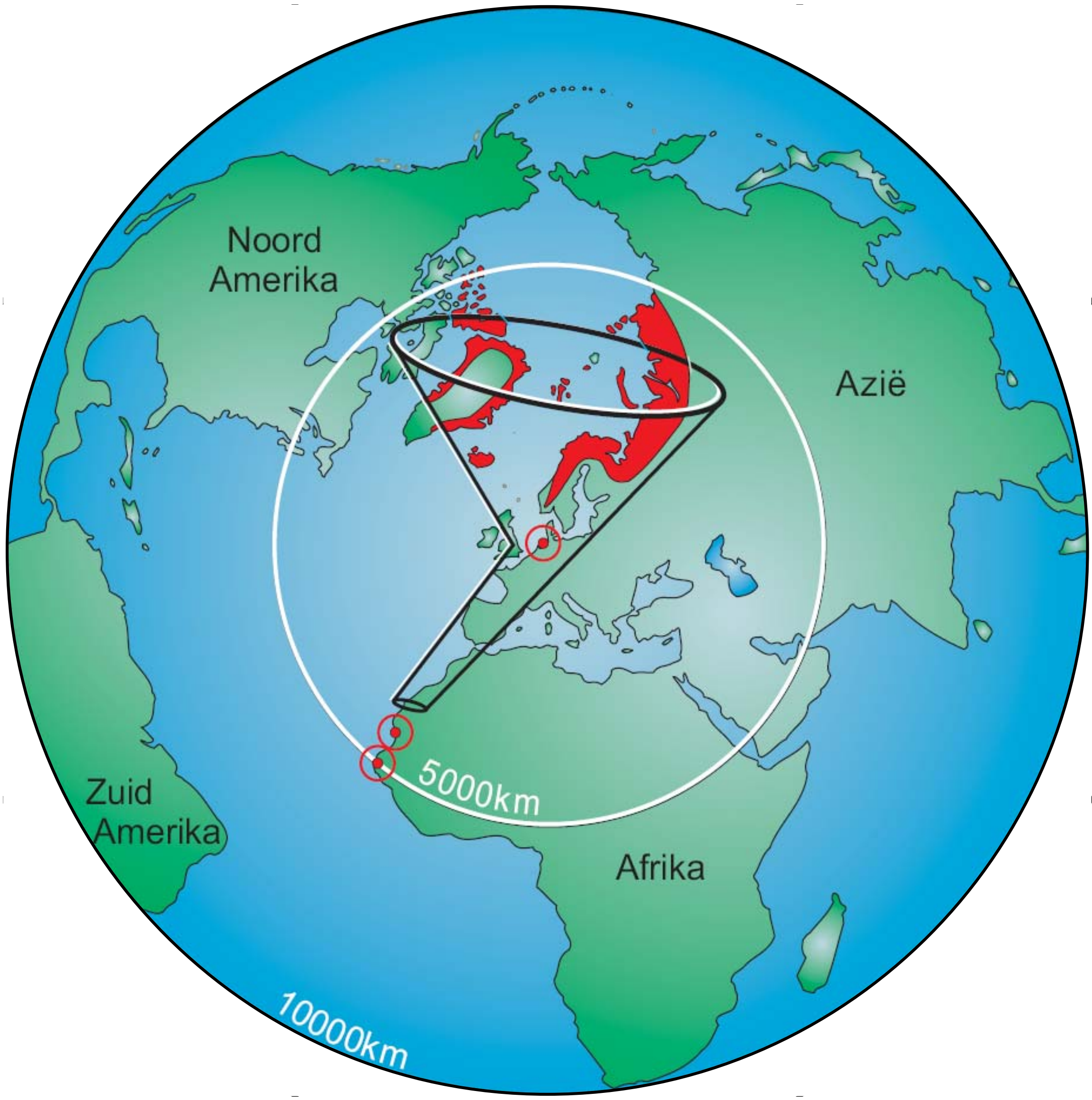
Towards *Integrated Population Monitoring* of *birds* of the Wadden Sea



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Cover picture shows the Wadden Sea as a crucial link in the East-Atlantic Flyway; a crossroad for birds on their way from Arctic breeding grounds to their African winter quarters and back (J. Reneerkens).

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Contents

Introduction

The Wadden Sea is a tidal area of crucial importance for millions of birds. Migratory birds use the area as a stopover site to refuel for long flights between wintering areas in West Africa and the Arctic breeding grounds between Northern Canada and Siberia. In this East-Atlantic Flyway, the Wadden Sea provides a crucial link. Breeding birds critically depend on the intertidal, subtidal and pelagic food resources that enable them to rear their offspring (van de Kam *et al.* 1999; Reneerkens *et al*. 2005).

Important components of the Wadden Sea ecosystem are the high densities of shellfish and worms. Especially the abundance of shellfish, or benthic fauna, enables the occurrence of highly specialised bird species, which are unique for this ecosystem. The vegetation of the salt marshes is utilised by geese and ducks for feeding, and by shorebirds, gulls and terns for breeding. Gulls, terns, mergansers, Egrets, Spoonbills and Cormorants prey upon the abundant small fishes. Biogenic structures like mussel beds and seagrass beds play an important role in the sediment cycles of the Wadden Sea and form biodiverse communities that offer a predictable food source for many bird species. Saltmarshes and sandbanks are used as high tide roosts where the shorebirds can stay undisturbed.

Most of the bird species that depend on the Wadden Sea are long-distance migrants that combine use of the Wadden Sea with breeding and wintering sites ranging from Southern Africa to High Arctic Canada and Siberia, and emphasize the key-role of the Wadden Sea in international biodiversity and ecosystem functioning. This high value to biodiversity of the Wadden Sea has been laid down in various international conservation agreements (e.g. EU Bird and Habitat Directives, RAMSAR Convention and the Africa Eurasian Waterbird Agreement). It has led authorities to propose to UNESCO to recognize the international importance of the Wadden Sea by assigning it the status of world heritage site. The Wadden Sea countries have also recognized the need to monitor the natural values of the Wadden Sea by installing the trilaterial monitoring and assessment program (TMAP).

However, the natural values of the Wadden Sea area are threatened by human activities. Large-scale exploitation of shellfish by bottomdredging fisheries severely affects the sediment and deprived birds of their food (Ens *et al*. 2004; Piersma *et al*. 2001). Shrimpfisheries probably result in many by-catches of non-target species (Walter & Becker 1997). Increasing mass-tourism and military activities disturb birds at high tide roosts and communal moulting areas (Krijgsveld *et al*. 2004; Heunks *et al*. 2007). Spatial developments, such as the construction of windfarms and the extension of industrial harbours, decrease the area available to birds for foraging or roosting (Witte & van Lieshout 2003). The impact of the large-scale exploitation of natural gas in the Wadden Sea is still largely unknown and difficult to quantify, but these activities warrant close scrutiny.

