might have detrimental affects on the grazing birds. However, it is widely believed that the overall increase in nutrients enhanced the growth of grazing grounds in the Wadden Sea and along the flyway, allowing the geese to refuel more easily at stop over sites, increase their fitness and reproduction success (Drent *et al.* 2006). There are however distinct differences between the two goose species in their Arctic breeding grounds. While the Brent Goose is restricted to high Arctic breeding sites, the Barnacle Goose breeds much further south and west. Both species expanded their ranges, the Barnacle Goose substantially, into new habitats, such as lowland tundra and coastal salt marshes, but both goose species hardly overlap in their distribution. It appears that the Brent Goose seem to be pushed to the edges of its range by a changing vegetation, as suitable habitats are shifting, but Barnacle Geese still benefit from a warming Arctic. There is still not enough evidence to support this theory. The fact that the species exclude each other on the breeding sites and even have replaced each other, as on the island of Kolguev where Brent Geese were still breeding in the early 1930s, according to local people, suggest some relation to changes in Arctic conditions.

Declining trends in Dunlin as observed on Taimyr and possibly on Kolguev (see Table 1) contribute to the suggested overall decline of the Arctic Dunlin population. This is also confirmed from Arctic Finland, where data generated from systematic monitoring revealed a sharp decline all over Finland, including the Arctic part between the 1970s and the late 1980s (Väisänen *et al.*, 1998). Although recent data are not available from Finland to further confirm the trend, research on the species over the last 15 years in neighbouring Norway also indicated a decline of the population (Ganter and Rösner, 2006). This widespread decline is also mirrored by declining Dunlin populations of other flyways in North America (Morrison *et al.*, 2001) and Eastern Siberia and Japan (Kashiwagi, in litt.) across the breeding range apart from Eastern Greenland (Meltofte, 2006) pointing to a circum-arctic factor. Trend data for this common wader species are not readily available for most regions, but, as for many other water birds, is highly desirable in order to fully understand the pattern of population changes.

The Shorelark might experience a similar fluctuation in population size and range, possibly in reflection to a changing climate. Due to the long-term observations from Helgoland and Finland we can detect a shift in the colonisation and trend over the last 160 years (Glutz and Bauer, 1985), but we do not understand what is underlying these changes, if they refer to all populations of the species and if they reflect similar changes in the Arctic environment, as those observed with waterbird populations.

Arctic birds are the majority of the species and numbers visiting the Wadden Sea (Figure 6). Declining Arctic populations represent all taxa and ecological guilds, including geese, swans, waders and larks, but also among grazers, mussel and worm feeders, predators and seedeaters. They occur widely across the Arctic region and cover all flyways. Not all species decline, some experience extraordinary increases and still for many taxa the trend is unknown.

In summary, this all points towards more global changes and climate change is the most likely global process which currently is affecting biodiversity in all regions and the Arctic in a particular strong way (Parmesan and Yohe, 2003; ACIA, 2005). Climate change is overriding all other impacts in the Arctic and it affects the actual Arctic population in many different ways directly through climatic parameters, such as warming, local cooling or increased and decreased snow- and rainfall patterns or indirectly by altering the vegetation, the food basis and the sensitive prey predator relationship. Little is known yet about these processes and research and monitoring is needed to fully understand and interpret the changes still to come.

The oil and gas development on the island Kolguev did not visibly affect the extraordinary explosion in the Barnacle Goose population. However, further development and expansion of oil and gas might have an impact on the geese and more likely on more vulnerable populations, such as birds of prey and other predators more vulnerable to human disturbance. On Yamal Peninsula oil and gas development has already altered the local bird population considerably, reducing species diversity in affected areas and impacting waders in particular more than any other group of birds (Paskhalny, 2000).

Not all of the declining trends can be referred to climate change only. Indeed, intrinsic factors within the Wadden Sea management have to be considered as well as the decline of the Red Knot in the Dutch Wadden Sea due to cockle dredging demonstrated (Piersma *et al.*, 2001; Piersma, 2007, this volume). The 20-year monitoring of water birds in the Wadden Sea is unique in its scope and scale. The potential for analyses goes well beyond just the Wadden Sea region as outlined above. It is of great importance that the long term monitoring will be continued and be based on a long-term financial and administrative commitment. The integration with other international coordinated monitoring schemes is highly desirable and mutually beneficial.

The Circumpolar Biodiversity Monitoring Program (CBMP)

The Circumpolar Biodiversity Monitoring Program is, first and foremost, a coordinating entity for all existing Arctic biodiversity monitoring programs and for data analyses and presentation (Peterson *et al.*, 2004). It is a mechanism for harmonising all biodiversity monitoring efforts across the Arctic in order to improve the ability to detect significant trends within a reasonable time frame and improve the ability to effectively report on these trends, engaging diverse audiences from northern communities to scientists, governments and the global community at large. It functions as an international forum of key scientists and conservation experts from all eight Arctic countries, the six international indigenous organisations and a number of global conservation organisations. It is an initiative of the Arctic Council, through the Conservation of Arctic Flora and Fauna Working Group (CAFF), to follow-up on the biodiversity related recommendations put forth in the Arctic Climate Impact Assessment (ACIA, 2005) and it is a vehicle by which the Arctic countries which signed the Convention on Biological Diversity can report on their progress towards the 2010 target.

There is a potentially huge overlap in common interests, data sets, analyses, data management and tools between the CBMP and the Joint Monitoring Program of Migratory Birds in the Wadden Sea (JMMB) in the framework of the Trilateral Monitoring Program (TMAP). These synergies require further in depth exploration and also provide unique opportunities for trend analyses on a previously unknown scale. Modern web-based technologies enable the integration of databases across regions. They provide links with physical and chemical parameters enabling analyses in previously unknown dimensions that allow us to understand trends in biodiversity in different contexts. The level of integration depends on the degree of cooperation of partners, networks, institutions and international programmes.

Acknowledgements

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Dark-bellied Brent Geese at Harlesiel (Lower Saxony) (Photo: B. Metzger)

Climate Change and Migratory Waterbirds in the Wadden Sea

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Worldwide 48% of wader species with known trends are declining (IWSG, 2003). On the East Atlantic flyway the wader populations which depend on the Wadden Sea of the southern North Sea as a staging area are of most concern. About 35% of migrating waterbirds using the Wadden Sea as staging or wintering grounds are still in decline (Blew *et al.*, 2007, this volume). Changes of habitat quantity and quality, disturbance by man, dredging, overfishing, euthrophication and pollution coincide with these declines, but there is also increasing evidence that climate change may be a contributory factor (*e.g.* Rehfisch *et al.*, 2004), becoming more and more important during the last decades as well as in the future.

The global climate is warming (IPCC, 2001a). The global average surface temperature has increased by around 0.6°C over the 20th century and precipitation as well as storminess have increased also over the same period, particularly over mid- and high-latitudes. The increase in global temperature in the 20th century was the largest in any century during the past 1,000 years and this has been associated with changes in weather patterns, precipitation, snow cover, sea-temperature and sea level, and the projected globally averaged surface temperature will increase by 1.4-5.8°C between 1990 and 2100 (IPCC, 2001a). There is overwhelming evidence that animals and plants have been affected by recent climate change (*e.g.* Walther *et al.*, 2002; Parmesan and Gallbraith, 2004; Root *et al.*, 2003; Crick, 2004, Robinson *et al.*, 2005). These effects include changes in timing of migration, earlier breeding, changes in breeding performance, changes in population sizes, changes in population distributions, and changes in selection differentials between various components of a population (*e.g.* Bairlein and Winkel, 2001; Bairlein and Hüppop, 2004; Crick, 2004). Historically, fauna and flora adapted to changes in environmental factors as weather, but the question arises if waders and waterfowl are plastic enough to adapt a far greater and faster change than previously encountered.

Climate change could also matter to shorebird populations (Piersma and Lindström, 2004). Global change is affecting the extent and quality of coastal intertidal habitats now and in the future and this has serious consequences for coastal shorebirds breeding, staging and wintering in the Wadden Sea. However, it is still very difficult to make precise predictions of the likely impact of climate change on the population of shorebirds and it will be likely difficult to disentangle the impacts of overall global change and changing local conditions from those of climate change, although the former may be far more significant in the short to medium term (Piersma and Lindström, 2004).

The aim of this paper is to summarize some

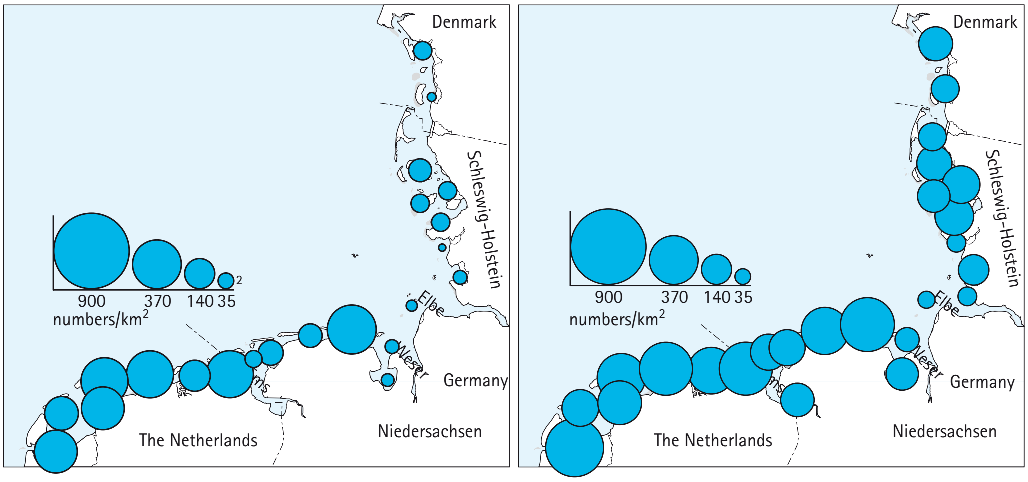


Figure 1: Distribution of waders in the Wadden Sea in cold (left) and mild (right) winters, respectively, between 1980 and 1991 (from Meltofte *et al.*, 1994).

of the likely scenarios how climate change and related sea level rise might affect habitats and population of staging or wintering migratory waterbirds of the Wadden Sea ecosystem, although much remains to be speculative, as there is still quite some uncertainty over the timing and extent of global warming, and there are currently many often diverse predictions (Watkinson *et al.*, 2004).

Changes in distribution

Winter distribution of many waterbirds in the Wadden Sea is related to winter temperature. In mild winters, many more species and birds stay in the northern part of the Wadden Sea as compared to harsh winters (*e.g.* Meltofte *et al.*, 1994; Figure 1). In the area of the Elisabethaußengroden of the Wadden Sea in Niedersachsen, the number of wintering waders is positively related to midwinter temperature (Figure 2; Thyen *et al.*, 2000). Eurasian Golden Plovers *(Pluvialis apricaria)*, for example, staying in The Netherlands during autumn moved to more southerly wintering areas with lower December temperatures (Jukema and Hulscher, 1988; Piersma and Lindström, 2004). Such hard weather movements are documented for many species. Consequently, climate warming may drive more birds to winter in the Wadden Sea in the future than in the past.

Moreover, it is shown that the number of at least some species in spring is inversely related to spring temperature with fewer birds during warmer springs (Figure 3; Thyen *et al.*, 2000). This may indicate that in milder springs the migratory shorebirds and waterbirds depart earlier to their northern breeding grounds than in colder springs. Thus, global warming with increasing milder springs might lead to earlier northbound migration. Due to the efforts of Joint Monitoring program of Migratory Birds (JMMB) the amount and quality of data has considerably increased over the last two decades. The available data should allow more detailed analyses on the distribution and phenology (see below) in the near future.

