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Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.

A COMPARISON OF SHIP AND AERIAL SAMPLING METHODS FOR MARINE BIRDS, AND THEIR APPLICABILITY TO OFFSHORE WIND FARM ASSESSMENTS

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Executive summary

- The coastal and offshore waters of the UK are of global importance for several species of seabirds. The United Nations Law of the Seas and the establishment of Exclusive Economic Zones gives coastal states extensive rights but also obligations over marine areas, including the assessment of potential effects of activities on the marine environment. The Crown Estate, as landowner of the seabed out to the 12 nautical mile territorial limit plays an important role in the development of the offshore wind industry by leasing areas of seabed for the placing of turbines. The planned erection of large numbers of offshore wind turbines has underlined our lack of knowledge relating to the distribution, abundance and habitat requirements (foraging ecology) of marine birds.
- As part of the Environmental Impact Assessments for offshore wind farms, the need for detailed knowledge on spatial and temporal patterns in seabird distribution has been identified. Dedicated censuses to sample the numbers and distribution of seabirds are a basic requirement for developers, to describe bird densities within, and in the immediate vicinity of, the construction area. Studies performed need to be related to some greater area studies, in order to assess the relative and the actual importance of the construction area for the species involved.
- This document evaluates existing census techniques and determine the best currently available methods for defining bird distribution and abundance at sea. The underlying question is twofold: (1) what are the research objectives and what data are required for EIAs for offshore wind farms, and (2) how good are existing census techniques at fulfilling the objectives?
- In order to assess the potential impact of the construction of an offshore wind farm and to understand how such a construction is likely to affect the birds associated with a site, dedicated research is required. The coupling of bird census data with geographical, hydrographical, and biological measurements is essential to begin to understand how an offshore construction such as a wind farm is likely to affect an area and how the seabirds associated with a site are most likely to respond. Natural variability issues are addressed and existing census techniques have been evaluated for their potential to provide data that can be used to describe habitat characteristics and area usage by seabirds.
- The two observation tools discussed in this study, aerial and ship-based surveys, potentially provide similar data for as far as basic seabird counts are concerned (accurate numbers, accurate maps). Census techniques are similar (distance techniques using parallel bands of known width), but the level of detail for individual species is considerably less during aerial surveys. Aerial surveys are quick, so enabling coverage of larger areas per unit time, and relatively cheap, whereas ship-surveys are more time-consuming.
- Data obtained during aerial surveys may be combined with environmental parameters in a correlative approach, whereas the advantage of a ship is that such parameters can often be collected simultaneously. The slower approach with vessels allows detailed observations on seabird behaviour (habitat utilisation, feeding conditions) and diurnal/tidal fluctuations in seabird abundance and distribution.
- The acquisition of information about migration routes, direction or height of flight, detailed spatial and temporal distribution require intensive radar and direct observation in the vicinity of a proposed wind farm development to determine bird use of the area and to predict collision impact probabilities under a range of differing temporal (day/night) and weather conditions. Similarly, assessment of actual collision risk and collisions after construction necessitates static measuring devices (such as infra-red movement triggered video surveillance and vibration detection equipment currently under development). However, these tools are not addressed further in this report.

Recommended methodology for ship-based surveys

Recommended census techniques for ship-based seabird surveys, as part of an EIA, are line-transects with sub-bands and with snap-shots for flying birds, and incorporating the full behaviour module recording detailed information on species, sex and age where feasible, foraging behaviour, flying height. Whenever possible, hydrographical data, such as sea surface temperature, salinity, water depth should be continuously and synoptically monitored. For a minimum set-up, the following techniques and qualifications are recommended.

- ❖ Line-transect methodology is recommended with a strip width of 300m maximum.
- ❖ Subdivision of survey bands to allow corrections for missed individuals at greater distances away from the observation platform (recommended subdivision for swimming birds: A= 0-50m, B= 50-100m, C=100-200m, D= 200-300m, E= 300+m or outside transect; all distances perpendicular to the ship).
- ❖ No observations in sea state 5 or more to be used in data analysis for seabirds, data not usable for marine mammals above sea state 3.
- ❖ Survey time intervals are recommended to be 1 or 5 min intervals (range 1-10m, longer time intervals are acceptable when less resolution of data is required; short intervals are preferred in small study areas), with mid-positions (Latitude, Longitude) to be recorded or calculated for each interval.