Many birds that make use of the Wadden Sea are in decline (Blew *et al.* 2007; van Roomen *et al*. 2005). Two species that stay in the Wadden Sea area year-round (Eider and Oystercatcher) are severely declining compared to elsewhere in their range. This indicates that the causes of these negative developments to a large extent have to be sought within the Wadden Sea, rather than elsewhere along the flyway (Reneerkens *et al*. 2005). However, as many birds spend part of the annual cycle in other areas along the East-Atlantic flyway, changes elsewhere may also affect these birds (e.g. Meltofte et al. 2007). For example, wintering shorebirds are also declining in estuaries along the west coast of the UK, but increase along the east coast, and these changes are related to global warming (Austin & Rehfisch 2005.

Birds can be used as reliable indicators of the state of the Wadden Sea ecosystem. Nowadays we have good knowledge of the (trends in) bird numbers in the Wadden Sea. However, threats to bird populations are often recognised too late, and just looking at bird numbers does not reveal the causes of the negative trends. We therefore propose to intensively study twelve typical Wadden Sea bird species that utilise the Wadden Sea area in different ways. By integrating detailed studies on survival, reproduction, condition, total numbers and distribution of Wadden Sea birds, it will be possible to detect negative and positive developments of bird populations at an earlier stage than by counting only. Furthermore, by making strategic comparisons between developments of different "indicator species", and by comparing local developments in the

Wadden Sea with developments elsewhere, we will be better able to pinpoint the most important bottlenecks for Wadden Sea birds, and take appropriate actions.

Aim of this document

The aim of this document is to first describe what goal an Integrated Population Monitoring program in the Wadden Sea serves: creating an annual index of the state of Wadden Sea birds. We subsequently describe how this can be achieved using IPM, and explain what the IPM program entails. We will present twelve model species that should be monitored intensively in the IPM program. A brief description of the present state shows that parts of the monitoring program are already in place, but these need to be gathered under the "IPM-umbrella" in order to achieve standardisation. For most species, additional projects have to be set-up. We present a number of steps that have to be taken to achieve this.

A more detailed description of current projects and basic information on the selected model species is given in two appendices.

Goal: an annual index of the state of Wadden Sea birds

The ultimate goal of the IPM program that we outline here is to construct an *annual index* of the state of Wadden Sea birds using a selection of representative and easy-to-study bird species that can serve as indicators. The idea has much in common with the UK Farmland Bird Index (Gregory *et al*. 2005), but goes well beyond it because in addition to numbers and distribution, we propose the use of demographic information as well as data on the condition of individual birds and their food supply. Building the annual index based on Integrated Population Monitoring serves a number of main purposes:

1. Creating an ***alert system*** that reacts to (potential) threats at an early stage.
2. ***Safeguarding*** the continued existence of bird species for which the Wadden Sea plays a crucial role, via the identification of crucial life stages that influence changes in population size.
3. ***Evaluating*** favourable conservation status of selected species as requested by the EU Bird and Habitat Directive and evaluating management policies.
4. ***Explaining*** observed trends in numbers and distribution from underlying demographic changes
5. ***Predicting*** future population developments under different scenarios

rate of population change

The annual index will be largely based on indices of the rate of population change, derived from IPM models, for all model species combined or for any combination of species regarding habitat, diet, taxonomy or conservation status. Since this estimate is not only based on count data, but stems from population models integrating count data *and* demographic data (box 2), it reacts more quickly to changes in the underlying processes (*early warning*) and has more predictive power, making it possible to forecast population trajectories for a number of years, depending on the longevity of the species considered (Figure 1). For each species, it is also possible to use IPM to pinpoint the most *crucial life stages* that influence changes in the population size (Figure 1). This information is important as it enables us to target conservation efforts at the appropriate scale, time of year or habitats.

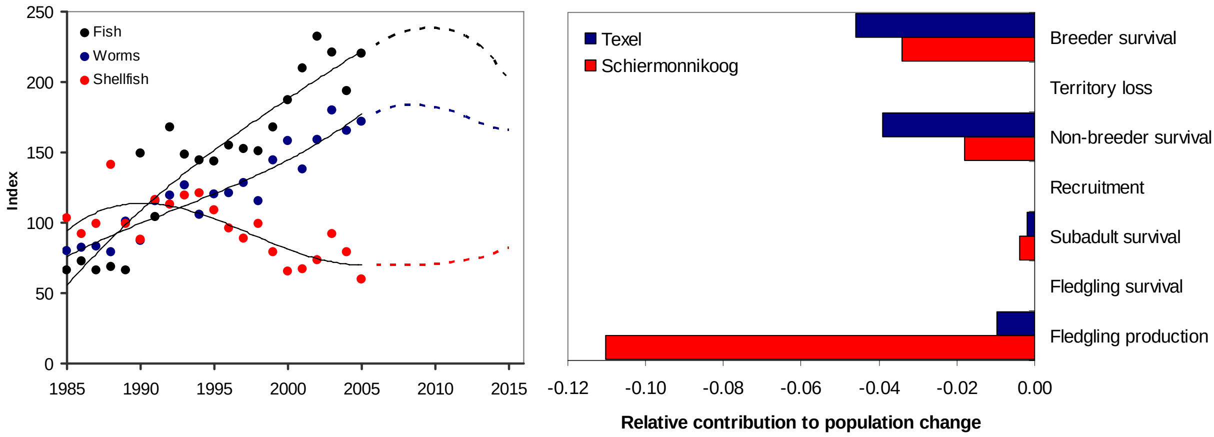

Figure 1. *Left: Actual and forecasted population trends of model species in the Wadden Sea by diet (fish, worms or shellfish; after van Roomen et al. 2005, 2006). Right: relative contribution of life stages that influence the change in size of two Eurasian Oystercatcher populations in the Dutch Wadden Sea based on Integrated Population Modelling (observed change x sensitivity, modified after Oosterbeek et al. 2006).*

Condition

The IPM index can be complemented by incorporating measures of *condition* of birds belonging to the target species. Adequate measures of condition can increase the *early warning* effect since especially in long-lived species, ecosystem deterioration is seen first in reduced condition (eg. Verhulst *et al*. 2004) before reproduction and survival are affected. Apart from the widely-used body mass residuals, blood samples may be taken to establish haematological parameters (hematocrit, buffy coat) that serve as indicators of condition. Condition measures can be included directly into the index in a way yet to be established, or can be presented separately for all species.

Parallel program: monitoring the food supply of Wadden Sea birds

At a later stage, monitoring of the food supply that selected bird species depend on in the Wadden Sea, can be a useful addition to the IPM program. Three broad categories of food can be distinguished: shellfish, worms, and fish (Figure 1). Food is not homogeneously distributed but, instead, occurs in patches. By mapping food densities within patches, the number of patches and patch sizes annually, temporal and spatial variation in food can be compared to changes in bird distribution, numbers, demography and condition. For example, ever since the early 1990s shellfish-eating shorebirds are decreasing in the Dutch Wadden Sea, while worm-eating shorebirds are increasing in numbers (van Roomen *et al*. 2005, 2006). These changes seem to run parallel to changes in food densities: shellfish stocks, at least the available fractions for migrant shorebirds, have collapsed, while worm-stocks show an upward trend (Kraan *et al*. 2007).

What is Integrated Population Monitoring?

Effective conservation and management of bird populations requires a sound understanding of the underlying biological processes. Environmental changes, often resulting from human activity, will alter resource availability and such changes in environmental factors will affect the *vital rates* (fecundity, survival and movement), which in turn determine population size. Integrated Population Monitoring (IPM) involves the *simultaneous* monitoring of numbers and vital rates in order to indicate changes in population size and also serves to indicate the likely causes of population change by identifying the *stage of the life cycle* affected by environmental changes.