There is evidence of differential population

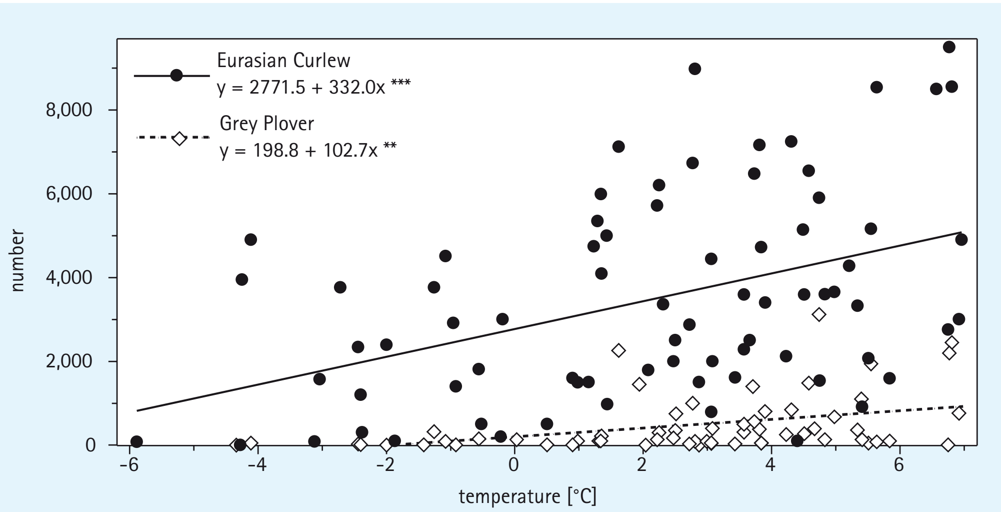


Figure 2: Numbers of Eurasian Curlew and Grey Plover in the Elisabethaußengroden (cc. 53°42' N, 07°52' E), Wadden Sea in Niedersachsen, in midwinter in relation to midwinter temperature (16 December to 15 February), 1969 to 1994. ** $p \leq 0.01$, *** $p \leq 0.001$ (from Thyen *et al.*, 2000).

shift of waders wintering in Britain's estuaries. As winters became milder wader distributions mostly moved eastwards (Austin *et al.*, 2000; Austin and Rehfisch, 2003; Rehfisch *et al.*, 2004). A higher proportion of these species used to winter in southwesterly Britain where climatic conditions during the winter were relatively mild due to the influence of the Gulf Stream. However, as mean winter temperatures have increased since 1960, such climatic constraints have eased and an increasingly large proportion of the wader population has wintered on the east coast where the quality of the feeding grounds is higher and the birds are nearer to their northern breeding grounds. This distributional shift is most pronounced for smaller waders, such as Dunlin *(Calidris alpina)*, Sanderling *(Calidris alba)* and Great Ringed Plover *(Charadrius hiaticula)*, which face greater thermodynamic costs in cold weather than larger species. This supports the hypothesis that changing climatic conditions are the main driver behind the distributional shift. Also, wader species wintering on the non-estuarine coast of Britain moved at least in part eastwards or northwards along the winter isotherms. These distribution changes are correlated with local winter weather with increasingly mild extreme temperatures and changes in rainfall, wind speed and wind-chill (Rehfisch *et al.*, 2004). However, wintering in more northern estuaries may cause another problem. Northern areas have a shorter daylight period in winter. It is well established that most wader species feed during the night, but at least in some species intake rates may be lower at night (Sitters, 2000).

Warming could have effects not only on winter distribution but also on survival. British east coast estuaries are more productive than those on the west and can thus support higher wader densities (Austin and Rehfisch, 2005). However, as shown for wintering Red Knots *(Calidris canutus)* the breeding success is affected by density-dependent effects on over-wintering populations (Boyd and Piersma, 2001). These examples prove that warming may affect different demographic factors and thus could have population impacts. If waders' distribution continue to change, the rationale for fixed site conservation needs be adapted (Rehfisch *et al.*, 2004).

Changes in phenology

Changes in migratory phenology of migrant bird species are meanwhile often reported (*e.g.* Bairlein and Winkel, 2001; Hüppop and Hüppop, 2003; Sokolov and Kosarev, 2003; Lehikoinen *et al.*, 2004). However, there are no such data published from the Wadden Sea but there is evidence from shorebirds staging in other areas that timing of migratory shorebirds is also sensitive to global warming as timing of breeding. At the inland staging site Rieselfelder Münster, northern Germany, Spotted Redshanks *(Tringa erythropus)* advanced their average spring passage between 1971-1976 and 1988-2002 by 2.4 days/10 years, and delayed their autumn passage by 4.5 days/10 years (Anthes, 2004). Near Tromsø, northern Norway, Eurasian Golden Plovers advanced their spring arrival between 1977 and 2000 by about eight days (Barrett, 2002). In line with an earlier migration, Golden Plovers breeding in the United Kingdom (UK) uplands advanced their laying dates by nine days in the 1990s (Pearce-Higgins *et al.*, 2005). Therefore, it is very likely that global warming also affects the timing of migration of shore- and waterbirds of the Wadden Sea. Earlier migration to subarctic and Arctic breeding grounds may be beneficial if it

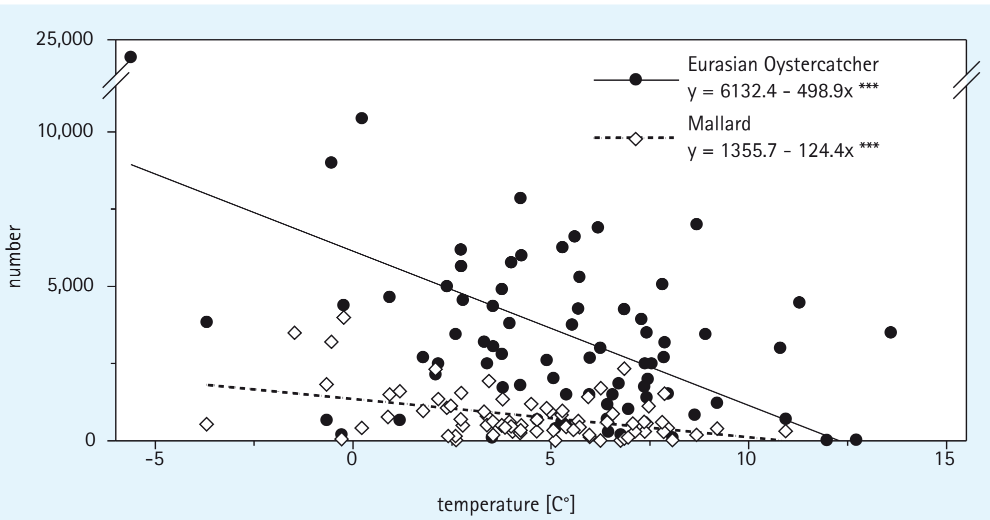
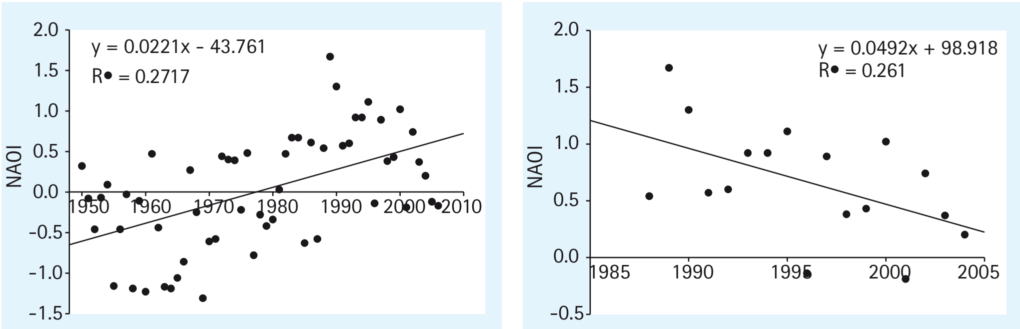


Figure 3: Numbers of Eurasian Oystercatcher and Mallard in the Elisabethaußengroden, Wadden Sea in Niedersachsen, during spring migration in relation to spring temperature (16 February to 15 May). *** p ≤ 0.001 (from Thyen *et al.*, 2000).

Figure 4: North Atlantic Oscillation in the past 50 years (left) and in the past 20 years (right), respectively (data source: http://www.ldeo.columbia.edu/NAO/).



provides waders and waterfowl greater opportunities for replacement clutches after nest failure, multiple brooding, a longer period to grow and, in turn, to improve body condition for autumn migration. On the other hand, there may be also even a mismatch when species arrive too early on Arctic breeding grounds (see below for geese).

A number of studies have shown that mean arrival dates of species breeding in Europe are advanced when the North Atlantic Oscillation (NAO) is in a more positive phase during winter and spring (*e.g.* Forchhammer *et al.*, 2002; Hüppop and Hüppop, 2003). More positive NAO phase results in more wet, windy, and mild winters and is associated with areas of high pressure over Western Europe. Thus, under these conditions migrants face more favourable conditions for flight and foraging along the migration route (Forchhammer *et al.*, 2002; Hulme *et al.*, 2002), and NAO is also suggested to influence population dynamics (Sæther *et al.*, 2004).

The NAO changed during the last 50 years with a trend to more positive index values between 1970 and 1990 and currently a reversed trend to more negative values (Figure 4). Among the set of 34 waterbird species of the Wadden Sea analysed by JMMB (Blew *et al.*, 2007, this volume) 12 species revealed significant declines between 1987/1988 and 2003/2004, while eight species increased significantly (Table 1). Of the 12 declining species eight species show a significant positive relationship between population size of

Table 1: Summary of population changes of 34 waterbird species wintering or staging in the Wadden Sea between 1987/1988 and 2003/2004, and of relationships to the North Atlantic Oscillation Index (NAOI; mean: January/February; correlation according to Pearson). Bird data and trends in bird numbers from Blew (pers. comm.; this issue); NAOI data from www.ldeo.columbia.edu/NAO; + denotes a significant positive correlation, - a significant negative correlation. O stable populations with no significant correlation, and F fluctuating populations also with no significant trend.

Species		Year	NAOI
Great Cormorant	*Phalacrocorax carbo*	+	-
Eurasian Spoonbill	*Platalea leucorodia*	+	-
Barnacle Goose	*Branta leucopsis*	+	O
Dark-bellied Brent Goose	*Branta bernicla bernicla*	-	+
Common Shelduck	*Tadorna tadorna*	-	+
Eurasian Wigeon	*Anas penelope*	O	O
Common Teal	*Anas crecca*	F	+
Mallard	*Anas platyrhynchos*	-	+
Northern Pintail	*Anas acuta*	F	O
Northern Shoveler	*Anas clypeata*	O	O
Common Eider	*Somateria mollissima*	-	O
Eurasian Oystercatcher	*Haematopus ostralegus*	-	+
Pied Avocet	*Recurvirostra avosetta*	-	+
Great Ringed Plover	*Charadrius hiaticula*	+	-
Kentish Plover	*Charadrius alexandrinus*	-	O
Eurasian Golden Plover	*Pluvialis apricaria*	-	+
Grey Plover	*Pluvialis squatarola*	+	O
Northern Lapwing	*Vanellus vanellus*	O	O
Red Knot	*Calidris canutus*	-	O
Sanderling	*Calidris alba*	+	-
Curlew Sandpiper	*Calidris ferruginea*	F	O
Dunlin	*Calidris alpina*	O	O
Ruff	*Philomachus pugnax*	-	+
Bar-tailed Godwit	*Limosa lapponica*	+	O
Whimbrel	*Numenius phaeopus*	-	O
Eurasian Curlew	*Numenius arquata*	O	O
Spotted Redshank	*Tringa erythropus*	O	O
Common Redshank	*Tringa totanus*	O	O
Common Greenshank	*Tringa nebularia*	+	O
Ruddy Turnstone	*Arenaria interpres*	O	O
Common Black-headed Gull	*Larus ridibundus*	O	+
Common Gull	*Larus canus*	O	O
Herring Gull	*Larus argentatus*	-	+
Great Black-backed Gull	*Larus marinus*	O	O