- Preferred ship's speed should be 10 knots (range 5-15 knots).
- Preferred ship type is a motor vessel with forward viewing height possibilities at 10m above sea level (range 5-25m), *not* being a commercial or frequently active fishing vessel.
- Preferred ship-size: stable platform, at least 20m total length, max. 100m total length
- Bird detection by naked eye as a default, except in areas with wintering divers *Gaviidae.* Scanning ahead with binoculars is necessary, for example to detect flushed divers.
- Two competent observers are required per observation platform equipped with range-finders (Heinemann 1981), GPS and data sheets; no immediate computerising of data during surveys to maximise attention on the actual detection, identification and recording.
- Observers should have adequate identification skills (i.e. all relevant scarce and common marine species well known, some knowledge of rarities, full understanding of plumages and moults).
- Observers must be trained by experienced offshore ornithologists under contrasting situations and in different seasons.
- A high resolution grid should be deployed, covering an area at least 6x the size of the proposed wind farm area, including at least 1-2 similar sized reference areas (same geographical, oceanographical characteristics), and preferably including nearby coastal waters (for nearshore wind farms only).
- Survey grid lines are recommended to be at least 0.5nm apart, maximum 2nm apart, and the grid should be surveyed such that time of day is equally distributed over the entire area (changing start and end time over the area to fully comprehend effects of diurnal rhythms in the area)
- The cost-effectiveness of the ship-based surveys are greatly enhanced if the vessel can be equipped with an Aquaflow (logging surface water characteristics including temperature, fluorescence (chlorophyll), and salinity logging hydrographical information simultaneously).
- The cost-effectiveness of the ship-based bird surveys can be greatly enhanced if combined with other surveys, such as those of marine mammals, for which a specialist observer and different methods will be required.
- The cost-effectiveness can be further enhanced by counting birds on both sides of the ship, i.e. cover two strips, for which additional observers will be required.

Recommended methodology for aerial surveys
For a minimum set-up, the following techniques and qualifications are recommended.

- Twin-engine aircraft (for safety and endurance)
- High-wing aircraft with excellent all round visibility for observers (e.g. twin-engine Partenavia P-68 Observer)
- Line-transect methodology is recommended with sub-bands.
- Transects should be a minimum of 2 km apart to avoid double-counting whilst allowing the densest coverage feasible
- Flight speed preferably 185 km h^{-1} at 80 m altitude
- Subdivision of survey bands to allow calculations of detection probabilities (recommended are 44-163m, 164-432m, 433-1000m, with a declination in degrees from the horizon being 60-25°, 25-10°, and 10-4° respectively for the Partenavia P-68 at 80m)
- Use of an inclinometer to measure declination from the horizon
- Two trained observers, one covering each side of the aircraft, with all observations recorded continuously on dictaphone
- GPS positions are recorded at least every 5 seconds (computer logs flight track)
- The time of each bird sighting should be recorded, ideally to the nearest second, but within 10 seconds accuracy, using a watch attached to the window of the plane.
- No observations in sea states above 3 (small waves with few whitecaps)
- All waterbirds should be recorded to the best level of identification (species or group)
- Sampling units are single birds or groups of birds within the three transect bands

Introduction

Major development of offshore wind power in the UK is expected in order to meet the UK Government's commitment to renewable energy targets (http://www.thecrownestate.co.uk/). The Crown Estate, as landowner of the seabed out to the 12 nautical mile territorial limit plays an important role in the development of the offshore wind industry by leasing areas of seabed for the placing of turbines. The Crown Estate established a Trust Fund administered by a Steering Group drawn from the offshore wind industry, government and conservation organisations. The Steering Group, named COWRIE (*Collaborative Offshore Wind Research into the Environment*) has identified and prioritised environmental studies that will be commissioned to inform the offshore wind farm industry as a whole.

The requirement of many marine birds for shallow, productive, nearshore waters combined with the limited extent of this resource in the UK and with the preference of wind farm developers to site turbines in shallow waters has resulted in concerns of potential negative effects on seabirds. For these top-predators in the marine environment, the establishment of an offshore construction such as a wind farm could potentially have a number of negative as well as positive effects. Habitat loss, more specifically the loss of foraging areas, restrictions of commercial fisheries (and the associated reductions in discards and offal provided as artificial sources of food), and the risk of collisions and death are obvious negative side-effects. For migratory seabirds and coastal nesting birds with frequent foraging trips from land to offshore feeding sites, the barrier effects of offshore wind turbines in localised areas cannot yet be discounted and must be considered. Positive effects of the construction of turbines may be that offshore constructions could provide roosting platforms or locally enhance foraging conditions to such an extent that some species or populations might profit from them.