IPM thus requires that numbers as well as vital rates of a number of model species are monitored simultaneously. Box 1 lists the different ingredients that are needed for a successful IPM program.

BOX 1. IPM Ingredients

Population size

Estimates of population size can be obtained from full counts at relevant times of the year, i.e. mid winter or during migration peaks. Breeding birds can be best monitored through breeding bird censuses at a sufficiently large number of representative sites or, alternatively, by integral counts of breeding pairs or nests for scarcer species or colonially-breeding species.

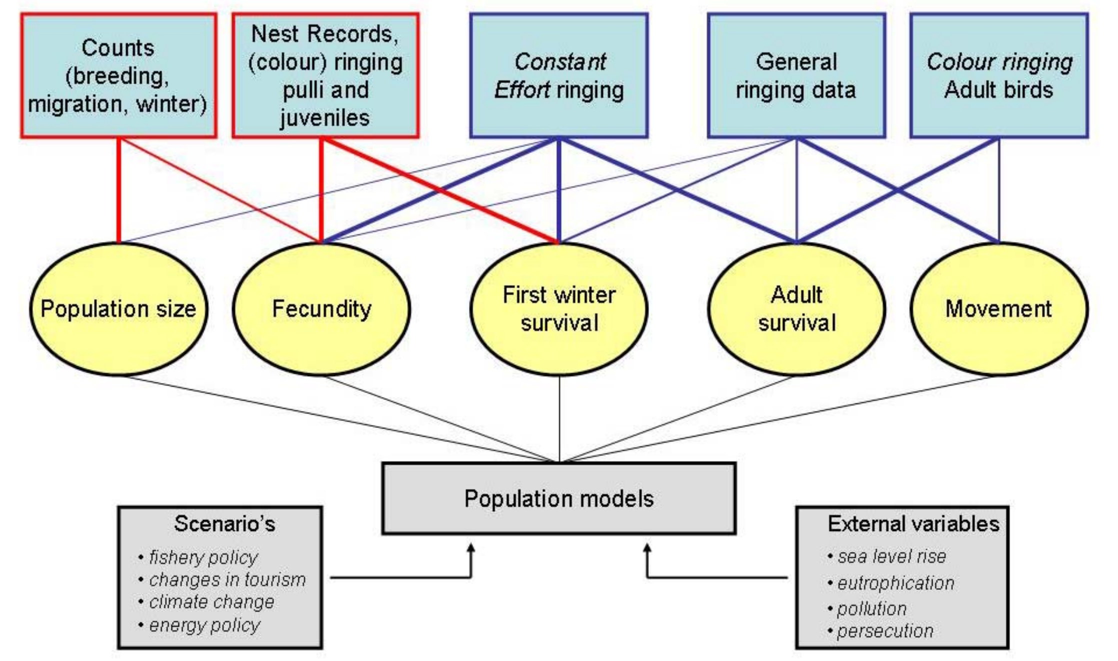

Figure 1. *Schematic overview of measuring and monitoring techniques (blue boxes) that can yield data to estimate IPM parameters (yellow ovals) that can subsequently be fed into population models that project the rate of population change and can be used to model the effects of certain scenario's or external variables (grey boxes). Modified after Greenwood et al. (1993)*

Fecundity

Measures of fecundity can be obtained by detailed studies of clutch size, hatching success, and nest failure rates (using the Mayfield method) of breeding birds. However, there are shortcuts possible for birds that breed outside the Wadden Sea by visually estimating juvenile recruitment (the method, of course, also works for local breeding birds that stay in the Wadden Sea). In autumn, the young of most shorebird species, geese, terns and gulls can be recognised visually in the field before they have moulted their juvenile plumage. Statistical methods have been developed to collate observations from different periods, sites and flock-sizes into indices of juvenile recruitment (Clark *et al.* 2006).

Survival and movement

Measuring survival and movement (immigration, emigration) requires that individual birds can be followed through time. For many years, recaptures and dead recoveries of birds marked with metal rings have been the primary source of information to estimate these parameters. However, due to the generally low recovery and reporting rates, estimating demographic rates using metal rings requires large sample sizes and long time series. The use of individual colour-marks combined with dedicated effort to read these marks from a distance can greatly improve the precision of such estimates, even at short time-scales and with fewer birds marked. Ringing efforts can be specifically targeted at measuring adult survival by (re)capturing adult birds at the nest, by constant effort ringing at fixed locations and time intervals, i.e. by setting up local ringing groups, or at measuring post-fledging and first-year survival by ringing (large numbers of) pulli or juvenile birds.

According to capture-recapture theory, the numbers of individuals that represent similar, unique time series of presence-absence, so-called capture-histories, follow a multinomial distribution, and can be used to construct Maximum Likelihood estimates of the probabilities of survival, recapture, and movement.

The integration of information on vital rates with estimates of population sizes can be achieved in a number of ways, and requires a great deal of sophisticated modelling (box 2).

Traditionally, mark-recapture studies are used to estimate annual survival probabilities (box 1). Other studies estimate population size or indices of population size, i.e. census data. To investigate whether census data are compatible with the estimated survival probabilities, survival rates (and measures of fecundity) can be incorporated into population models in an attempt to explain the observed population declines (Freeman *et al*. 2007; Box 2). This is a first and fruitful step towards Integrated Population Modelling. However, these approaches ignore the sampling variability of the estimators of the demographic rates. To come around this problem, it is important to realise that census data themselves also contain information on survival. By modelling census data and demographic rates simultaneously, imprecision and correlation in the estimators are treated more accurately and all available data is used in the most efficient way (Besbeas *et al*. 2002; 2005; Thomas *et al*. 2006; Box 2). .

BOX 2. Population models

There are several ways to treat integration of count data with vital rates. Traditionally, estimates of vital rates obtained from field studies are collated into age- or stage-structured matrix population models. The predictions from these models are then contrasted with the count data. It is also possible to use a deterministic population model, and use a Generalized Linear Model (GLM) to obtain estimates of the (changes in) population size incorporating site-specific data. The method is briefly illustrated here, based on Freeman et al. (2007):

Consider a deterministic population model:

$$N_{j+1} = N_j\,(\varphi_{aj} + \varphi_{1j}\varphi_{pfj}\, pFPA_j) \qquad 1a$$

Where $FPA_j = CS_j \times HS_j \times (1 - EFR_j)^{EP} \times (1 - NFR_j)^{NP}$ 1b

And N_j = population size in year j; N_{j+1} = population size in year j + 1; φ_{aj} = adult survival; φ_{1j} = first year survival; φ_{pfj} = postfledging survival; p = number of breeding attempts. CS = clutch size; HS = hatching success; EFR and NFR = nest failure rates during the egg and nesling stage; EP and NP = lengths of the incubation and nestling periods.