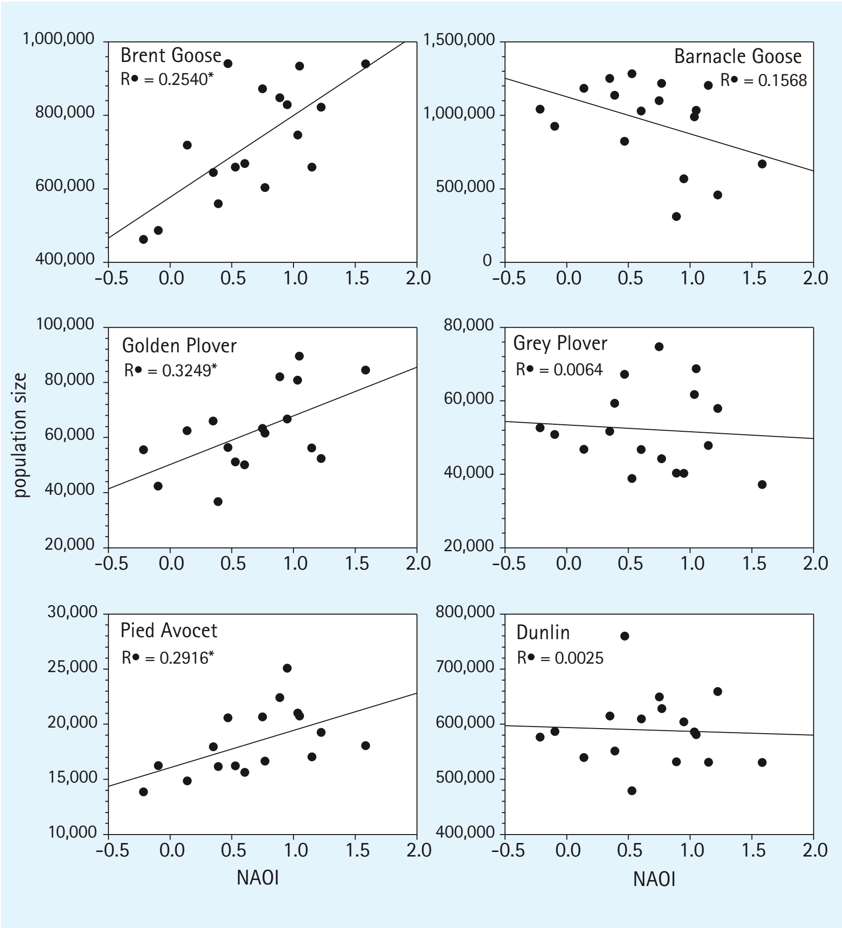


Figure 5: Relationships between population changes in Barnacle Goose, Brent Goose, Eurasian Golden Plover, Grey Plover, Pied Avocet and Dunlin and the winter values of the North Atlantic Oscillation (data sources: bird data: J. Blew pers. comm.; NAOI: www. ldeo.columbia.edu/NAO ; mean: January/February). Note the different scales. * p ≤ 0.05.

wintering or staging birds in the Wadden Sea and the winter value of the North Atlantic Oscillation Index (NAOI), four species did not respond to NAO. All but one (Ruff) of the declining species showing a significant positive correlation to the NAOI are short-/medium-distance migrants wintering in NW- or S-Europe. Most of the long-distance migrants wintering in tropical Africa showed no significant association with the winter NAOI. Influence of the NAO on the environment is more pronounced in coastal and central Europe (Visbeck *et al.*, 2001). In short- and medium-distance migrants exogenous factors may play a larger role than in long-distance migrants (Bairlein and Hüppop, 2004). Of the eight species with recent increases in population size in the Wadden Sea four showed a significant negative relationship to NAOI, the four other did not respond significantly to NAOI. Though causality has not satisfactorily shown, it could be speculated that the recent trend of the NAO to less positive values as compared to the years before with resulting cooling decreases the number of overwintering and staging birds of the Wadden Sea. Thus, the patterns of responses to changes in the North Atlantic Oscillation are complex, and even species with similar migratory life styles show opposite responses. While, for example, the Barnacle Goose *(Branta leucopsis)* reveals a significant increase in population size in the Wadden Sea associated with a negative relationship to NAO ($R^2 = 0.158$, $p = 0.116$), Brent Goose *(Branta bernicla)* is declining with an associated significant positive relationship to NAO ($R^2 = 0.2540$, $P = 0.039$, Table 1, Figure 5; see also Zöckler, 2007, this volume). Relationships between bird numbers and NAO may be superposed by a variety of confounding factors. Therefore, relationships between NAO and population sizes require careful consideration.

Changes in food resources

Temperature is one of the environmental cues which affect the reproductive system of benthic invertebrates. Intertidal zoobenthos constitute important components of the diets of most staging and overwintering birds in the Wadden Sea. A potential advantage of climate change, to wintering waders, is that severe cold winters may become less frequent (Hulme *et al.*, 2002). Cold weather can adversely affect waders directly by mortality from hypothermia or indirectly by reducing net energy intake rates (Clark, 2004). Harsh weather increases energy expenditure and additionally low temperature can also reduce energy intake depressing the activity and therefore availability of intertidal invertebrates (Zwarts and Wanink, 1993; Atkinson *et al.*, 2002).

Nevertheless, in the long-run warmer climates could also have a negative effect on food intake as the reproductive cycle of many marine invertebrates is controlled or synchronised by environmental cues. Cold winters with ice formation may lead to mass mortality of cold sensitive species, in particular of suspension feeders such as *Mytilus edulis*, *Cerastoderma edule* and *Lanice conchilega* and epibenthic predators, *e.g.* Shore Crabs *(Carcinus maenas)* and Brown Shrimps *(Crangon crangon)*. On the other hand, several species, bivalves in particular, show a highly successful recruitment during the summer following a cold winter (*e.g.* Beukema, 1992). As shown by Beukema *et al.* (2001), the abundance of intertidal invertebrates is significant reduced in years following mild winters. Therefore, continued global warming may cause a long-term decline of bivalve stocks. Moreover, global warming is likely to uncouple and alter the relationships between temperature and photoperiod and this is like to have severe consequences for the benthic invertebrates (Lorenz and Soame, 2004). Significant impacts on fecundity, spawning success and recruitment are likely to have significant implications for staging and overwintering birds in the Wadden Sea. Yet, it is uncertain whether intertidal invertebrates could adapt rapidly enough, with consequences for the available prey base for foraging shorebirds. Another unsolved question is, how will non-native species respond, for example, the Pacific Oyster *(Crassostrea gigas)*, which already seems to pose a threat to natural benthic communities and therefore also for birds feeding on benthic species.

As a result of increasing temperatures and changes in nutrient supply phytoplankton species composition may change with consequences for the food supply for filter feeding invertebrates. Flooding of the tidal flats in the Wadden Sea is expected to lead to a decrease in zoobenthic biomass, especially of the lower flats. Increased storminess may lead to a decrease of epibenthic species such as Blue Mussel and sea grass (*Zostera* spp.). An increase in temperature results in a higher activity and therefore also in a higher availability of intertidal invertebrates for waders. In contrast, increased precipitation and storminess may reduce the feeding efficiency of sight-feeding waders, such as plovers, by disturbances of the sediment surface. Thus, the number of birds and species composition may change due to changes in food availability by a decrease of tidal flat benthos and loss of roosting sites due to erosion (see below). On the other hand, milder winters may be beneficial for overwintering birds because their energy requirements will be smaller.

Temperature increase may not only affect the distribution and abundance of benthic invertebrates, it could also affect their nutritional quality for wintering and staging migrants. There is evidence that in warmer winters Blue Mussel digest considerable parts of soft tissue for self-maintainance because the water temperatures are still too low for active filtering while the mussel's metabolism is increased due to the higher temperatures. This results in a decreasing ratio between digestible soft tissue and mussel shell mass. Consequently, mussel feeding birds such as Common Eider *(Somateria mollissima)* or Eurasian Oystercatcher *(Haematopus ostralegus)* may not be able to fulfill their daily energy requirements by feeding on mussels although mussels may be still abundant, which may have consequences for winter survival of Common Eiders (Scheiffarth and Frank, 2006).

A further mismatch between dietary requirements for migration and subsequent successful breeding is evidenced for Arctic geese wintering in the Wadden Sea ecosystem (J. Stahl, pers. comm.). Successful migration and breeding in these species depend on the nutritional quality of their foods prior to departure to the breeding grounds in spring (Ebbinge, 1989). To achieve appropriate feeding these geese select for protein and lipid rich diets which are low in the content of secondary plant compounds which would affect as feeding deterrents (Bairlein, 1996a, b). Increasing temperature is predicted to increase the amount of plant secondary compounds (Müller *et al.*, 2006). Consequently, this would lower the nutritional quality of the diets for feeding geese with likely effects on their abilty to build up the required nutrient reserves for migration and subsequent breeding.

Sea level rise

Global average sea level rose between 0.1 and 0.2 m during the 20th century (IPCC, 2001b). As global temperature rises, sea level is predicted to rise by a world average of 13 cm by 2020 to 40 cm by 2080 (Kendal *et al.*, 2004). In the North Sea area, sea level increased about 2 mm per year (Beukema, 2002). Locally, sea level rises may be even more pronounced (IPCC, 2001b). Moreover, it is predicted that it will become windier and that mean wave height and tidal dynamics will increase as will the frequency of storms (Kendal *et al.*, 2004). While sea level rise occurred regularly in the southern North Sea (Behre, 2003) the current system is completely different from the past. In the past, sea level rise resulted in the migration of coastal landforms and in the establishment of new equilibrium coastal forms. As a consequence of 1000 years dike building nowadays, flood defences hinder natural migration which results in a loss of habitats with increasing sea level rise. The remaining coastal natural sources are suffering from a sustained net decline largely related to coastal squeeze of intertidal habitats (Crooks, 2004).

Rising sea level results in a spatial shift of coastal geomorphology and in a re-distribution of coastal land such as intertidal flats, salt marshes, sand dunes, cliffs, and coastal lowlands. But an increase in sea level, wave action, currents and tidal dynamics will only have a major impact on the distribution and the extension of intertidal flats and salt marshes and therefore also on plant and invertebrate communities where shore topography prevents the upward shift of the biota and therefore a new equilibrium (Kendal *et al.*, 2004). Where a sea-wall limits the spread of shores, biological production will be curtailed as the area available for colonization decreases. Moreover, increases in the size of waves and the frequency of storms will affect the hydro-dynamical properties of the near shore habitats, and consequently the structure of the sediments. Increased tidal range and wave action would keep finer particles suspended in the water column, therefore sediments would be expected to become sandier. Consequently, species which prefer muddier sediments such as Dunlin *(Calidris alpina)* and Redshank *(Tringa totanus)* may decrease and, in contrast, species that favour sandier flats as the Eurasian Oystercatcher *(Haematopus ostralegus)* and the Ruddy Turnstone *(Arenaria interpres)*, for example, should increase. In general, the predicted sea level rise may induce a sediment deficit in the Wadden Sea and a decrease in biomass (CPSL, 2005). However, such changes will occur only if sea level rise proceeds too fast to be compensated by extra sedimentation (Beukema, 2002). Beukema (2002) assumes that up to a doubling of the present rate of about 2 mm per year, not much will change, and changes will depend on the local topography.

For tidal flats, a sea level rise of 85 cm over the next 100 years may result in at least 4 cm loss of relative height of tidal flats and 18 cm at maximum (Oost *et al.*, 2005). Sea level rise results not only in a spatial shift and reduction of tidal flats and coastal lowlands, moreover it could result in a longer, sometimes permanent inundation of especially lower tidal flats and therefore also in the time the potential prey is available for staging and wintering birds. This may cause severe problems for waders staging and wintering in the Wadden Sea. A comparative study of the time-budgets of Grey Plovers *(Pluvialis squatarola)* resting in the Wadden Sea showed that the birds use much of the available time for foraging, often ≥ 12 h/day (Exo and Stepanova, 2000; Exo, 2000). Thus, the reduction of the tidal area and the reduction of feeding times can result in the reduction of the carrying capacity of an area as well as in the condition of wintering and migrating birds. Especially small waders will have markedly less feeding times. In contrast, ducks and geese will not be affected much.

Sea level rise will also cause a loss of roosting sites for waders. Higher rates of relative sea level rise and higher storm frequencies will result in a higher flooding frequency of the salt marshes. At first, an increased rate of sea level rise will particular effect the pioneer zones of the salt marshes where sedimentation cannot keep up with sea level rise. On the other hand, salt marsh vegetation of higher salt marshes can become more "typical" (CPSL, 2001). With increasing storminess and raising sea level and, in turn, higher inundation frequency and higher inundation time morphology will become more typical, *e.g.* with meandering creeks and salt pans. A more typical morphology will lead to an increased variation in habitats and an improved vegetation structure favouring the specialised typical salt marsh plants as well as salt marsh invertebrates. But above a "break point" a larger sea level rise may cause erosion and regression of the plant-cover which, in turn, causes a loss of roosting and breeding sites. A reduction of salt marshes and therefore roost site availability may lead to a higher risk of disturbance. Feeding areas are only of use for waders if they are associated with adjacent undisturbed roosts. As recently shown by Rogers *et al.* (2006), a relatively small increase in disturbance levels can result in a substantial increase in energy expenditure and hence limit population size.