COWRIE (COWRIE Steering Group, 22nd August 2002) recognised that the coastal and offshore waters of the UK are of global importance for several species of resident and migratory marine birds. Many marine bird species utilise shallow productive waters at different stages of their annual cycle, yet the general understanding of the marine environment remains poor compared to that of terrestrial and freshwater systems. The planned erection of large numbers of offshore wind turbines throughout European coasts from Estonia to Spain has underlined our lack of knowledge relating to the distribution, abundance and habitat requirements (foraging ecology) of marine birds. The United Nations Law of the Seas and the establishment of Exclusive Economic Zones gives coastal states extensive rights but also obligations over marine areas, including the assessment of potential effects of activities on the marine environment under Article 206. Increasingly, domestic and international legislation requires Environmental Impact Assessment (EIA) of development projects in offshore waters (e.g. the EIA and Strategic Environmental Assessment (SEA) Directives of the European Union). Many states are already bound by international agreements and legislation (such as the Ramsar Convention and European Union Birds Directive) to maintain migratory bird populations throughout the annual cycle, including the provision of reserves and the general protection of habitat.

Proper EIAs should investigate all potential effects of the establishment and development of wind farms on marine wildlife, but that is beyond the scope of this document. As part of the EIAs for offshore wind farms, the need for detailed knowledge on spatial and temporal patterns in seabird distribution has been identified. Fundamental to this process, is the simple definition of the distribution and abundance of marine birds in time and space. As a minimum, there is a requirement upon states to define the most important bird areas (potentially for site safeguard) but ultimately the process should aim to describe the overall distribution and abundance of particular populations throughout their annual cycle. The process is severely hampered by natural variability and by the long-distance migratory nature of many marine species, which often use very distant areas for breeding, moulting, staging and wintering, such that there is great seasonal variation in their distribution and abundance. Factors affecting prey availability, including access to food supplies, also vary in time and space, and the general abundance of a species varies as a result of differential patterns of survival and reproductive output, imposing further variation on patterns of distribution and abundance.

The need for the establishment of common standards in survey of offshore marine birds has been drawn into sharp focus by the current proposals to construct large wind farms in marine waters around the coasts of Europe. Many of the proposed wind farms are extensive in area and most planned developments involve the construction of turbines 500-800 m apart, in wind farms covering several square kilometres, so the spatial scale of these developments necessitates mapping bird densities at high spatial resolution (of a few hundred metres) over extensive areas (tens of square kilometres). At the local level, dedicated censuses to sample the numbers and distribution of seabirds are a basic requirement upon developers, to describe bird densities within, and in the immediate vicinity of, the construction area. In order to assess the potential impact of the construction of, for instance, an offshore wind farm and to understand how such a construction is likely to affect the birds associated with a site, dedicated research is required. Any studies performed need to be related to some greater area studies, in order to assess the relative and the actual importance of the construction area for the species involved. The cumulative description of bird densities over time and space enables some assessment of the relative importance of the impact area relative to other areas used by the same species. The routine coupling of bird census data with geographical (e.g. depth, substrate, distance to land), hydrographical (water masses), and biological measurements (e.g. benthic communities, fish abundance) will further enhance the understanding of the actual habitat characteristics of a given area and their influence on the distribution of marine birds. Such data is essential to begin to understand how an offshore construction such as a wind farm is likely to affect the birds associated with a site.

Given the recent round of proposals for offshore wind farm developments in shallow inshore areas and the expected future developments in this area, it is essential to obtain some consensus on common standards and best practice in survey techniques used to describe the distribution and abundance of marine birds in key areas. For this reason, COWRIE has issued an invitation to tender for a project comparing ship and aerial sampling methods for marine birds and their applicability to offshore wind farm assessments. Despite reasonably complete data on broad distribution patterns of seabirds around the UK, lack of detailed understanding about local distribution, at the scale of wind farm sites, temporal variability of numbers and the underlying determinants of their timing of occurrence was identified. This document evaluates existing census techniques and determines the best currently available methods for defining bird distribution and abundance at sea. The underlying question is twofold: (1) what are the research objectives and what data are required for EIAs for offshore wind farms, and (2) how good are existing census techniques at fulfilling the objectives?

Arctic Tern with sandeel returning to colony, Farne Islands, summer 2003 (CJ Camphuysen)

Aim of the project

The overall aim of the project is to produce a standardised guidance document/manual for bird counts in relatively small areas of sea, using either ships or aircraft as observation platforms (but not necessarily always both), for all involved in the offshore wind energy industry. The protocol will offer guidance to optimise accuracy and minimise bias when estimating bird numbers, while taking into account spatial and temporal variability, underlying determinant factors and the specific needs of an individual project. Existing methodologies for sampling seabirds at sea have therefore been reviewed and compared; keeping in mind the need to provide information on the scale associated with offshore wind farms.