Applying Eq. (1a) recursively over T years we get:

$$N_j = N_1 \times \prod_{i=1}^{j-1} (\varphi_{ai} + \varphi_{1i}\varphi_{pfi}\, pFPA_i) \qquad 2$$

And hence:

$$\mathrm{Ln}(N_j) = \ln(N_1) + \sum_{i=1}^{j-1} \ln(\varphi_{ai} + \varphi_{1i}\varphi_{pfi}\, pFPA_i), \qquad 3$$

Substituting into a model of bird counts where the expected population size μ depends on factors specific to site (S) and total population size in that year (N):

$$\ln(\mu_{ij}) = \ln(S_i) + \ln(N_j) = s_i + n_j \qquad 4$$

yields:

$$\ln(\mu_{ij}) = s_i + \ln(N_1) + \sum_{i=1}^{j-1} \ln(\varphi_{ai} + \varphi_{1i}\varphi_{pfi}\, pFPA_i), \qquad 5$$

since the year-specific survival estimates, and the year-specific productivity parameters are known, the only unknown parameters in the equation are the initial population size N_1, the site effects s_i and the number of breeding attempts *p.* P is usually known from field studies or literature, and thereby the whole last term of the equation can be replaced by a single symbol (k_j) for simplicity:

$$\ln(\mu_{ij}) = s_i + \ln(N_1) + k_j$$

This model can be fitted in most statistical packages using GLM. The next step then is to test all possible combinations of constant versus time-varying parameters for survival and fecundity (theoretically it would also be feasible to incorporate parameters estimates for movement between sites) and use Maximum Likelihood to evaluate which combination best predicts the observed trend from the count data. We can thus identify the most crucial life stages.

Unfortunately, this approach ignores the fact that the count data themselves also contain information on the underlying vital rates. This is particularly unfortunate because count series often span several decades, covering a large variety of changing environmental conditions, and thus potentially enabling scientists to detect the intrinsic and extrinsic drivers of population dynamics. By specifying the relevant population processes in one integrated statistical model that includes all available data sources in the estimation process, a more efficient use of data is achieved, resulting in better estimates. The idea can be easily illustrated by recalling equation 1a:

$$N_{j+1} = N_j\,(\varphi_{aj} + \varphi_{1j}\varphi_{pfj}\ pFPA_j)$$

Where N are estimates of the population size and φ are estimates of survival. When estimates of N are *known* from census or count data, Maximum Likelihood estimates of φ can be obtained from the Likelihood of the census data L_c. At the same time, Maximum Likelihood estimates of φ can be obtained from capture–recapture studies, where Lr is the likelihood derived from the multinomial probabilities of the different capture-histories (Box 1). Both Likelihoods can then be combined into one joined Likelihood, $L_j = L_c L_r$, yielding a single ML estimate of φ based on both census and capture-recapture (or recovery) data (Besbeas et al. 2002; 2005).

The recent introduction of Bayesian state-space models (Thomas et al. 2006; Ter Braak 2006) have made it possible to fit complex models where separate likelihood functions for all kinds of data sources (e.g. counts, colour-mark resightings, ring recoveries and recruitment observations) can be be combined by maximizing the joint likelihood L_j. This new, alternative approach is now being developed further and will soon be ready for implementation in the Wadden Sea IPM. However, the simplicity of the GLM approach as described above makes this method more accessible, and can be used as a first step towards IPM.

An IPM framework for the Wadden Sea

There is already a wide variety of studies on birds in the Wadden Sea, including many long-term single-species studies and monitoring projects that target multiple species. Most of the relevant studies are listed in Appendix 1. We envisage that Integrated Population Monitoring of birds in the Wadden Sea makes as much use as possible from these ongoing studies, by providing a common framework rather than by setting up new parallel research activities on the same species. In this setup, the scientists involved in these ongoing studies join forces under the umbrella of the IPM program, contributing their data for joint analysis and reporting and where necessary making adjustments to existing routines enabling collection of data relevant to IPM. The program will adopt a selection of 'target species' amenable to IPM. A provisional selection of thirteen species is outlined here (Figure 2) and additional information on these species is given in Appendix 2. The species have been selected on the basis of three important criteria: 1). The Wadden Sea represents an important part of their *distribution* during either the breeding- or the non-breeding season; 2). The species migratory habits *connects* the Wadden Sea to area's elsewhere in the species range; and 3) the species should be comparatively easy to study. The thirteen selected species include seven out of the twelve high priority species selected for inclusion in the *TMAP monitoring scheme for breeding success* (Koffijberg 2008). The other six species only occur as non-breeding visitors to the Wadden Sea. Not all of the target species are currently fully covered (i.e. including numbers, breeding productivity, survival parameters, and condition) by existing studies and programs. We envisage that these gaps are identified and filled –if funding can be ascertained- by setting up new research activities or additions to existing studies.

What data are needed?

- *Numbers (high frequency))*
    - Wintercounts
    - Migration-peak counts
    - Monitoring of breeding birds
- *Reproductive success*
    - Local
    - Large-scale juvenile counts
    - Juvenile proportions in catches
- *Survival*
    - (Colour)ringingprogrammes breeding birds
    - Coordinated capture-recapture programmes for migratory and wintering birds
- *Additional information*
    - Condition measures of birds
    - Species-specific diet
    - Monitoring the food supply
    - Low-tide distribution of foraging birds
    - Year-round distribution of Wadden sea birds using ringing