A reduction of salt marshes may also affect wintering passerines, *e.g.* Shorelarks (*Eremophila alpestris)*, Snow Buntings *(Plectrophenax nivalis)* and Twites *(Carduelis flavirostris)*, which feed to a large extent on the seeds of *Salicornia* sp. and

Suaeda maritima, for example, in winter (Dierschke and Bairlein, 2002). Salt marsh vegetation itself is consumed only by a few species, *e.g.* Brent Goose *(Branta b. bernicla)* and Eurasian Wigeon *(Anas penelope)*. Moreover, we have to keep in mind that salt marshes are areas of high primary productivity, in contrast to tidal flats, and that they export detritus and organic carbon to adjacent mudflats which, in turn, affects biomass productivity of the mudflats and therefore of the feeding areas (Hughes, 2004). In addition, salt marshes are particularly important as breeding sites for Common Redshanks *(Tringa totanus)*, for example, up to 90% of the population of Niedersachsen nest there.

Perspectives

Climate changes and in consequence sea level rise in the Wadden Sea are mainly related to large-scale changes in global climate. The precise response of the Wadden Sea ecosystem, however, depends to a large extent on local conditions, especially location and topography of the tidal basins. Effects of changes in temperature, hydrodynamic regimes and in geomorphology on the ecology of the coastal zone are expected to affect habitat structure and quality of feeding and roosting sites, food availability, the composition and quality of the diet, and therefore also energy requirements for staging and overwintering waterbirds of the Wadden Sea. Because of sea defences, sea level rise might be expected to result in a loss of intertidal flats and salt marshes for migrant birds that overwinter on temperate coasts. Changes in climate and sea level at the Arctic breeding grounds are likely to have as large an impact on populations as changes in the wintering grounds (Zöckler, 2007, this volume). Therefore, assessing the result of climate change on coastal migrant birds requires considering effects of climate change during the annual cycle, that means across the breeding, passage, and wintering grounds. Although, there may be impacts of climate change in the Wadden Sea ecosystem and on the abundance and distribution of staging or wintering migrants, other effects may be more vital and sometimes more difficult to monitor or to assess.

For example, many of the waders and waterbirds wintering or staging in the Wadden Sea are breeding in the high Arctic (Zöckler, 2007, this issue). There, climatic conditions not only influence the abundance of insects, and therefore the availability of food for the offspring, they also affect the size of the lemming (*Lemmus* spp. and *Dicrostonyx* spp.) populations (Summers and Underhill, 1987; Blomqvist *et al.*, 2002; Soloviev and Tomkovich, 2003). In years when lemmings are scarce, avian and mammalian predators such as skuas (*Stercorarius* spp.) and Arctic Foxes (*Alopex lagopus*) turn their attention to the contents of nests, reducing the breeding success of the ground-nesting wader and waterbird species. Initially, such warming might be beneficial due to an increase in arthropod prey items and a more rapid growth in the population of lemmings than in predator numbers. However, habitat changes with respect to vegetation, food, predators and disease are likely to result in increasingly detrimental effects (Lindström and Agrell, 1999; Piersma and Lindstöm, 2004). Moreover, with further increasing Arctic temperatures the extent of breeding habitat may decline, especially of high Arctic breeding areas (Piersma and Lindström, 2004). The comparatively slower advancement of spring phenology in subarctic and Arctic areas, *e.g.* a delayed vegetation growth, may result in a mismatch between bird populations and their prey. To achieve an up-to-date understanding of the ecological status of Arctic breeding grounds requires the development of an integrated environmental monitoring program (Zöckler, 2007, this issue).

One of the urgently needed research is to know more about the intrinsic and extrinsic factors that could potentially inhibit adaptation to climate change (Crick, 2004). However, pinpointing singular impacts of climate change on long-distance migratory birds is problematic. Birds that traverse the globe during the course of their annual cycle are affected not only by local conditions, but also by events in remote locations. Accurate predictions of the long-term impacts of climate change thus require a much greater understanding of how birds use a series of changing sites and of how demographic parameters interact with events throughout their life cycle (Piersma and Lindström, 2004). There may also be carry-over effects with decisions and experiences in the breeding and non-breeding parts of the cycle influencing activities in the other. This is an emerging area of research and its importance is only just becoming clear. Besides detailed field studies population modelling is urgently needed so that one can go beyond to single parameter relationships and begin to understand the complexities of the interactions between different components of a species demography and life history tactics. In a first step, complex analyses of the available data of the influencing factors on bird numbers and distribution should be carried out. Based on the results, targets for further research and monitoring in the Wadden Sea can be identified. However, the Joint Monitoring Program of Migratory Birds in the Wadden Sea (JMMB) should be integrated with other international monitoring programs, the monitoring of waterbirds in the Arctic as well as on African wintering grounds.

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Flock of Red Knots
(Photo: John Frikke)

Why Do Molluscivorous Shorebirds Have Such a Hard Time in the Wadden Sea Right Now?[1]

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Abstract

The global flyways of coastal shorebirds, which connect the northernmost lands on earth with the southernmost shorelines, are supported by small fringe habitats that are neither sea nor land. The Wadden Sea, shared by The Netherlands, Germany and Denmark, is one of the biggest such systems worldwide. Intertidal ecosystems like the Wadden Sea support networks of intercontinental shorebird flyways, phenomena for which the Dutch government has pledged responsibility through international agreements such as the Ramsar Convention and EC Habitats and Birds Directives. Of the many factors threatening the ecological integrity of coastal shallow-water ecosystems, sustained bottom disturbance (mainly caused by the fishing industry) appears the most overlooked and pervasive threat. By way of example, I outline how mechanical dredging for shellfish in the Dutch Wadden Sea has caused long-term ecological damage and the loss of shorebird populations dependent on shellfish resources. After dredging, soft-sediment systems always come out much impoverished in both biomass and biodiversity, with serious negative effects for both the birds, the fish and the humans living off these coastal ecosystems. Such losses are thus easy to predict but hard to reverse: large scale mechanical disturbance of intertidal flats and other sea bottoms often have been shown to lead to irreversible or at least very long-term changes in ecosystem properties. If intertidal soft-sediment habitats are to be exploited by humans at all, they should be exploited with care and caution, with due respect for the fragility of the support systems. In practice this means that industrial, mechanical harvesting methods such as those allowed by the Dutch government in protected coastal nature reserves under their management are unsustainable.

Introduction

Tidal flats occur along the edges of shallow seas with soft sediment bottoms, in areas where the tidal range is at least a meter or so (Eisma, 1998; Kam *et al.*, 2004). The lowest intertidal areas are largely barren, except for the occurrence of seagrass meadows (*Zostera*) and of reefs formed by shellfish (*e.g.* oysters *Ostrea*) or tubeworms (*e.g. Sabellaria*). Soft-sediment systems worldwide provide living space for a group of highly specialized migrant shorebirds, birds that breed spread-out over boreal to Arctic areas in the northern hemi-

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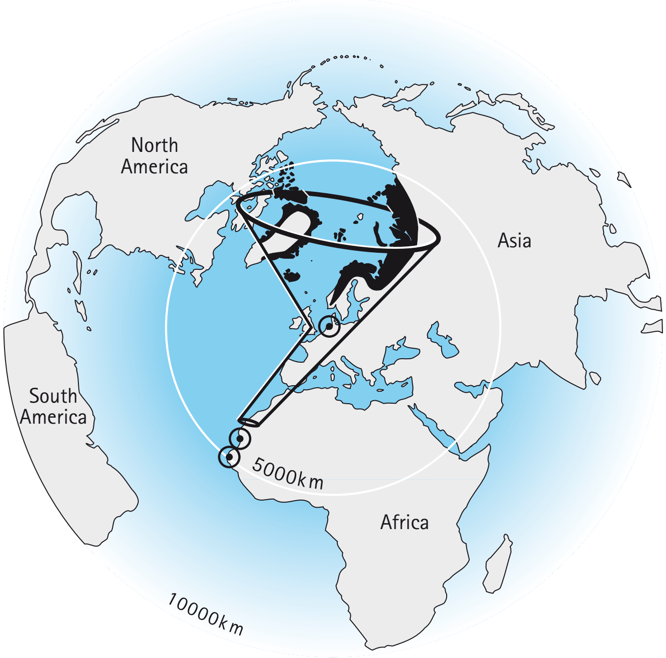

Figure 1: The Wadden Sea's strategic location is rather like the neck of a funnel running from the extensive arctic tundra breeding grounds of North America and Eurasia (shown in black) down to the two large tidal areas of West Africa (Banc d'Arguin in Mauritania and the Achipelago dos Bijagos in Guinea-Bissau). This map shows the positions of other countries relative to the Wadden Sea, and from this perspective the directions shown are accurate. The distances displayed on the map are distances to that point from the Wadden Sea following great circle routes.

sphere during June and July and that migrate very long distances to much smaller coastal intertidal ecosystems the world over. During the 10 months (from August to May) spent in these coastal areas, the birds are found in large concentrations. For this and other reasons, long-distance migrant shorebirds are particularly susceptible to the effects of human encroachment on coastal habitats, overexploitation of marine resources and global climate change (Piersma and Baker, 2000; Piersma and Lindström, 2004). A recent survey by the international Wader Study Group showed that of 207 shorebird populations with known population trajectories (out of a total of 511 known shorebird populations), almost half (48%) are now known to be in decline, whereas only 16% are increasing (International Wader Study Group, 2003). With three times as many populations in decline rather than increase, shorebirds belong to the most globally endangered segment of the migrant birds of the world.

In this chapter, I focus on the role of intertidal ecosystems such as the Wadden Sea in supporting such intricate networks of intercontinental shorebird flyways (Figure 1), phenomena for which the Dutch government has pledged responsibility through international agreements like the Ramsar Convention on Wetlands and EC Habitats and Birds Directives. The Ramsar Convention on Wetlands (www.ramsar.org) is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources; it was signed in Ramsar, Iran in 1971. Presently, the convention has 153 contracting parties, with 1631 wetland sites covering a total of 145.6 million hectares being designated in the Ramsar List of Wetlands of International Importance. The Habitats Directive of the European Community of 1992 aims to ensure biodiversity through the conservation of natural habitats and of wild fauna and flora in Europe. Under this Directive EC member states aim to design, maintain or restore natural habitats and species of wild fauna and flora, including the establishment of a coherent European ecological network of special areas of conservation, set up under the title Natura 2000. This network should enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored to a favourable conservation status. The Birds Directive of the EC of 1979 embodies a far-reaching protection scheme for all of Europe's wild birds, particularly those that are threatened and in need of special conservation measures. Under the Birds Directive, member states are required to designate Special Protection Areas (SPAs) for the 194 threatened species and all migratory bird species. SPAs such as wetlands are scientifically identified areas critical for the survival of the targeted species. The SPAs form part of Natura 2000. The designation of an area as an SPA gives it a high level of protection from potentially damaging developments.

Of the many factors threatening the ecological integrity of coastal shallow-water ecosystems, sustained bottom disturbance from fishing appears the most overlooked and pervasive threat (Jackson *et al.*, 2001; Worm *et al.*, 2006). By way of example, I will outline in some detail here how mechanical dredging for shellfish in the Dutch Wadden Sea has led to long-term ecological damage and the loss of shorebird populations dependent on shellfish resources. This builds on lines of argument developed in Bakker and Piersma (2005) and Piersma (2006).

Soft sediment ecosystems

Soft sediment shores in general, and intertidal sand- and mudflats in particular, in contrast to rocky shorelines, are in dynamic flux. The nature of the sediments is determined by the sediment types available, the currents, the tides and the wind-generated waves, as well as the presence or absence of 'ecosystem-engineering' organisms (*e.g.* reef-building oysters or mussels, but also subsurface living species producing faecal pellets that help consolidate sediments; *e.g.* Risk and Moffatt, 1977) and of human activities such as bottom-fishing and dredging. Good general introductions to the nature of intertidal soft sediment habitats can be found in Reise (1985), Raffaeli and Hawkins (1996), Eisma (1998) and Little (2000).

Coarse-grained sediments are mostly found on wave-exposed shores, but may even be found in sheltered places if currents are strong enough. Fine-grained sediments accumulate in areas with some shelter, with lower currents and less wave action. Biofilms of microscopic algae and bacteria (which produce polymeric substances) trap and bind sediments and produce a sedimentary surface that is more resistant to erosive forces (Paterson, 1997; Austen *et al.*, 1999). The presence of seagrass meadows not only suppresses erosion, but also increases the accretion rate relative to non-vegetated areas (Gleason *et al.*, 1979; Ward *et al.*, 1984; Fonseca and Fisher, 1986).