The outcome of this exercise, a set of guidelines, details the strengths and weaknesses of a range of recorded parameters within each method, the circumstances under which different approaches would be recommended, and recommends standard sampling procedures for both. This standardised protocol for conducting seabird surveys at sea in connection with any offshore wind farm development around the UK, using agreed common standards and optimal methodologies, will improve the comparability of data from different future studies. Consultation on the proposed methodology has been via written comments, based on a draft text posted at the COWRIE web site, and discussions at an international workshop in Aberdeen, Scotland, November 2003. This final document is the result of these consultations. The agreed protocol for assessing (changes in) seabird numbers in wind farm EIAs for the UK are guidelines for any organisation within the UK examining the problem at any site within the domain of the Crown Estate (shallow coastal seas) in the foreseeable future.

At the international workshop in Aberdeen, it was noted that a standardised protocol will never be able to meet the most detailed of specific requirements at certain sites. The protocol proposed here ensures adequate data sampling in marine (coastal) areas, using either aircraft or ship. Specific problems, such as highly localised flyways of foraging birds, complex shorelines, the location of migration routes, poor weather conditions, may not be addressed using this same protocol or may require specific adjustments. Since it will be hard to foresee all the peculiarities and research objectives for wind farms in UK coastal waters, the establishment of a board of experts is suggested. This board should be consulted where the protocol proposed here is insufficient, or when an adjusted research protocol has to be critically evaluated.

Seabirds at sea can be counted from either platform following appropriate observation protocols, and accurate density estimates can be obtained from the air as well as at sea level. Important differences occur, however, and these differences are most important when choosing to use either an aircraft or a boat. Ship-based surveys, for example, provide a higher level of accuracy in species identification and assessments of age and behaviour of seabirds at sea, important in studies where the distribution of seabirds in areas needs background information to explain and measure natural variability in the system. Aircraft can work areas that are completely or virtually inaccessible to ships of recommended size and may be more effective in counting certain species groups that are easily disturbed by traffic such as seaduck and divers.

The choice between either craft, apart from the issue of availability, has to be made with specific research objectives in mind. Since either method has both advantages and disadvantages, the strong points and weaknesses of ships and aircraft are highlighted in the present document, and linked to specific research objectives, so that any wind farm developer could make a choice based on local circumstances and particular requirements. There is not just one 'best' research tool to be recommended for all places and circumstances. The pros and cons of either method have been listed with annotations.

Existing approaches

Objectives and methods of early offshore observations

Early researchers have used several methods for counting birds at sea (Powers 1982), but very few managed to collect and analyse their data in a systematic manner and tried to describe different areas on the basis of bird data. The sinking of the oil tanker Torrey Canyon at Land's End in 1967 and the associated mass mortality of (oiled) seabirds gave a clear sign, however, that our knowledge of the offshore distribution of seabirds was still very incomplete. When gas- and oil exploration activities in the North Sea developed rapidly in the 1970s, the need for adequate data became even more urgent. When asked for specific advice with respect to the densities of (vulnerable) seabirds in different areas of the North Sea, there was little more than maps of breeding colonies and the expectation that seabird numbers were probably relatively high in the waters around them. The Canadian Wildlife Service had developed and deployed a useful method to study seabirds at sea in Canada and to analyse the results with the use of a computer (Brown *et al.* 1975). This method, the **strip-transect** technique, formed the basis of work conducted by JNCC's Seabirds At Sea Team formed in the late 1970s. The strip-transect method was thought to be the most useful at the time, cost-effective and repeatable (Tasker *et al.* 1984). The first results of this work were published in the early and mid-1980s (Blake *et al.* 1984; Tasker *et al.* 1987). The strip-transect method, with a snapshot for flying birds (explained later in this document), was adopted by most workers around the North Sea as an easy and repeatable standard method in an attempt to be able to join forces while mapping large areas of the North Sea. It should be highlighted that the method was refined soon after the publication by Tasker *et al.* (1984), using parallel narrow strips within the band transect to allow for corrections for birds missed at greater distances from the observation platform (Komdeur *et al.* 1992). With this modification, the **line-transect** technology became adopted (see below). The establishment of a joint database (the European Seabirds at Sea database, ESAS) was a further important step to collect, store and utilise a large amount of comparable data in a single format.