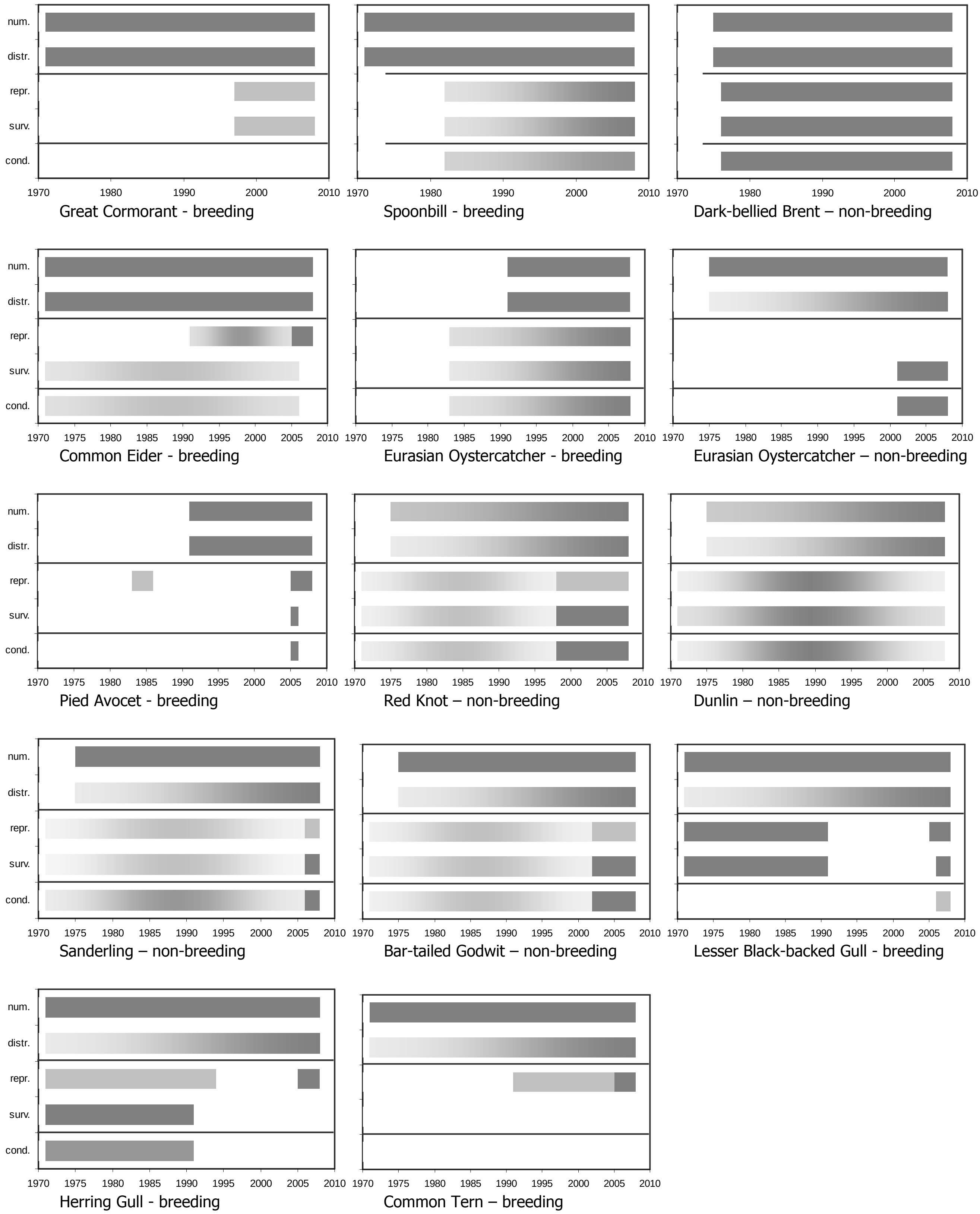

Figure 2. *Selection of IPM species. Bars indicate monitoring of numbers, distribution, reproduction, survival and condition from 1970 to present. Darkness of bars indicates the intensity of the studies.*

IPM Wadden Sea: State of the Art

Data collection

At present, monitoring of numbers and distribution in the Dutch Wadden Sea of all thirteen proposed target species is adequately covered by the schemes of the "Network Ecological Monitoring" from GAN/CBS, coordinated by SOVON (at least since 1975) and in the German and Danish Wadden Sea by the activities of TMAP (since 1991). However, for some species, additional counts during the migration peak are needed to be able to estimate the maximum number using the Wadden Sea. At present, the low-tide distribution of foraging birds is largely unknown and cannot be linked to data on their food supply.

Monitoring of breeding success, and especially survival and condition, is fragmentary and continuation is not guaranteed by inclusion into long- term schemes for a number of species (e.g. Common Eider, Pied Avocet, Lesser Black-backed Gull, Herring Gull, Common Tern). In other, non-breeding migratory shorebirds, monitoring of reproduction (through identification of juvenile birds during catching) and survival (from ringing with metal rings) does occur, but at an intensity that is (far) too low to yield accurate and representative estimates (e.g. Red Knot, Dunlin, Sanderling, Bar-tailed Godwit), although small colour-ring schemes have been set up recently for some species. Yet other species are fully covered at present within special projects, but activities rely almost entirely on the efforts of volunteers, while time that can be allocated to coordination of the work by professionals is limited, often not part of their professional duties and therefore entirely at the merit of their employers (e.g. Spoonbill, Dark-bellied Brent, Oystercatcher).

Data analysis

Analyses of numbers, distribution, and reproduction of a number of species is now adequately covered by SOVON/TMAP. Analyses of survival or condition are scarce and not standardized across species. Developing statistical models to analyse new and old mark-recapture and resighting data together with recruitment observations and long-term bird counts in an integrative and spatially explicit way is lacking completely.

Reporting

Numbers and distribution of birds of the Wadden Sea are reported annually by SOVON/TMAP. Data on reproduction of a number of species are reported annually by SOVON/TMAP. No annual reports on survival or condition exists today.

IPM Wadden Sea: Setting priorities and targets

All species

1) Collating existing (colour-)ring-recovery and condition data from various single-species studies and projects in the Wadden Sea in the 1970s to the 1990s, that will form a valuable baseline for comparison with current and future developments.
2) Develop new and expand existing *web-based* reporting facilities for observations of colour-ringed birds made by professionals and the general public.
3) Developing statistical models to analyse the new and old mark-recapture and resighting data together with recruitment observations and long-term bird counts in an integrative and spatially explicit way.
4) Developing annual reports of the *IPM-Wadden Sea Bird Indicator*, comprehensive information on status (numbers, distribution, reproduction, survival, condition) of selected model species, predictions of population trajectories, overview of identified bottlenecks and directions for improvement.

*Breeding birds within Reproduction Monitoring scheme Wadden Sea (*Common Eider, Lesser Black-backed Gull, Herring Gull, Common Tern).

Establishing a program for collecting field data on demographic rates (i.e. survival, recruitment and movements) and body condition throughout the Wadden Sea, by means of:

a. Securing long-term commitment for the Reproduction Monitoring Scheme, intensification of work and where necessary increasing the number of sites.

b. Setting-up or intensifying of intensive colour-ringing and resighting studies at a representative number of sites in combination with a.

Migratory shorebirds (Oystercatcher (non-br.), Bar-tailed Godwit, Red Knot, Dunlin and Sanderling)

Establishing a program for collecting field data on demographic rates (i.e. survival, recruitment and movements) and body condition in shorebirds throughout the Wadden Sea, by means of:

a. Trapping and ringing of a wide spectrum of shorebird species (including large numbers of target species) by local ringing groups at 4-5 fixed locations in the Dutch Wadden Sea.

b. Setting-up or intensifying of intensive colour-ringing and resighting studies at at least a number of the fixed locations in the Dutch Wadden Sea.

c. Visual assessment of the proportion of juvenile birds in the population by volunteer observers during fixed periods of the year (early autumn) at a selection of sites.

(Breeding) Birds now covered by special projects (Great Cormorant, Spoonbill, Dark-bellied Brent, Oystercatcher).

Establishing a program for collecting field data on demographic rates (i.e. survival, recruitment and movements) and body condition throughout the Wadden Sea, by means of:

a. Securing long-term commitment and funding for these projects, intensification of work and where necessary increasing the number of sites.

b. Intensifying of colour-ringing and resighting studies in the Dutch Wadden Sea where necessary.

Link with other programs and initiatives

Worldwide, there is growing concern about the negative impact of increasing human encroachment on coastal and other habitats, overexploitation of resources, increasing human-wildlife conflicts, and global climate change. More then ever, policymakers are in need of powerful tools to monitor the status of ecosystems and to evaluate their measures. At the same time, knowledge about population dynamics, and sometimes even numbers and distribution, is sketchy for a large number of important species (either threatened or "conflict" species) and inadequate to fill this need. Especially in the Netherlands, with its large populations of migrating and wintering waterfowl and shorebirds that so heavily rely on our wetlands, (giving rise to numerous threats and conflicts with an ever growing human population), there is surprisingly little demographic research going on. Several initiatives have been deployed that identify this knowledge gap and try to set goals and priorities for its solution. At least three of these initiatives are of direct relevance to the IPM framework for the Wadden Sea outlined here.