Mussel- and oysterbeds have similar roles in providing shelter and enhancing accretion rates by their capacity to increase particle size of flocculate matter (Verwey, 1952) but themselves are prone to erosion by the forces of wind and currents. For the Wadden Sea, Nehls and Thiel (1993) concluded that the longest-living musselbeds occurred in areas where the beds get some degree of protection from storms. In general terms, wind and tidal stress factors seem to influence benthic community structures quite strongly (*e.g.* Warwick and Uncles, 1980; Thistle, 1981; Emerson, 1989). Thus, one of the most interesting phenomena affecting the appearance and biodiversity of intertidal flats is the mutual interaction between abiotic factors (wind and currents) and the organisms present (Verwey, 1952; Bruno and Bertness, 2001). The establishment on bare intertidal flats of species that influence the complexity of the habitat (*e.g.* seagrasses, oysters, mussels or tubeworms) generally generates even greater habitat complexity, more variations in sediment structure and greater biodiversity.

Intertidal soft sediment systems belong to the most productive natural ecosystems, even compared with those in terrestrial habitats (*e.g.* Beukema, 1975, Kam *et al.*, 2004). To a large extent this is because the waters and sediments are nutrient rich and because sunlight has easy access, both in the shallow water layer and on the mud-surface at low tide, enabling high primary productivity that is then channelled to the higher trophic levels according to the principle of the 'food pyramid'. Food pyramids in European tidal flat systems such as the Wadden Sea usually consist of four levels, with seals and fishermen providing the fourth level. Birds and fish form the third level, which feeds on invertebrates such as shellfish, worms and crustaceans (the second level), which feed on algae (the first level). One could say that invertebrates transfer the nutrients and energy from algae into bite-sized food portions for the birds (Kam, *et al.* 2004).

Human threats to intertidal ecosystems

Although rich in principle, coastal marine ecosystems have suffered much in the hands of humans over the last few 100 years (Jackson *et al.*, 2001; Pauly and MacLean, 2003; Worm *et al.*, 2006). Upon discovering the Americas for the Spanish king, Christopher Columbus found it hard going in the Caribbean, because the passage of his ships was obstructed by the presence of myriad sea turtles, grazers of seagrass meadows that have since been decimated by humans greedy for their meat and eggs. In most parts of the world, and certainly in Europe, intertidal flats have experienced human exploitation from the mid-Holocene onwards. Most of the human exploitation of intertidal flats was relatively non-intrusive for a long time, as it consisted of small-scale fishing and the taking of shellfish by hand. With the advent of motorized power over the last century and the use of large nets and dredges, however, human exploitation patterns of intertidal flats have begun to influence the natural processes a great deal. For example, mussel-'farming' has been around in the western Dutch Wadden Sea since the specialists from the province of Zeeland moved in during the early 1960s. This industry not only involves the filling up and dredging out of the artificial subtidal mussel beds, it also entails the bringing together of mussel spat from much larger areas, including mussels from the nearby intertidal zone and from stocks outside The Netherlands (Kamermans and Smaal, 2002). These mussels may be replaced several times during their lives before final transport to the market, and each replacement involves bottom dredging.

In response to the development of markets for bait used in sport-fishing (angling), techniques to mechanically dredge for lugworms *(Arenicola marina)* were developed in The Netherlands in the early 1980s. Given the considerable depth at which lugworms live (30-40 cm), dredging for lugworms is very invasive (leaving 40 cm deep gullies) with considerable consequences for the

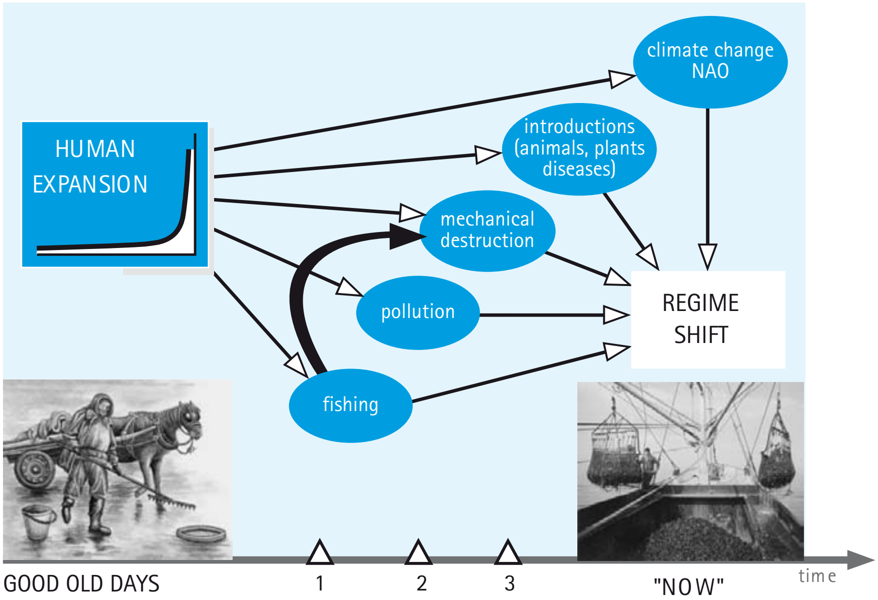

Figure 2: Historical sequence of human disturbances affecting coastal ecosystems. Fishing (step 1) always preceded other human disturbance in all cases examined. In later times fishing usually involves the use of mechanical gear leading to step 3. This is the basis for our hypothesis of the primacy of overfishing in the deterioration of coastal ecosystems worldwide. (Based on Jackson *et al.*, 2001, from Drent *et al.*, 2005).

intertidal biota (Beukema, 1995). Over a 4-year dredging period, lugworm densities over a 1 km^2 declined by half. Simultaneously, total biomass of benthic organisms declined even more with an almost complete local disappearance of the large sandgaper *(Mya arenaria)* that initially comprised half of the biomass. Recovery took several years.

Edible cockles *(Cerastoderma edule)* have not been a popular food in The Netherlands, but the demands by foreign markets nevertheless made this fishery profitable (albeit on a limited scale) from the early 1900s onwards. With the discovery of new markets, notably in countries in the Mediterranean region, and the development of mechanical harvesting techniques this fishery has, over the past decades, seen a large expansion. From the late 1970s onwards, dredging for cockles became a veritable industry. Ecological studies have shown long-term, near decadal, effects on rates of recruitment of cockles and baltic tellins *(Macoma balthica)* (Piersma *et al.*, 2001). Also on the shorter term there appear to be strong negative ecological effects of the mechanical cockle-dredging practices (see below).

In the Wadden Sea, reclamation, pollution of various kinds (organochlorines and heavy metals in the 1960s, fertilizers such nitrates and phosphates in the 1970s and many rare and exotic organic compounds since), as well as the release and subsequent invasions of exotic species can be counted as threats (Kam *et al.*, 2004). However, as emphasized by Jackson *et al.* (2001) in their review, among the many threats to coastal ecosystems, fishing is always the first of the human disturbances to take place (Figure 2). Especially in modern times, when fishing involves the use of capital- and energy-intensive mechanical harvesting devices rather than manual or wind-power (*e.g.* reflected in the use of bottom nets, scrapes and dredges), fishing plays a primary role in the deterioration of coastal ecosystems. This is particularly the case in the Wadden Sea, where industrial forms of fishing that include scraping and dredging by bottom-nets and dredges induce serious habitat transformation (Bakker and Piersma, 2005). When intertidal structures are removed as a result, local biodiversity and the generative processes of this biodiversity are greatly reduced.

Summarizing detailed faunistic information from the Wadden Sea dating back to 1869, Reise (1982) concluded that, whereas bivalves and some other groups of invertebrate animals show long-term decreases in species diversity, especially the smaller polychaete species with short life spans are doing well. Small polychaetes can take rapid advantage of environmental disturbances leading to faunal depletions. The disappearance of 28 common macro-invertebrate species was attributed to the loss of the many microhabitats provided by the complex physical structures such as oyster beds, tubeworm (*Sabellaria*) reefs, and seagrass meadows. When mussel beds and seagrass meadows that provide shelter, nutrition and other favourable conditions to various species disappear, so does the fauna that associates with them.

In summary, evidence for serious negative effects of trawling, digging and dredging on the sediment characteristics and community structure of intertidal flats and other sea bottoms is now overwhelming (*e.g.* Hall *et al.*, 1990; Dayton *et al.*, 1995; Hall and Harding, 1997; Roberts, 1997; Watling and Norse, 1998; Collie *et al.*, 2000; Kaiser *et al.*, 2000; Jackson *et al.*, 2001, comprehensive review in Dieter *et al.*, 2003). Hall (1994, p. 194), in an early review of physical disturbance and marine benthic communities, summarizes this by saying: "*there is increasing recognition of the role man plays in physically disturbing marine sediment environments, the most obvious and widespread being commercial fishing*".

How Red Knots were dredged out of the Dutch Wadden Sea

As stated, the intertidal flats of the Dutch Wadden Sea are a State Nature Monument, and are protected under the Ramsar Convention and the EC Habitats and Birds Directives (Reneerkens *et al.*, 2005). Despite the high-level conservation status and the wide-spread scientific concerns about the damaging effects of shellfish-dredging to marine benthic ecosystems (see above), until 2004, three-quarters of the intertidal flats of the Dutch Wadden Sea were open to mechanical dredging for edible cockles (*Cerastoderma edule*). A direct, immediate effect of dredging is the complete removal of all organisms larger than 19 mm in the 5-cm top layer. As the dredged sites usually exhibit the most biodiversity (Kraan *et al.*, 2007), dredging may also affect smaller cockles, other bivalves such as blue mussels (*Mytilus edulis*), baltic tellins (*Macoma balthica*) and sandgapers (*Mya arenaria*), polychaetes, and crustaceans such as shorecrabs (*Carcinus maenas*). More indirectly, and over longer time scales, sediments lose fine silts during dredging events, and this leads to long-term reductions in settlement success in both cockles and baltic tellins (Piersma *et al.*, 2001; Hiddink, 2003). Between the winters of 1997/1998 and of 2002/2003, the numbers of wintering Red Knots (*Calidris canutus*) in NW-Europe declined by about 25% (from c. 330,000 to c. 250,000; unpubl. data of BTO, SOVON and others), and the numbers in the Dutch Wadden Sea decreased by some 80%, from a level of about 100,000 to 20,000 or fewer (Roomen *et al.*, 2005). Before we examine whether these declines in red knot numbers can be attributed to the mechanical down fishing of the intertidal food webs in the Dutch Wadden Sea, a few words of introduction about this shellfish-eating shorebird are due.

Red Knots are highly specialized with respect to feeding and habitat use. Outside the breeding season in the High Arctic, their occurrence is restricted to open coastal intertidal wetland habitats and their diet to hard-shelled molluscs and crustaceans (Figure 3). Red Knots are sandpipers that breed on High Arctic tundra *only*, but move south from their disjunctive, circumpolar breeding areas to non-breeding sites on the coasts of all continents (apart from Antarctica) between latitudes 58° N and 53° S. Due to their specialized sensory capabilities (Piersma *et al.*, 1998), Red Knots generally eat hard-shelled prey found on intertidal, mostly soft, substrates (Piersma *et al.*, 1995; 2005). As a consequence, ecologically suitable coastal sites are few and far between, so they must routinely undertake flights of many thousands of kilometres.

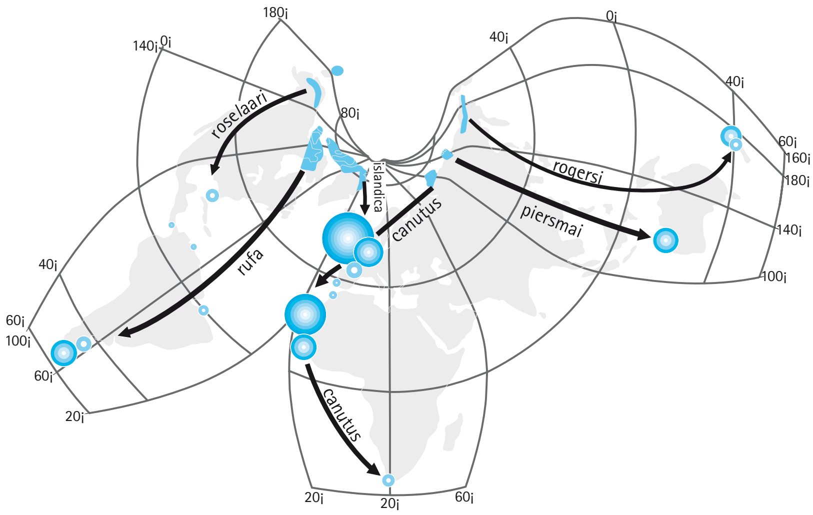

Figure 3: Worldwide connectedness: the flyways of the six identified subspecies of Red Knots *Calidris canutus*.