Recent work (1) Ship-based surveys

The ESAS strip-transect method (Tasker *et al.* 1984), slightly revised to a line-transect technique, is still the backbone of modern ship-based surveys of seabirds at sea in NW European waters (Camphuysen & Leopold 1994; Durinck *et al.* 1994; Stone *et al.* 1995; Skov *et al.* 1995; Bloor *et al.* 1996; Offringa *et al.* 1996; Pollock *et al.* 1997; 2000; Maes *et al.* 2000; Taylor & Reid 2001; Mitschke *et al.* 2001; Seys 2001; Skov *et al.* 2002). Results have been analysed to answer the more specific questions about the vulnerability of different sea areas for oil pollution, and vulnerability indices were used to transform plain densities at the species level into densities/levels of vulnerability (Tasker *et al.* 1990; Carter *et al.* 1993; Webb *et al.* 1995; Williams *et al.* 1995; Begg *et al.* 1997; Maes *et al.* 2000). Since the late 1970s, joint knowledge of offshore seabird distribution has increased substantially, as a result of several large programmes of seabirds at sea studies (NCC, later Joint Nature Conservation Committee (JNCC), culminating in the establishment of the database. The standardisation of methodology at a very early stage, followed by the adoption of such methods by a large, international group of researchers and organisations (ESAS), were the backbone of a success-story that has resulted in a number of atlases summarising seabird distribution patterns in most of North West Europe and in the Baltic. Waterfowl counts in coastal wetlands have been conducted at least since the 1960s in many European countries, and offshore sites have increasingly been incorporated in the research set-up of these surveys (Rüger *et al.* 1986; Laursen 1989; Rose & Scott 1994; Delany *et al.* 1999).

More recently, ESAS has focussed more on the marine ecological background to the distribution of seabirds at sea (e.g. Harrison *et al.* 1994, Garthe 1997; Camphuysen & Webb 1999). Studies wished to address other aspects of the marine life of seabirds at sea by using ESAS data and shortcomings in the material led to further refinements, again while keeping the underlying framework intact (e.g. Camphuysen & Webb 1999; Camphuysen & Garthe 2001). The ESAS coding structure is now such that each of the outlying methods can be identified, so that although there is one joint database format, different methods can be entered and selected for subsequent analysis.

Recent work (2) Aerial surveys

Although aerial survey techniques have been used in European offshore waters for many years, their use has been relatively limited, possibly because of the high financial costs involved. Their development was accelerated in the 1960s, especially in Denmark, following the pioneering work of Joensen (1968, 1973, 1974). The technique at that time was highly limited by the ability of pilots and observers to navigate with any accuracy out of range of navigation beacons or sight of the coast. The surveys at that time were carried out at a variety of altitudes between 50 and 300 metres, according to weather conditions, habitat and species. The routes and extent of coverage undertaken varied between years, but essentially the technique aimed to record and describe all aggregations of seabirds encountered along the areas covered by the aerial survey aircraft (Joensen 1974). The objective at that time was to map the larger concentrations and assess the overall numbers and distributions of birds at the national level, rather than provide a statistical basis for comparisons in time and space. Joensen (1974) was well aware of the difficulties involved with sampling bird distributions based on this type of aerial survey, but these assessments were the first ever attempts to determine the numbers of birds using the offshore waters around Denmark and were a remarkable contribution at the time.

In Britain, aerial surveys have been conducted side by side with ship-based surveys, for example to cover coastal areas that are difficult or less efficiently to reach by boat (e.g. Barton *et al.* 1994b). German and Dutch surveys were initially mainly conducted as part of the international waterfowl census (Bräger 1990), but are increasingly used to survey marine areas for seabirds and marine mammals (Diederichs *et al.* 2002). In The Netherlands, aerial surveys covering the Dutch sector of the North Sea became established as a monitoring programme conducted by the Dutch government since the mid 1980s (Baptist 1990; Baptist & Wolf 1991, 1993; Baptist & Meininger 1996).

In Denmark, aerial survey methods were further developed in the late 1980s (Laursen *et al.* 1997) and subsequently extended to cover much of the Baltic Sea for wintering seaducks (Durink *et al.* 1994) and UK waters (Dean *et al.* 2003). For these surveys, the methods used varied with species and conditions in the survey areas. In shallow coastal waters, the coastline was followed 300-500 m from the shore, with supplementary coverage 1.5-2 km offshore. For "total counts" sea areas were defined on the basis of natural ecological, topographical or geographical units and attempts were made to fly each of these areas in a systematic fashion and assess the total numbers of birds present (Pihl & Frikke 1992). In the open sea, parallel tracks were flown at regular (2-3 km) intervals, always ensuring coverage of known reefs and shoals, with reduced efforts at water depths less than 10 m. During these flights, observers registered birds on both sides of the aircraft within 100 m of the observers (excluding the 10 m on either side directly below the aircraft; Laursen 1997). These strip transect approaches represented a considerable improvement on the previous methods and exploited the improvements in navigation aids at that time (notably the new satellite navigation techniques just becoming available).