Network for Population Dynamics

The Network for Population Dynamics *NPD* is a network of researchers from several Dutch Institutes (currently NIOO-KNAW, WUR, SOVON) that aims to collect, manage and analyse data on, and bring together and expand knowledge about, population dynamics of a selection of species (primarily birds and mammals). As the IPM Wadden Sea framework, it identifies the need for collecting demographic data using standardised mark-resighting techniques (e.g. colour-ringing), to secure long-term funding for projects that are already running (now largely dependent on volunteers), to set up structures for data storing and handling, and to increase knowledge to analyse data and construct population models. The *NPD* now focuses on species that are subject to human-wildlife conflicts (geese and other waterfowl, large mammals, introduced species) but also wants to apply the knowledge that will be gained to other species and systems. Of direct relevance here is the inclusion of the Dark-bellied Brent as one of the focal species that also is among the thirteen target species of the IPM program.

Trilateral Monitoring and Assessment Program (TMAP)

Since 1978, The Netherlands, Denmark and Germany have been working together on the protection and conservation of the Wadden Sea covering management, monitoring and research, as well as political matters. In 1997, a Trilateral Wadden Sea Plan was adopted, and the *TMAP* common package was implemented. The *TMAP* covers the entire Wadden Sea area including islands and offshore areas and spans a broad range from physiological processes over population development to changes in landscape and morphology. Its aims are to provide a scientific assessment of the status and development of the Wadden Sea ecosystem and to assess the status of implementation of the trilateral Targets of the Wadden Sea Plan. Currently, the number and distribution of Wadden Sea breeding birds are monitored as part of the *TMAP*, and inclusion of the monitoring of *breeding success* is in progress (Koffijberg 2008). The IPM framework outlined here can be viewed as an extension of the *TMAP* activities, and can aid successful inclusion of monitoring of breeding success *and survival* into the program.

Global Flyway Network

With funding support from Vogelbescherming Nederland (BirdLife Netherlands), the *Global Flyway Network* formally started its activities in 2007. Briefly, the *Global Flyway Network* is a partnership between researchers worldwide devoted to long-term — usually demographic — work on long-distance migrating shorebirds. The partnership aims to build on the strengths of comparative demographic shorebird studies worldwide, with the aim to understand and analyse the factors determining shorebird numbers in a rapidly changing world. In practice it also tries to fill major gaps in coverage of fieldwork of the world's most threatened shorebird flyways. The *Global Flyway Network* currently supports research on shorebirds in Argentina and Australia. Although focusing on a wider range of species, the IPM framework for the Wadden Sea outlined here contributes directly to the objectives and deliverables of the GFN by setting-up and intensifying detailed long-term demographic studies in one of the internationally most important stop-over sites for waders: the Wadden Sea.

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Appendix 1 Current projects and initiatives in The Netherlands.

For German and Danish projects see koffijberg (2008).

Breeding Bird Monitoring Wadden Sea (TMAP/JMBB/NEM)

Bidder: Directie Regionale Zaken-Noord Ministerie van LNV in het kader van TMAP
Contractor: SOVON Dutch Centre for Field Ornithology, volunteers
Parameters: Number of breeding pairs of selected species
Method: annual census of common species in of 36 plots; annual census of colonial and rare species in whole area; census of all species in whole area every 5 years.
Start: 1991 End: continuing

Waterbirdmonitoring Wadden Sea (IWC/JMMB/TMAP/NEM)

Bidder: NEM (LNV, RWS-RIZA, Vogelbescherming Nederland)
Contractor: SOVON, RIKZ & RWS-RIZA, volunteers
Parameters: Numbers of all waterbirds (Divers through auks), and selection of raptors and coastal passerines.
Method: Full count of all waterbirds during five times / year in whole area.
Monthly or two-weekly count of same species in selection of sites.
Monthly count of all geese and swans September – May
Annual (January) areal count of of scoters and Eiders
Start: 1975 (Areal counts 1993) End: continuing

Population monitoring Herring Gull and Lesser Black-backed Gull

Bidder:
Contractor: formerly RIN, now NIOZ
Parameters: reproductive success, annual survival probability, condition, dispersal
Method:.
Start: 1984 (RIN) End: 1996
Start: 2006 (NIOZ) End: continuing

LNV Boatcounts Wadden Sea

Bidder: Directie Regionale Zaken-Noord van het Ministerie van LNV
Contractor: Directie Regionale Zaken-Noord van het Ministerie van LNV.
Parameters: number of waterbirds.
Method: monthly boatcounts of watebirds along twelve fixed transects
Start: 1985 End: continuing

Reproduction Monitoringscheme Wadden Sea

Bidder: Directie Regionale Zaken-Noord van het Ministerie van LNV (WOT)
Contractor: SOVON , volunteers, staff of nature management organisations.
Parameters: reproductive success
Method: Measuring of nesting and fledging success of representative samples of nests within colonies of Eider, Oystercatcher, Avocet, Herring Gull, Black-headed Gull and Common Tern. In addition information on Lesser Black-backed Gull, Sandwich tern, Arctic Tern and Little Tern.
Start: 2005 End: continuing

Population monitoring of Red Knot and Bar-tailed Godwit

Bidder: NIOZ
Contractor: NIOZ, VRS Calidris, VRS Castricum (Bar-tailed Godwit only), VRS Franeker (Bar-tailed Godwit only)and volunteers (resightings)
Parameters: annual survival probaility
Method: Annual catching of Red Knots and bar-tailed Godwits at various locations in the Dutch Wadden Sea and application of coloured legrings. 'Additional catches at mailnad sites and on islands during spring. All resightings along the Flyway are gathered and processed.
Start: 1998 (Red Knot), 2001 (Bar-tailed Godwit) End: continuing

Population Monitoring Oystercatcher

Bidder: University of Groningen (until 2004), LNV, RWS-RIKZ (Delfzijl 1997-1999).
Contractor: SOVON, University of Groningen, IMARES-Texel, volunteers.
Parameters: Size of local breeding populations, reproductive success, annual survival probability
Method: Annual mapping of territories, measuring of nesting and fledging success. Catching and colourringing of all adult and young birds. All resightings are gathered and processed.
Start: 1983 (Texel, Schiermonnikoog), 1997 (Delfzijl), 2003 (Ameland), 2004 (Vlieland)
End: continuing

Winterpopulation Monitoring Oystercatcher

Bidder: None (STW untill 2005). SOVON.
Contractor: University of Groningen (until 2005), SOVON (from 2005), volunteers (resightings)
Parameters: Annual survival probability, condition, spatial distribution
Method: Catching, bloodsamples (condition) and colour ringing
Start: 2001 End: continuing, but intensity decreased after 2004

Population Monitoring Dark-bellied Brent Goose

Bidder: LNV, NWO.
Contractor: Alterra, volunteers
Parameters: Population size, Annual survival probability, reproductive success, spring condition.
Method: Annual catching of wintering and spring staging Brent in the Netherlands, annual catching in Siberian breeding areas, measuring and weighing, colour ringing, estimating reproductive success by counting proportion of young birds in population and determining family size in individual birds.
Start: 1976 End: continuing.