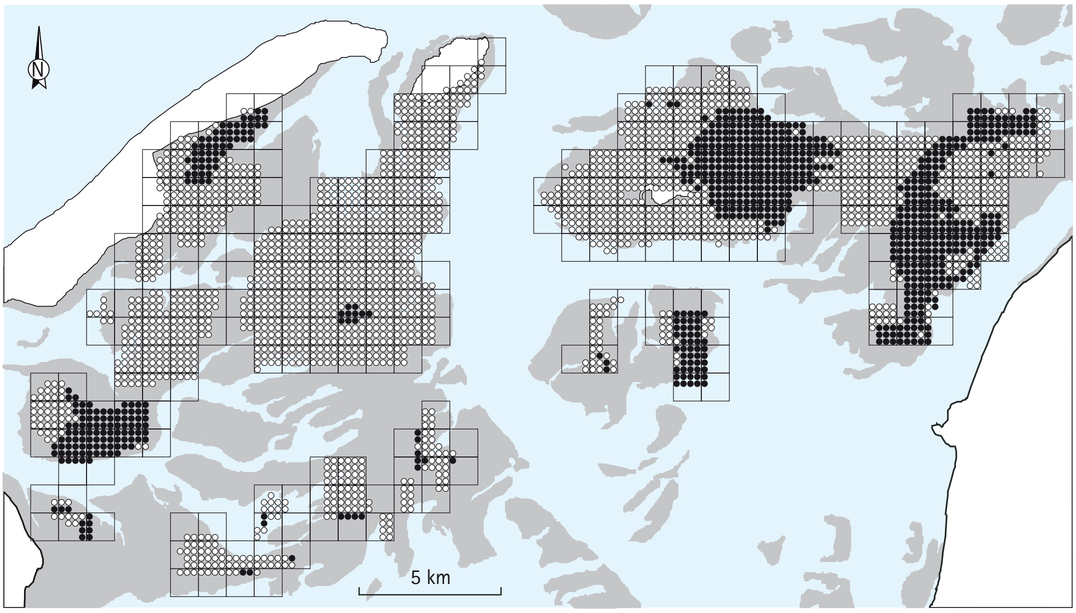

Figure 4: Map of the study area with 2,846 sampling stations (dots) categorized into 272 km² blocks (squares containing 16 stations at most). A dot is filled when a station has been dredged at least once in 1998–2002 and is open when the station was never dredged during that period.

The six separate tundra breeding areas each host a population with a sufficiently distinct external appearance during the breeding season (body size and plumage) as to have been assigned subspecies names (Piersma and Davidson, 1992; Tomkovich, 2001). Red Knots shared a common ancestor as recently as within the last 20,000 years or so (Baker *et al.*, 1994; Buehler and Baker, 2005), and as a result, the subspecies show little genetic divergence.

Having introduced the focal shorebird, we can now move to the Wadden Sea. In an area of roughly 250 km² in the western Dutch Wadden Sea, we annually sampled the densities and qualities of Knot food in great detail (*e.g.* Piersma *et al.*, 2001; Gils *et al.*, 2006a). Each year, from early September into December immediately after completion of our sampling programme, mechanical dredging took place at some of the intertidal flats previously mapped for benthos (Figure 4). Using the black-box GPS data on dredging activity that fishery organisations are obliged to present annually to the Dutch government (Kamermans and Smaal, 2002), we could categorize 1-km² sample blocks as dredged or undredged (this was partially verified based on observations of damaged sediments surfaces as in Figure 5). During the years of our study, Red Knots mostly consumed first-year cockles (58%, based on 174 dropping samples of 50-100 droppings) and for this reason we focused our analysis on the effects of dredging on freshly settled, first-year cockles (the so-called 'spat'; see Gils *et al.*, 2006b).

In dredged areas densities of cockle spat remained stable, whereas densities increased by a marginal amount (2.6%) per year in undredged areas (Gils *et al.* 2006b). This result is consistent with a previous assessment that showed that dredged areas become unattractive for cockles to settle in, perhaps because such sediments lose silt and good structure (Piersma *et al.*, 2001). In addition, the *quality* of cockle spat (here defined as the ratio of flesh over undigestible shell mass) declined by 11.3% per year in dredged areas and remained stable in undredged areas, something we explain by the fact that coarser sediments may lead to worse feeding conditions (Drent *et al.*, 2004) and therefore to reduced body condition in deposit-feeding bivalves such as freshly settled cockles (Rossi *et al.*, 2004). Thus, both the abundance and the quality of the food of Red Knots decreased in areas where dredging took place (regarding the question as to the length of recovery periods, see below).

The consequences of these declines were quantified by calculating, for each year, the percentage of the intertidal area that would yield *in*sufficient intake rates for Knots to maintain a positive energy balance (Figure 6). In the Wadden Sea only a limited part of the available intertidal flats is rich enough in suitable prey to be of any use to foraging Red Knots in the best of years (Piersma *et al.*, 1995; Gils *et al.*, 2006a). However, from 1998 to 2002 the percentage of 1-km²-blocks that were too poor for red knots to obtain a threshold intake rate of 4.8 Watts (based on food requirements at that time of year; see Piersma *et al.*, 1995) increased from 66% to 87% (Gils *et al.*, 2006b). This loss was entirely due to an increase in previously suitable blocks that were dredged; the

Figure 5: Visual effects on the surface of the intertidal flats after mechanical dredging for cockles in the Dutch Wadden Sea (Photo: B. Spaans).

number of previously unsuitable (and undredged) blocks did not increase.

As a consequence of the widespread dredging in the areas of intertidal flat with the most biodiversity (Kraan *et al.*, 2006), dietary quality declined by 11.7% per year and, to compensate for such reductions in prey quality, red knots should (Dekinga *et al.*, 2001; Gils *et al.*, 2003) and did (Gils *et al.*, 2006b) increase gizzard mass. This permits processing of the larger amounts of shell material necessary to maintain a sufficient intake of shell-meat. Despite increasing gizzard size over the years, re-sightings of individually colour-banded birds, the gizzards of which were measured before release with ultra-sonography, demonstrated that birds not seen in our study area within a year after release had undersized gizzards; individuals that we did see again had gizzards large enough for a balanced daily energy budget (Gils *et al.*, 2006b). The local annual survival rate (calculated from re-sighting rates of colour-ringed birds) increased with year-specific food quality. This means that birds arriving from the tundra breeding areas with too small a gizzard needed more time to adjust their gizzard than their energy stores allowed them: they faced starvation unless they left the area.

Individually colour-ringed Knots that disappeared from our study area may have died or, perhaps more likely for a wide-ranging migrant, emigrated to other areas such as the estuaries in the United Kingdom (UK). Here, they probably paid a mortality cost due to the extra travel and/or due to uncertainties in the food supply at their new destination. Whatever happened to them, the stark decline in numbers of Red Knots wintering in the Dutch Wadden Sea can be explained satisfactorily by these documented population effects of declining food conditions (Gils *et al.*, 2006b). The local disappearance can also account for much of the 25% decline of the entire NW-European wintering population over the same period. We must thus

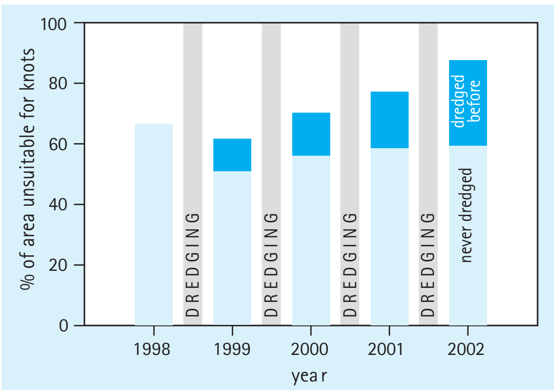

Figure 6: The percentage of intertidal area in the western Dutch Wadden Sea (an analysis of 272 km^2 blocks; see Figure 5 in Gils *et al.*, 2006b) that yielded insufficient intake rates for Red Knots (< 4.8 W) increased between 1998 and 2002 due to an increase in unsuitable blocks being dredged in previous years (filled bars; as opposed to open bars indicating unsuitable blocks that were never dredged). The small increase in the number of undredged unsuitable blocks is not statistically significant.

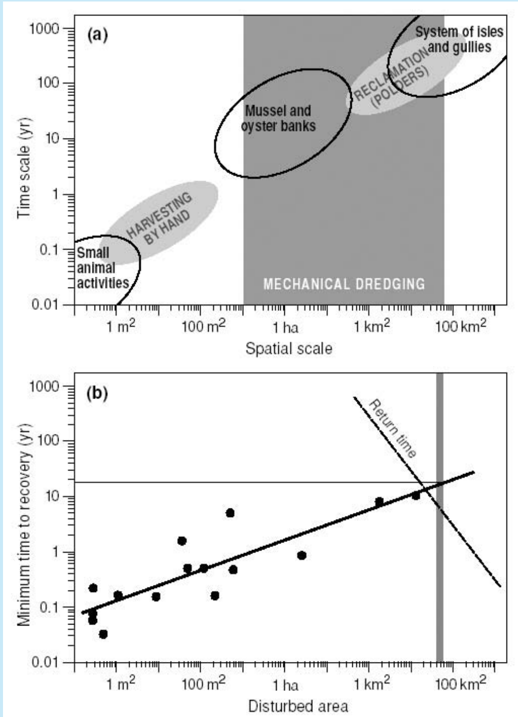

Figure 7: (a) Timescales of natural and human-induced processes with different spatial scales based on processes in the Wadden Sea. (b) Relationship between the minimal time to recovery (or some aspect of it) and the spatial scale of the disturbance studied. This graph includes observations on natural and man-made disturbances, some of which took place in the Wadden Sea. The vertical shaded bar indicates the average extent of the intertidal area affected by cockle-dredging in 1998–2001 in the Dutch Wadden Sea, the horizontal line indicates the calculated time to recovery. The return time is the time for mechanical cockle-dredgers in the Dutch Wadden Sea to revisit the same intertidal location, given random site selection. It is given as a function of the spatial extent of the fisheries and is calculated relative to the total intertidal area available. As the point where the return time line crosses the vertical shaded bar is much lower than the minimum recovery time, the present cockle-dredging practice is highly unsustainable. (After Versteegh *et al*., 2004).

conclude that the industrial forms of commercial exploitation allowed by the Dutch government in one of its best legally protected nature reserves have been directly responsible for the population decline of an, also fully protected, long-distance migrant shorebird species. Precisely the same conclusion has been reached by studies on the decline of another fully protected shellfish-eating shorebird, the Eurasian Oystercatcher (*Haematopus ostralegus*) in the Dutch Wadden Sea (Verhulst *et al*., 2004) and a nearby UK estuary (Atkinson *et al*., 2003), and for a strictly molluscivorous seaduck, the Common Eider (*Somateria mollissima*, Camphuysen *et al*., 2002).

Obeying a finding of the European Court that mechanical dredging for cockles is a new economic activity that has to be evaluated in the context the EC Habitats and Birds Directives, The Netherlands State Court (Raad van State) rejected the existing governmental permits for mechanical cockle dredging issued by the Dutch Ministry for Agriculture, Nature Conservation and Food Quality. This forced the Ministry to close the mechanical forms of cockle dredging from 2004 onward, the international companies affected receiving a generous compensation sum of over 100 million Euros (www.wildekokkels.nl). Although this may have meant the end of industrial dredging for cockles in the Dutch Wadden Sea, since 2004, the Ministry has issued new permits for mechanical dredging for lugworms, worked towards an increase in the number of permits for hand-cocklers and in the harvesting of intertidal mussels, and has failed to examine the degree that shrimp-fishing negatively affecting bottom communities warrants fresh examination (*e.g.* Buschbaum and Nehls, 2003; Buhs and Reise, 1997).