At present, the Danish protocol as outlined below under "Aerial surveys" (or very similar derivatives) is deployed in the UK (e.g. JNCC, BTO, WWT), in Denmark and in Germany (BioConsult, FTZ/Univ. Kiel). The Dutch protocol for aerial surveys is rather different (Baptist & Wolf 1991) and is not recommended in this document.

Seabird at sea survey, Wee Bankie (E Scotland), summer 2003 (CJ Camphuysen)

COWRIE research objectives

While the purpose of the present document is to evaluate existing techniques for ship-based and aerial surveys, in terms of their historical use, demonstrated efficiency, quality, and cost-effectiveness, it was suggested at the start of the project that research objectives should be made very clear. The following research objectives have been identified (COWRIE, London, 30 May 2003) and each of the research tools (platforms used, protocols and techniques deployed) will be evaluated with these goals in mind.

- Seabird distribution patterns
- Seabird abundance
- Migratory pathways
- Foraging areas
- Factors explaining seabird distribution and abundance
- Variability in spatial and temporal patterns
    - Seasonal
    - Diurnal
    - Spatial
- Evaluation of collision risks

The objectives of these large-scale seabirds at sea programmes discussed earlier, partly overlap with the objectives for specific EIAs in marine coastal areas, but they are different, particularly in scale. For a better understanding of local areas, fine-scale distribution patterns have to be investigated while the diurnal, spatial and seasonal variability can only be understood with at least some basic knowledge of the type of birds found (breeding, transit, wintering, feeding) and underlying determinants of their timing and *reason* of occurrence in a given location. It is clearly understood that a full blown ecological study is not what has been asked for (COWRIE 2002). Yet, it is important that census techniques should not be evaluated just on their merits for measuring seabird abundance and distribution, but be set-up such that our understanding and appreciation of the underlying mechanisms will be enhanced, preferably at the same cost level. As a simple and straightforward example: where fisheries enhance foraging opportunities for certain species of seabirds locally and will thus increase seabird numbers in a given area, measuring trawler activity and the associated seabird movements and congregations simultaneously will increase our understanding as to how the two interact and how fisheries influence local bird numbers by providing an artificial food source (discards and offal). Natural variability issues are issues of great importance and some level of ecological understanding of sea areas is essential if any changes in seabird distribution and abundance have to be forecasted or evaluated.

It must be stressed here that aerial and ship-based surveys *per se* are unlikely to provide a complete answer on all research aims, but some research protocols will provide valuable data. Aerial and boat based studies of distribution patterns and absolute numbers in a given area, land and "pseudo-stationary" boat studies of migratory pathways, and collision risks estimated from boat survey data, are unlikely to be all accommodated by a single research tool, and it should be made clear at the onset of future research what a particular method is most likely to offer. Other tools will have to be deployed (e.g. radar, heat, impact or motion sensors, etc.) to answer the numerous questions underlying these topics, but these tools are not addressed in this project.

Observation-techniques should be evaluated for their potential to be used in different conditions such as visibility (day, night, fog, low cloud), weather circumstances (sea state, rain, ice cover) and water depth (accessibility of the area for research platforms chosen). The type (technical requirements) of craft and the quality and training of observers are further issues that need to be addressed.

The research objectives listed above can be lumped into two main categories; one mainly addressing changes in seabird distribution and seabird abundance (for example through potential habitat loss), the other mainly considering the risks for collisions (seabirds in flight hitting rotor blades or masts of turbines). As main research aims, we have summarised and annotated the objectives as follows:

(1) Evaluation of effects of wind farms on seabird distribution and abundance
(2) Evaluation of collision risks (in relation to density, migratory pathways, flying height and weather)

Site-specific knowledge should be obtained prior to any surveys to fine-tune the methodology, including bathymetry, geographical characteristics, results of previous surveys within the area, likelihood of use by breeding birds (nearby colonies), by migrants (flyways), by foraging birds (habitat descriptions), by wintering birds or moulting birds, by fisheries, by marine mammals and the use of the area for mining (platforms, vessels) and by shipping (traffic lanes).