Population Monitoring Barnacle Goose (Baltic population)

Bidder: Uppsala University (untill 1999), Gotland University (1999-2000), SOVON (from 2004)
Contractor: Uppsala University & Gotland University (fieldwork in breeding areas,), volunteers (resightings), SOVON and Alterra (processing resightings).
Parameters: Population size, Annual survival probability, reproductive success, condition.
Method: Nest counts in all colonies, nesting and hatching success, colourringing of adults and fledged young (until 2001), all resightings are gathered and processed.
Start: 1984
End: continuing, but intensity decreased after 2001. Colour ringing ceased after 2001.

Population Monitoring Barnacle Goose (Barents Sea population)

Bidder: NWO, RWS-RIZA (until 2005), University of Groningen (until 2005), Bird Ringing Centre Moscow, SOVON
Contractor: University of Groningen , Bird Ringing Centre Moscow, SOVON and Alterra (from 2005; processing resightings) volunteers (resightings)
Parameters: Size of local breeding populations, reproductive success, annual survival probability, condition.
Method: Nest counts in study colonies, nesting and hatching success, colourringing of adults and fledged young, all resightings are gathered and processed.
Start: 2002 End: continuing

Population Monitoring Spoonbill
Bidder: none.
Contractor: Werkgroep Lepelaar, University of Groningen (from 2006).
Parameters: Population size, Annual survival probability, reproductive success, condition.
Method: Nest counts, counts of fledged young, colour ringing of fledged young, All resightings along the Flyway are gathered and processed.
Start: 1982 End: continuing.

Population Monitoring Sandwhich Tern
Bidder: Alterra (until 2000), Natuurmonumenten (from 2000)
Contractor: Alterra (until 2000), Natuurmonumenten (from 2000)
Parameters: reproductive success.
Method: measuring of reproductive success in enclosures, ringing of chicks.
Start: 1986 End: continuing, but intensity decreased after ?

Population Monitoring Eider
Bidder: NIOZ (1964-1995), University of Groningen & Alterra (2001-2004)
Contractor: NIOZ (1964-1995), University of Groningen & Alterra (2001-2004)
Parameters: Annual survival probability, reproductive success
Meetmethode: Counting size of breeding population, measuring reproductive success, ringing of chicks, measuring annual survival probability through analysis of ring recoveries.
Start: 1964 End: 2004

Population Monitoring Cormorant
Bidder: RWS-RIZA
Contractor: RWS-RIZA
Parameters: Annual survival probability, reproductive success
Method: measuring reproductive success, colourringing of fledged young, all resightings are gathered and processed.
Start: 1997 End: continuing

Wader ringing
Bidder: Free Universitity of Amsterdam (until 1997).
Contractor: Volunteers and students of Free Universitity of Amsterdam (until 1997), VRS Calidris and Steltlopervanggroep FFF, Vogeltrekstation (processing of ringing data)
Parameters: condition, timing of moult, annual survival probability.
Method: Monthly catching of waders at night during new moon at fixed location. All birds are ringed measured and weighed.
Start: 1967 (VRS Calidris), 1980 (Steltlopervanggroep FFF) End: continuing, but intensity decreased after c. 2000.

Appendix 2 Proposed model species – status in Dutch Wadden Sea

Great Cormorant *Phalacrocorax carbo*	Breeding bird, migrant
Breeding pairs 1999 – 2003 (% int. pop.)	1 000 (1-5%),
Non-breeding 1999/00 – 2003/04 (% int. pop.)	4 200 (3%)
Adults ringed (recovered) 1990-2006*	2 (0)
Pulli ringed (recovered) 1990-2006*	680 (66) ?
Monitoring breeding success, number of sites	-- (?)
Monitoring survival, number of studies	1 (RIZA)
Population studies	-- (?)
Diet:	Medium-sized to large fish (mainly bottom-dwelling)
Feeding habitat:	Subtidal and high-tide intertidal
Breeding range of migrants visiting WS:	NL, Germany, Denmark, Norway?
Suitability for monitoring reproduction	Good (breeding colonies)
Suitability for monitoring survival	Amenable to colour-marking, reading at roosts difficult
Other features	Top predator with potential impact on fish community

Eurasian Spoonbill *Platalea leucorodia*	Breeding bird (migrant)
Breeding pairs 1999 – 2003 (% int. pop.)	720 (> 25%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	520 (22%)
Adults ringed (recoveries) 1990-2006*	154 (37 002 including resightings of colour-ringed birds)
Pulli ringed (recoveries) 1990-2006*	3 302 (1 202)
Monitoring breeding success, number of sites	9
Monitoring survival, number of studies	1 (Working Group Spoonbills International)
Population studies	1 (Schiermonnikoog)
Diet:	fish, crustaceans
Feeding habitat:	intertidal
Breeding range of migrants visiting WS:	NL, German and Danish Wadden Sea
Suitability for monitoring reproduction	Good, due to distribution in breeding colonies
Suitability for monitoring survival	Good, Amenable to colour-marking, reading relatively easy
Other features	Recent shift to breeding in Wadden Sea from mainland

Dark-bellied Brent *Branta bernicla*	Migrant, winter
Breeding pairs 1999 - 2003 (% int. pop.)	--
Non-breeding 1999/00 – 2003/04 (% int. pop.)	26 400 (30%)
Adults ringed (recovered) 1990-2006*	841 (439)
Pulli ringed (recovered) 1990-2006*	9 (3)
Monitoring breeding success, number of sites	n.a.
Monitoring survival, number of studies	1 (WUR)
Population studies	1
Diet:	Grass, seaweed, algae, eelgrass
Feeding habitat:	Saltmarsh, intertidal
Breeding range of migrants visiting WS:	Arctic Russia
Suitability for monitoring reproduction	Good, juvenile counts in autumn
Suitability for monitoring survival	Good, extensive colour-marking, rings are easily read
Other features	Population breeding success highly variable

* Refers to metal-ringed birds and recoveries only, unless stated otherwise

Common Eider *Somateria mollissima*	Breeding, migrant, wintering
Breeding pairs 1999 - 2003 (% int. pop.)	7 500 (1-5%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	68 000 (7%)
Adults ringed (recovered) 1990-2006*	1 201 (1 031)
Pulli ringed (recovered) 1990-2006*	16 (7)
Monitoring breeding success, number of sites	5
Monitoring survival, number of studies	1 (NIOZ, now ceased)
Population studies	--
Diet:	Shellfish, crustaceans
Feeding habitat:	Subtidal and intertidal
Breeding range of migrants visiting WS:	NL, SE Scandinavia, Baltic
Suitability for monitoring reproduction	Good, nests easily found, juvenile counts in crèches
Suitability for monitoring survival	Fair, only through recaptures and recoveries
Other features	Recent population decline