Industrial fishing and mismanagement of intertidal nature reserves

In view of the commitments made by the international community to safeguard the flyway populations of shorebirds such as the Red Knot, the direct and indirect effects of bottom trawling and dredging on intertidal ecosystems is a major concern. The probability that damaged intertidal flat communities will recover has not been determined, but is likely to be even lower than the recovery of fish stocks after overfishing (Hutchings, 2000). There is little doubt that the time course of any recovery will be a function of the spatial scale at which the disturbance took place (Lenihan and Micheli, 2001). The time constant of general processes in the coastal zone is quite tightly correlated with their specific spatial scale

(Figure 7a). Given the extent to which intertidal flats are dredged for cockles in the Dutch Wadden Sea, the time to any recovery would be somewhat longer than a year (see Figure 7b, Piersma *et al.*, 2001). Using data from the literature for minimum recovery times after disturbance for intertidal and subtidal soft-sediment habitats, a preliminary quantitative assessment of time to the beginning of a recovery can be made (Figure 7b); this is, however, only semi-quantitative, as only data points from studies where recovery was positive could be included (Versteegh *et al.*, 2003). Affecting up to 100 km^2 of intertidal flats, the mechanical dredging for cockles alone is predicted to require recovery times of 20-30 years. We regard this as the most optimistic assessment, as recovery times may be even much longer if mechanical dredging moves the intertidal ecosystem into a different, and much less diverse and productive, stable state (Scheffer *et al.*, 2001).

In summary, I have shown how mechanical dredging for shellfish in the Dutch Wadden Sea has caused long-term ecological damage and the loss of shorebird populations dependent on shellfish resources. After dredging, soft-sediment systems come out strongly impoverished in both biomass and biodiversity, with serious negative effects for the birds, the fish and the humans living off these coastal ecosystems. Such losses are thus easy to predict but hard to reverse: large scale mechanical disturbance of intertidal flats and other sea bottoms often have been shown to lead to irreversible, or at least negative on a very long-term, changes in ecosystem properties. If intertidal soft-sediment habitats are to be exploited by humans at all, they should be exploited with care and caution and with due respect for the fragility of the support systems. In practice this means that industrial, mechanical harvesting methods such as allowed by the Dutch government in protected coastal nature reserves under its management are unsustainable. We have to put lie to the notion that commercial exploitation is consistent with conservation (Gross, 2006). Only some limited forms of gill-netting and the hand-picking of intertidal resources may qualify as sustainable forms of intertidal exploitation.

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Possible Effects and Impacts of Recreational Activities on Bird Populations in the Wadden Sea – Can Disturbance Explain the Negative Trends?

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Background and aim

During migration and winter, the greatest concentrations of waterbirds occur on large relatively undisturbed wetlands, such as the Wadden Sea, which provide suitable feeding and roosting opportunities. Generally, wetlands and their waterbird populations are under pressure, due to the cumulative effects of physical development, unsustainable resource utilisation, pollution, climate change and disturbance from recreational use. To protect migratory waterbirds and their most important wetland habitats, most western European countries are bound by international conventions and directives as well as by national legislations and agreements. Whereas it is obvious that pollution, land-claim, drainage and over-exploitation are unsustainable activities, it has been widely discussed to what degree various recreational activities and associated disturbances are compatible with waterbird use of wetlands and, ultimately, may affect their conservation status. Hence, it is questioned that some of the recent observed declines in migratory and breeding waterbird populations in the Wadden Sea may be due to increasing pressure from recreational activities. In this presentation, I shall provide some definitions of disturbance, evaluate possible consequences of disturbance and discuss, with an overall perspective, the likelihood that waterbird numbers in the Wadden Sea are likely to be negatively affected by recreational activities. The focus will be on migratory waterbirds, with only few comments on the situation of breeding birds.

Definitions of disturbance

Field studies on disturbance have to a large extent focussed on local *effects*, i.e., the behavioural and distributional responses by birds to disturbance stimuli. As a result it is well known that disturbance can cause temporary changes in behaviour and locally affect the temporal and spatial distribution of migratory and wintering waterbirds. It is also known that birds are able to compensate for disturbance by altering their behaviour or habituating to human activities. Comparatively little is known about the *impacts* of disturbance, i.e. fitness consequences manifest in break-up of family or pair structures, reduced body condition, productivity or survival of the individual or population. Especially in migratory birds the study of impacts is a challenge, partly because it is sometimes difficult to single out the impact of disturbance from other confounding factors, partly because the impacts can be difficult to quantify because they may show up thousands of kilometres away from the actual disturbance event.

To be able to scientifically evaluate causal effects and impacts of disturbance, it is not sufficient to correlate bird numbers against densities of human activities, because responses by birds may be related to the type of activity, its spatial and temporal occurrence, the physiological state of the birds (*e.g.*, birds which are energetically stressed may trade-off risks differently from birds in good condition), their behavioural adaptations to the site (*e.g.*, dependent on whether birds have alternative sites in which they can seek refuge or compensate for lost feeding time) and the specific human activity (*e.g.*, affected by the protection status of the species involved) (Fox and Madsen, 1997; Madsen, 1998a). For example, people in large groups, walking along marked routes may be far less disturbing than a single person walking outside trails, because birds will perceive trail walking people as predictable and directional in their movement, while a person roaming around is unpredictable and undirectional and hence, constitutes a higher potential risk (Beale and Monaghan, 2004). To examine such causal relationships, detailed observational studies at large scale combined with experiments are required (Madsen, 1998a,b).

Susceptibility and consequences of disturbance

The susceptibility of species will depend on several factors, such as its 1) diet and ability to compensate for lost feeding time, which is relatively limited in birds which live from intertidal food resources, 2) distribution and dispersal patterns depending on the distribution of food resources, 3) flock size, with susceptibility increasing with increasing flock sizes and, 4) protection status, with quarry species being less tolerant than protected species. In a study of anatidae, we concluded that geese, dabbling ducks (excluding Mallard *Anas platyrhynchos*), Pochard (*Aythya ferina*), Tufted Duck (*Aythya fuligula*) and Scaup (*Aythya marila*) were most vulnerable (Madsen *et al.*, 1998).

Waterbirds are most likely to be critically disturbed, i.e., with consequences for fitness, at times when they are energetically stressed, which may occur during late winter when food resources and body reserves become depleted, or during spring when migratory species accumulate energy and nutrient stores as a prelude to breeding and hence are in a demand for feeding at a high rate (Madsen and Fox, 1995). In theory, however, the circumstances under which food resources in the late winter grounds become depleted and birds start to starve, may be affected by the levels of disturbance encountered along the flyway towards the wintering grounds, by which birds are "pushed" down the flyway to encounter earlier food shortage (Madsen and Fox, 1997; Figure 1). To achieve this effect, disturbance has to be massive. One such example is shown in the studies of hunting disturbance in Danish coastal wetlands, which are used for recreational hunting during autumn. With the creation of experimental refuge areas and subsequently a national network of refuge areas established in Danish Special Protection Areas, the national total of autumn-staging dabbling ducks increased dramatically (Figure 2; Madsen, 1998b; Clausen *et al.*, 2004). This demonstrated indirectly that hunting in the past was a major disturbance factor controlling duck numbers and that ducks left the country at a time when food resources

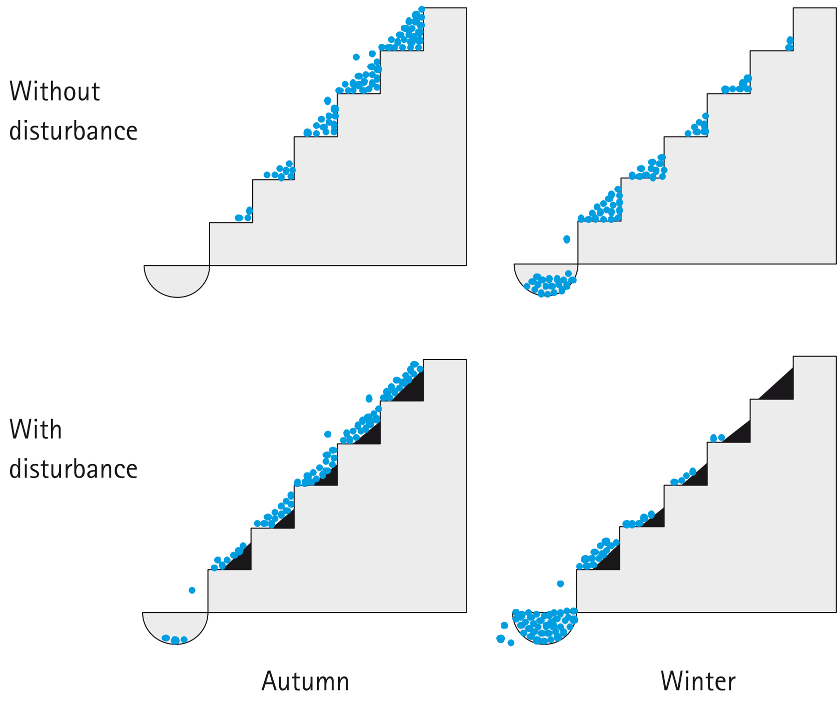

Figure 1: A schematic "marble model" illustrating how disturbance in autumn can have a density dependent impact on population size in migratory waterbirds when winter resources are limited. Marbles illustrate birds which in autumn position themselves as northerly as possible on the flyway (the highest steps on the stair). As food resources are gradually depleted or naturally dying off, birds move south towards the ultimate wintering area (the bowl). In an undisturbed situation, birds make full use of resources before reaching the wintering quarters. In a situation where disturbance reduces the available food supplies (shown by shaded wedges), birds are pushed down the flyway. This will result in increased competition for resources on the wintering grounds, with an increased mortality risk or emigration, illustrated by marbles spilling over the edge of the bowl. The number of birds, i.e., population size, is the same in both scenarios. Source: Madsen and Fox (1997).

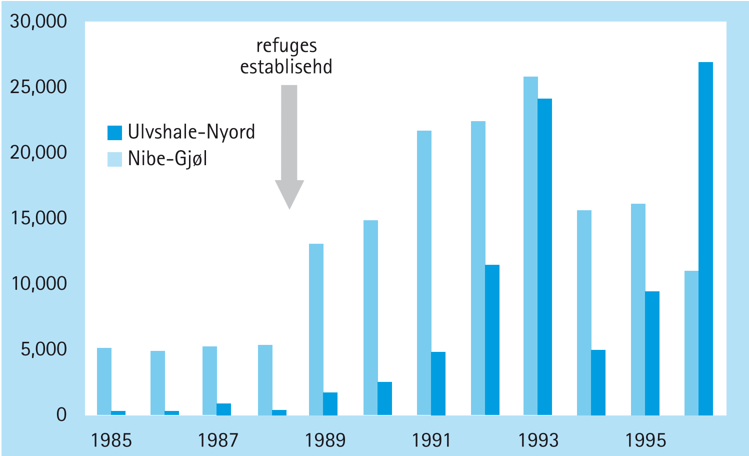

Figure 2: Peak numbers of Wigeon (*Anas penelope*) in two Danish coastal wetlands before and after refuge creation. In Ulvshale-Nyord, Wigeon hardly occurred before refuge creation; since then the area has in some years become the most important single site in Denmark; however, numbers fluctuate depending on water level conditions in autumn. In Nibe-Gjøl Bredning, numbers increased dramatically after refuge creation but have decreased since 1993 due to a serious decline in eelgrass abundance which is the primary food source of the Wigeon on that site. Source: Madsen (1998b).

were still abundant. In the Danish Wadden Sea, it was also demonstrated that autumn-staging dabbling ducks foraging on salt marsh plant seeds left areas with hunting without significantly using the resources, whereas in the adjacent reserve, seeds were depleted (Madsen, 1988).

Another case of flyway impact of disturbance is provided by spring migration of Pink-footed Geese (*Anser brachyrhynchus*) on the Denmark-Norway-Svalbard flyway. In the course of the 1990s, farmers in northern Norway increasingly implemented a systematic campaign to scare geese away from grasslands on which geese and sheep with their lamb were competing for the sprouting pasture grasses (Tombre *et al.*, 2005). In these ultimate spring staging areas, Pink-footed Geese rapidly build up energy stores for the subsequent migration and nesting in Svalbard. As a consequence of the scaring, geese were unable to gain weight, and the body condition in which they departed for Svalbard decreased during the years of the scaring campaign. Furthermore, it was demonstrated that both subsequent fecundity and survival was related to the condition in which geese departed from northern Norway (Madsen, 1994, Madsen unpubl. data). On basis of the empirical data, an individual-based model was developed to predict the impact of scaring in northern Norway on the migratory decisions and fitness of geese. It was predicted that an outcome of scaring would be a redistribution of geese along the flyway. Furthermore, the outcome of the modelling exercises were highly dependent on whether or not the geese were omniscient or naïve, i.e., not familiar with the scaring regime (which was the case due to introduction of scaring in the alternative staging area in mid Norway); hence, at moderate scaring levels naïve geese were predicted to succumb. On a qualitative basis we found good correspondence between the predictions from the model and the empirical evidence gathered to date (Klaassen *et al.*, 2006).