Patterns in seabird distribution and abundance

The first research aim is based on a more usual set of objectives for offshore surveys and the research protocols outlined below will produce data that serve our needs. Spatial patterns of seabirds should be studied with a high resolution given the size of planned wind farm sites, the expected variance in seabird presence and usage over the area and the need to enhance our understanding of underlying mechanisms. Temporal resolution should also be high, as seabird densities and behaviours, and thus, the risk of collisions or other impacts, may be highly variable at any one place. Seabird abundance (number of birds per unit area) needs to be assessed with a high accuracy and with clear confidence intervals. Inter-observer differences should be measured and minimized as much as possible and corrections should be made for animals missed (distance sampling techniques).

There is a rather large “but”, however, and this has to do with natural variability issues and the use that may need to be made of reported or forecasted abundance estimates. The reason why wind farm developers should address seabird distribution issues is that these patterns may be influenced by the building and/or subsequent operation of a wind farm in a coastal area. These effects may be clear (turbines take physical space and will trigger avoidance response at least to some extent), or they may be very subtle (enhanced or deteriorating foraging conditions for certain species). Changed use of an area is notoriously difficult to measure and distribution patterns are meaningless if explanatory factors are not considered. Distribution patterns should be described in a context of geographical characteristics (e.g. topography, bathymetry, sediments), oceanographical parameters (water masses, currents, river outflows etc.), food supplies, and anthropogenic influences (shipping, fisheries). Many of these data are more or less fixed over geological time-scales or at least many years, others are more variable and need to be measured simultaneously. As part of the evaluation of ecological mechanisms and factors underlying distribution patterns, the use of sea areas for foraging and feeding of the respective species should be examined. Pre-survey studies and survey protocols should accommodate this topic in as much detail as possible.

Evaluation of disturbance and habitat loss
Wind farms that appear in the open sea, will possibly scare birds away from the site. This will lead to disturbance (birds flying around or over the wind farm) or to habitat loss, through avoidance. At first, habitat loss seems a small problem, as projected wind farms are small in size compared to the vastness of the sea. However, the number and size of wind farms will increase rapidly in the future and this may lead to more excessive disturbance or more extensive habitat loss. This is particularly so, as most European wind farms will be situated in nearshore areas, that are by nature of a more limited extent than the open sea and that support important migration routes and specific habitats. Moreover, coastal waters are often relatively important for feeding, breeding, moulting, and migrating compared to waters further offshore. If many wind farms occur, one after the other along a migration route, the same birds will need to fly around many more obstacles than just those in the one wind farm that is under study at any particular time. Likewise, habitat loss will be cumulative for all the wind farms that occur in the same habitat, such as coastal sites around Britain and Ireland. Such sites are the only habitat (on a national scale) where specific coastal seabirds, such as divers or seaduck, come to winter in the North Sea. The amount of habitat lost (if any, this needs to be assessed first) should thus be compared to the total amount of that specific habitat available in the country, rather than to the total surface area of e.g. the North Sea. If habitats can be described in more detail in future, habitat loss may prove to be more severe in relative terms than can currently be estimated.

Migratory pathways
Migratory pathways, or intensively used flying routes (including foraging flights to and from breeding colonies) are not easily described from moving platforms such as aircraft or seagoing vessels. However, a detailed analysis of directions of flight of seabirds observed with time of day and time of year, and behavioural observations will fill in some aspects. Detailed studies of migratory pathways require more or less fixed (stationary) platforms of observation and the use of radar is to be recommended.

Evaluation of collision risks
Birds can only be hit by a rotor when they are flying and even then only when flying at rotor altitudes. As long as birds are on the water they are not vulnerable. Seabirds fly mostly rather low, below most rotor heights, but they may reach surprising altitudes on migration (e.g. Bergman & Donner 1971; Bergman 1974; Kerlinger 1982) or during soaring during the daytime (gannets, gulls). The risk may be assessed as a function of seabird density and the percentage of time spent in the air, at risky altitudes.

The research techniques evaluated in this document are not designed to evaluate collision risks in great detail. However, while previous surveys have produced two-dimensional distribution patterns (numbers of birds per unit area), ship-based survey design could be adjusted such that a 3-D image for at least the lower layers of the atmosphere (up to a few hundred metres a.s.l.) can be produced. The distribution of flying height can be assessed during seabirds at sea counts from ships, by categorising any birds seen in flight to its altitude (classes used in Dutch studies are: 0-2m, 2-10m, 10-25m, 25-50m, 50-100m 100-200m, >200m; a system adopted from landbird migration monitoring programmes; Lensink *et al.* 2002). This provides an estimate of seabird numbers in flight per volume in different weather conditions; information that is very sparse, but important to evaluate seabird numbers potentially in conflict with moving rotor-blades. This may give a first impression of which birds will be at risk in a study area. Additional information may be gained from seawatching data (e.g. Krüger & Garthe 2001). As most collisions will probably take place during the night or during misty, rainy or very windy conditions, when observers will probably not be able to measure altitudes of flying birds from ships, additional work using radar will be needed to fully explore this.