Eurasian Oystercatcher *Haematopus ostralegus*	Breeding, migrant, wintering
Breeding pairs 1999 – 2003 (% int. pop.)	35 000 (5-25%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	130 000 (19%)
Adults ringed (recovered) 1990-2006*	5 358 (1 376)
Pulli ringed (recovered) 1990-2006*	5 475 (572)
Monitoring breeding success, number of sites	12
Monitoring survival, number of studies	3 (Imares, SOVON)
Population studies	2 (Schiermonnikoog, Texel)
Diet:	Shelfish, small invertebrates
Feeding habitat:	Intertidal, mussel beds
Breeding range of migrants visiting WS:	NL, Scandinavia, Baltic, NW Russia
Suitability for monitoring reproduction	Good, nests easily found, birds highly visible
Suitability for monitoring survival	Good, amenable to colour-marking, reading relatively easy
Other features	Recent population decline

Pied Avocet *Recurvirostra avosetta*	Breeding, migrant
Breeding pairs 1999 - 2003 (% int. pop.)	3 800 (>25%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	6 700 (16%)
Adults ringed (recovered) 1990-2006*	479 (33)
Pulli ringed (recovered) 1990-2006*	753 (8)
Monitoring breeding success, number of sites	14
Monitoring survival, number of studies	--
Population studies	--
Diet:	Crustaceans, worms, small invertebrates
Feeding habitat:	Intertidal
Breeding range of migrants visiting WS:	NL, Germany, Denmark (Baltic)
Suitability for monitoring reproduction	Fair, colonial breeder, but distribution clumped and erratic
Suitability for monitoring survival	Poor, due to erratic dispersal behaviour
Other features	Nomadic breeder

* Refers to metal-ringed birds and recoveries only, unless stated otherwise

Red Knot *Calidris canutus*	Migrant, wintering
Breeding pairs 1999 - 2003 (% int. pop.)	--
Non-breeding 1999/00 – 2003/04 (% int. pop.)	44 000 (16%)
Adults ringed (recovered) 1990-2006	4 740 (47)
Pullus ringed (recovered) 1990-2006	709 (67)
Monitoring breeding success, number of sites	Na
Monitoring survival, number of studies	1 (NIOZ)
Population studies	--
Diet:	shellfish
Feeding habitat:	intertidal
Breeding range of migrants visiting WS:	Arctic Russia (*canutus*), Greenland, Canada (*islandica*)
Suitability for monitoring reproduction	Fair, juvenile ratios during counts and catches
Suitability for monitoring survival	Good, amenable to colour-marking, reading relatively easy
Other features	Recent population decline

Sanderling *Calidris alba*	Migrant, wintering
Breeding pairs 1999 - 2003 (% int. pop.)	--
Non-breeding 1999/00 – 2003/04 (% int. pop.)	3 700 (6%)
Adults ringed (recovered) 1990-2006*	216 (1)
Pullus ringed (recovered) 1990-2006*	24 (0) ?
Monitoring breeding success, number of sites	n.a.
Monitoring survival, number of studies	1
Population studies	--
Diet:	worms, small invertebrates
Feeding habitat:	
Breeding range of migrants visiting WS:	Arctic Russia, Greenland, Canada
Suitability for monitoring reproduction	Fair, juvenile ratios during counts and catches
Suitability for monitoring survival	Fair, recaptures and recoveries, colour-ringing possible
Other features	

Dunlin *Calidris alpina*	(breeding), Migrant, wintering
Breeding pairs 1999 - 2003 (% int. pop.)	0-3
Non-breeding 1999/00 – 2003/04 (% int. pop.)	206 000 (24%)
Adults ringed (recovered) 1990-2006*	11 277 (291)
Pullus ringed (recovered) 1990-2006*	2 121 (36)
Monitoring breeding success, number of sites	n.a.
Monitoring survival, number of studies	--
Population studies	--
Diet:	worms, small invertebrates
Feeding habitat:	
Breeding range of migrants visiting WS:	Scandinavia, Baltic, Arctic Russia
Suitability for monitoring reproduction	Fair, juvenile ratios during counts and catches
Suitability for monitoring survival	Fair, recaptures and recoveries, colour-ringing possible
Other features	Most common non-breeding wader in Wadden Sea

* Refers to metal-ringed birds and recoveries only, unless stated otherwise

Bar-tailed Godwit *Limosa lapponica*	Migrant, wintering
Breeding pairs 1999 - 2003 (% int. pop.)	--
Non-breeding 1999/00 – 2003/04 (% int. pop.)	54 400 (25%)
Adults ringed (recovered) 1990-2006*	5 440 (96)
Pullus ringed (recovered) 1990-2006*	120 (2)
Monitoring breeding success, number of sites	na
Monitoring survival, number of studies	1
Population studies	--
Diet:	worms, small invertebrates
Feeding habitat:	
Breeding range of migrants visiting WS:	Northern Scandinavia, Arctic Russia
Suitability for monitoring reproduction	Fair, juvenile ratios during counts and catches
Suitability for monitoring survival	Fair, recaptures and recoveries, colour-ringing possible
Other features	

Lesser Black-backed Gull *Larus fuscus*	Breeding, migrant
Breeding pairs 1999 - 2003 (% int. pop.)	35 500 (>25%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	3 000 ()
Adults ringed (recovered) 1990-2006	279 (40)
Pullus ringed (recovered) 1990-2006	3 630 (141)
Monitoring breeding success, number of sites	5
Monitoring survival, number of studies	1
Population studies	--
Diet:	
Feeding habitat:	
Breeding range of migrants visiting WS:	NL, Denmark, Germany, UK, SW Scandinavia, Baltic?
Suitability for monitoring reproduction	Good, nests easily found, colonial, birds highly visible
Suitability for monitoring survival	Good, amenable to colour-marking, reading relatively easy
Other features	Recent population increase

Herring Gull *larus argentatus*	Breeding, migrant, wintering
Breeding pairs 1999 - 2003 (% int. pop.)	34 500 (5-25%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	35 000 ()
Adults ringed (recovered) 1990-2006*	686 (284)
Pullus ringed (recovered) 1990-2006*	4 013 (1 436)
Monitoring breeding success, number of sites	11
Monitoring survival, number of studies	1
Population studies	
Diet:	
Feeding habitat:	Sub-tidal, intertidal
Breeding range of migrants visiting WS:	NL, Denmark, Germany, Scandinavia, Baltic
Suitability for monitoring reproduction	Good, nests easily found, colonial, birds highly visible
Suitability for monitoring survival	Good, amenable to colour-marking, reading relatively easy
Other features	Recent population decrease

* Refers to metal-ringed birds and recoveries only, unless stated otherwise

Common Tern *Sterna hirundo*	Breeding, migrant
Breeding pairs 1999 - 2003 (% int. pop.)	5 300 (5-25%)
Non-breeding 1999/00 – 2003/04 (% int. pop.)	2 000 ()
Adults ringed (recovered) 1990-2006*	1 525 (293)
Pullus ringed (recovered) 1990-2006*	4 971 (1 060)
Monitoring breeding success, number of sites	27
Monitoring survival, number of studies	1
Population studies	
Diet:	Small fish, crustaceans, small invertebrates
Feeding habitat:	Sub-tidal
Breeding range of migrants visiting WS:	NL, Denmark, Germany, S. Scandinavia, Baltic
Suitability for monitoring reproduction	Good, nests easily found, colonial, birds highly visible
Suitability for monitoring survival	Fair, recaptures and recoveries, colour-ringing possible
Other features	Colonial breeding

* Refers to metal-ringed birds and recoveries only, unless stated otherwise