A third example of flyway impacts of disturbance comes from southern Quebec, Canada which is a major spring-staging area for Greater Snow Geese (*Anser caerulescens atlanticus*), breeding in Arctic Canada. Spring hunting has been introduced to control the population size. As a side effect, disturbance of geese has increased (Béchet *et al.*, 2004); similarly to the case of the Pink-footed Geese, it has been demonstrated that the body condition of geese at departure has decreased (Féret *et al.*, 2003) and that the fecundity of female geese has possibly been affected (Mainguy *et al.*, 2002).

In all three above-mentioned examples, disturbance was massive and it was a targeted human persecution. Hence, they describe extreme disturbance events which are very different in scale and intensity compared to the diffuse effects of recreational activities in general. Furthermore, at least in the two examples with geese, disturbance took place at a crucial time in the life cycle of the birds, *viz.* fuelling up at the final staging area before migration to the breeding grounds. In case of the Pink-footed Geese, we know that alternative sites are not at hand at the northernmost staging area; hence, food availability is limited. Finally, in the three examples, habituation to the disturbance source is not an option!

Is recreational disturbance in the Wadden Sea likely to have an impact?

During the last decades, the level of protection in the Wadden Sea has increased due to the international effort to improve the conservation of the area. Therefore, it is counterintuitive that disturbance in itself inside the Wadden Sea has caused the observed population declines. The Wadden Sea Quality Status Report (2004) stated that recreational activity in the Wadden Sea is stable or partially increasing (Dutch part); however, regulation is in place to mitigate adverse disturbance; possibly there remains a problem with some breeding species, such as Kentish Plovers (*Charadrius alexandrinus*) nesting on beaches. According to national experts, the intensity of recreational activities in core areas used by migratory species is generally negligible (*e.g.*, K. Laursen, pers. comm.). This raises the question whether the general indicators used as a measure of the intensity of recreational activity are sufficient and appropriate to be used in an evaluation. I propose that experts on migratory birds shall evaluate the efficiency of the indicators in the light of the biological information needed to judge about disturbance pressures.

In theory, some of the observed negative trends may result from the generally improved conservation outside the Wadden Sea, such as the creation of a refuge network in Denmark, or protection of species in western Europe in general which may have halted or diverged the migration to other regions. This emphasizes the need to interpret the Wadden Sea trends in a flyway perspective.

To conclude, I find it unlikely that disturbance inside the Wadden Sea is responsible for the observed declines in bird populations in the Wadden Sea, with the exception of breeding birds which need careful conservation management.

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Final penal discussion at the workshop. From left to right: Hermann Hötker (Wader Study Group) with the speakers Jan Blew, Jesper Madsen, Franz Bairlein and Theunis Piersma **(Photo: Nationalparkverwaltung).**

Recommendations of the International Workshop "Seriously Declining Trends in Migratory Waterbirds in the Wadden Sea"

Wilhelmshaven, Germany August 31, 2006

The Workshop

The Wadden Sea constitutes one of the world's most important wetlands for migratory waterbirds and the single most important staging, moulting and wintering area for waterbirds on the East Atlantic flyway from the Arctic to South Africa.

According to the results of the twenty-year period 1980-2000 of the Joint Monitoring of Migratory Birds (JMMB) program in the Wadden Sea, which is carried out in the framework of the Trilateral Monitoring and Assessment Program (TMAP), decreasing trends of several migratory waterbird species were detected in the Wadden Sea. Particularly, the trends detected for the main migration periods gave reason for concern: of the 34 species, for which the Wadden Sea represents a major stepping stone during migration, 15 species (44%) show significant decreases, 7 species (21%) show non-significant decreases. In contrast, only three species (Cormorant *Phalacrocorax carbo sinensis*, Spoonbill *Platalea leucorodia* and Barnacle Goose *Branta leucopsis*) show significant increases.

Also on a global scale concern has been expressed regarding migratory birds. On a workshop held by the International Wader Study Group in Cadiz/Spain in 2003, it was noted that the populations of waders (shorebirds) are in decline worldwide. With respect to the Wadden Sea, it was stated that "*Declines of the biogeographic popu-*

lations of long-distance migrant waders heavily dependant on the Wadden Sea have occurred and are continuing."

Activities, which should be taken in connection with these declines, should also be seen in light of the World Summit on Sustainable Development (Johannesburg/South Africa 2002), at which world leaders expressed their desire to achieve "*a significant reduction in the current rate of loss of biological diversity*" by 2010, as well as of the Heads of European Union Member States, who met in Gothenburg/Sweden 2001, and expressed their intention "*that biodiversity decline should be halted ... by 2010.*"

To mark the 20th anniversary of the Wadden Sea National Park in Lower Saxony the National Park Administration of the Lower Saxony Wadden Sea, the Common Wadden Sea Secretariat and the Institute of Avian Research "Vogelwarte Helgoland", Wilhelmshaven organized an international workshop in Wilhelmshaven, Germany on 31 August 2006 to discuss causes and consequences of seriously declining trends in migratory waterbirds in the Wadden Sea as well as to formulate further aspects regarding future ecological research and necessary management measures. About 80 leading Wadden Sea experts from Denmark, Germany and the Netherlands participated in the workshop including representatives from English Nature and AEWA.

The workshop started with a review of recent monitoring data. The review confirmed that the populations of at least 11 out of 34 species have declined significantly over the past years. Especially shellfish-eating species have shown significant decreases.

Further presentations related to recent changes in the Arctic breeding areas and along the migration route, responses of birds to climatic change, feeding ecology of waterbirds in the Wadden Sea, as well as case studies on disturbance of waterbirds.

Main findings of the workshop

Climate change

Climate change will affect waterbird populations in the Wadden Sea in different ways, either directly by habitat loss and habitat change due to sea level rise and by changes in weather characteristics, or indirectly by habitat changes in the arctic breeding grounds and changes of the food resources respectively. In addition, changes in temperatures and other environmental factors may cause changes in the food availability on the tidal flats in the Wadden Sea. Signals of the probably already ongoing processes are confounded by various other factors influencing the populations of migratory waterbirds.

Disturbance

Disturbance can influence individual birds up to whole populations. At present, disturbance within the Wadden Sea, however, is unlikely to be the main cause for the observed large-scale population declines in migratory species due to the increased protection level. However, the recent review "High Tide Roosts in the Wadden Sea" has shown that the distribution of waterbirds is susceptible to high levels of disturbance. In addition, disturbance still may have an effect on the populations of some species breeding in the Wadden Sea (*e.g.* Kentish Plover *Charadrius alexandrinus*).

Food resources

As a case study the effects of cockle fishery were highlighted. The decline in biomass and in quality (as diet for migrating waterbirds) of shellfish stocks due to bottom fishing in the Dutch Wadden Sea have caused declines in the survival and consequently the numbers of migrating Red Knots (*Calidris canutus*) on population level and probably other shellfish feeders. The process of recovery of dredged mudflats is very slow.

Breeding/Wintering areas

Conditions for migratory waterbirds in their Arctic breeding grounds are changing in many respects (*e.g.* hunting, disturbance, habitat change). Very probably this will also be valid for the wintering grounds. Causal links between these changes and the observed declines of migratory and wintering populations in the Wadden Sea are yet poorly understood.

Monitoring

It is greatly acknowledged that due to the efforts of the Joint Monitoring Program for Migratory Birds (JMMB) in the framework of the Trilateral Monitoring and Assessment Program (TMAP) the amount and quality of migratory bird data has increased considerably over the last two decades and that the information on population trends of migratory waterbirds in the Wadden Sea has been made available at short notice and therefore meet the monitoring obligations of the trilateral policies and relevant international regulations such as the EC Birds and EC Habitats Directives and AEWA.

Ongoing monitoring is needed in order to keep track with the development of Wadden Sea bird populations and in order to evaluate the effectiveness of conservation measures.

Recommendations

In order to halt the observed declines of migratory waterbirds in the Wadden Sea and aware of the fact that immediate actions should have first priority, combined with research studies, the participants of the workshop concluded and recommended:

1. The current protection level regarding migratory birds in the Wadden Sea (*e.g.* in relation to disturbance) has to be maintained or improved.

2a. The mechanical dredging for cockles (*Cerastoderma edule*) has been shown to significantly reduce the intertidal food resources for the Red Knot. The decline of the population can be explained by a reduced survival rate due to reduced food resources. Consequently, dredging for cockles should not be allowed in the Wadden Sea.

2b. There is also evidence that mussel fisheries have affected Oystercatcher (*Haematopus ostralegus*) and Common Eider (*Somateria mollissima*) populations in the Dutch Wadden Sea. Consequently, shellfish-fisheries and other bottom-affecting activities should be assessed in combination with the population trend of the concerned species in the Wadden Sea. The results should be taken into consideration for further revision of relevant management plans in the Wadden Sea.

3. The direct or indirect release/introduction of alien species in the Wadden Sea should be prevented as far as possible. The spread of the Pacific Oyster (*Crassostrea gigas*) already poses a big threat to natural benthic communities in a wide area and therefore also for birds feeding on benthic species.

4. Long-term monitoring of bird populations in the Wadden Sea is essential for detecting changes in population trends and for measuring the efficiency of protection measures. The current level of monitoring has to be maintained as a minimum. Furthermore,
   - improved monitoring (smaller counting intervals, turn-over studies etc.) with regard to particular research questions should be carried out in selected countries and regions;
   - monitoring of breeding success and survival of waterbirds breeding in and migrating through the Wadden Sea (integrative monitoring) is necessary for a sound understanding of the demographic features underlying the population changes;
   - the JMMB program should be integrated with other international monitoring initiatives; in particular the monitoring of waterbirds in the Artic breeding grounds and African wintering areas should be reinforced and internationally coordinated.

5. For most species in the Wadden Sea – except for the knot – the causes of the declines are not well understood. Since there are many factors, which are possibly relevant for the bird populations (climate, eutrophication and pollution, socio-economic aspects etc.) as well as management systems/protection regimes in the different Wadden Sea regions, it is necessary to enlighten the actual role they play in more detail.
   - In a first step, complex analyses of the available data of the influencing factors in relation to the bird data should be carried out;
   - In a second step, based on the results of these analyses, targets for further research can be identified, which will reveal the causal relationships and processes involved in the observed population dynamics.

6. Indicator species and core sites in the Wadden Sea should be identified for long-term studies on the ecology of Wadden Sea birds. These studies should be focussed on food resources, habitat quality and disturbance sources in the Wadden Sea, to explain underlying processes of population developments. Such studies should primarily aim at the evaluation of turn-over-processes, the assessment of the carrying capacity of the Wadden Sea or the appraisal of the conservation status.

7. Measures for halting the observed declines can only be implemented if the causes of the declines are understood. Studies into possible causes of the observed declines, therefore, are urgently required. Such studies have to be species-specific.

   The following topics are of top priority and appropriate studies should be started soon (results should be available before the next trilateral Wadden Sea Conference in 2010):

- Studies of the diet and the numerical response to food densities/quality in a range of species, especially during the stopover periods and in midwinter period when stresses are highest.
- Improved studies of the distribution, density and quality of benthic food organisms utilized by waterbirds and the factors influencing them. Emphasis on anthropogenic factors like dredging and other mechanical disturbances of the mudflat surfaces.
- The quality of roosting sites as well as the role of disturbance (at the current level in the Wadden Sea) in context of decreasing waterbird populations is still unclear and therefore needs to be studied further.
- Studies of relevant factors for the population dynamics of waterbirds outside the Wadden Sea within the flyway context of the population, *e.g.* predator-prey systems and weather in the Arctic as well as in African wintering areas or other critical stop-over sites.
- Models for predicting the reactions of waterbird populations on the flyway level become increasingly available. Studies should focus on parameterizing these models.