Natural variability

Seabirds are highly mobile animals, with long-distance migration and dispersion patterns. On top of that, seabirds may quickly respond to temporarily available food sources, such as discarding fishing vessels, tidally induced feeding opportunities, food (small fishes) being driven to the surface by underwater predators, etc. Such events may attract hundreds or even thousands of seabirds to a given spot and if this spot falls into a standard survey, the resulting enhanced densities greatly affect results. Seabirds at sea studies should therefore incorporate an evaluation of seasonal patterns, diurnal rhythms, and spatial variability caused by any external factors that can be identified. For most birds, seasonal patterns are such that areas should be surveyed at least on a monthly basis, but chosen in response to key moments in the annual cycle of the animals living in the area (wintering, migration, nesting, fledging, post-fledging care, moult, etc.). An appropriate planning of surveys (survey design) requires a review of existing knowledge of the animals expected to occur in the area studied. Diurnal patterns and tidal influences on seabird distribution should be measured and evaluated to allow an appropriate planning of surveys.

Seabird distributions around the British Isles are known mainly in broad terms (e.g. Stone *et al.* 1995), but in some parts, e.g. around some colonies, in greater detail (Webb *et al.* 1985; McSorley *et al.* 2003). Most distribution maps that have been produced so far are composites based on data from several survey years. Such overviews are suitable for determining an average base line situation, but the underlying data need to be re-analysed for temporal variance. As the ESAS data were not normally collected with a high temporal resolution in any one place, one will probably find for any particular site, that the data are fragmentary.

Scale and variability

Knowledge of bird densities at a large scale are not generally helpful when addressing more detailed questions relating to the cause of observed patterns in abundance and distribution, but are crucial to put local findings into context. Smaller flocks of seaduck and divers may utilise large coastal areas over a short space of time, moving from one spot to the other and vice versa in response to factors such as weather (exposure), tidal currents and food supply. Migration corridors can only be understood and described by combining data over large areas and by effort related observations revealing the often highly peaked seasonal patterns and diurnal rhythms. The usage of an area by coastal and/or pelagic seabirds and physical boundaries that are of significance to either of these need attention. It may be so that a physical boundary such as an hydrographical front is just within, or just beyond the study area, explaining many of the seabird movements and distribution patterns observed. It may also be that factors outside a study area will control bird numbers within a given study area.

Monitoring seabird numbers in a given area to reveal seasonal or gradual long-term trends or to study the spatial and temporal variability of seabird numbers in more localised areas in connection to certain environmental parameters requires a different approach. In these situations, statistical tests between densities in time and space are a prerequisite of the methods, together with the need for a high level of spatial resolution in localising birds. In particular, the process of environmental impact assessment, or the identification of geographical boundaries for the process of site safeguard, requires a high level of spatial precision to describe bird distribution and abundance and the ability to demonstrate changes in these densities.

Migratory pathways (routes, direction of flight, seasonal patterns).

Seabird movements over the North Sea can be swift or slow and peaks in occurrence may be in the timeframe of a couple of days or even hours only. Large-scale movements, e.g. from season to season may be inferred from sequential, monthly or bi-monthly maps that are available for all common species of seabird for large areas of sea around the British Isles. For instance, the slow migration (by swimming) of Common Guillemots across the North Sea, between the UK and the Kattegat/Skagerak area may be followed this way. Faster migrations, by birds moving on the wing will be harder to trace as these may happen within one month, over large distances. Surveys need to be planned to maximise the likelihood that migrants are actually recorded. Additional information on timing and direction of flight is available from many coastal, “seawatching” sites around the North Sea. Some information on seabird movements is available from offshore platforms, that have sometimes been manned by experienced seawatchers (Camphuysen *et al.* 1982; Platteeuw *et al.* 1985).

Weather effects

Seabirds are known to respond to adverse weather by movement, sometimes over large distances. This may lead to occurrence of offshore species in nearshore waters in connection with specific weather conditions (e.g. Blomqvist & Peterz 1984) or wrecks (e.g. Camphuysen & Leopold 1996). Obviously, any massive movement of seabirds may cross a wind farm site and affect densities therein temporarily. Some sites will be more prone to this than others, and emphasises requirement to survey during all weather conditions which are safe for the survey platform, not just nice weather! Risk assessments can use meteorological data to predict the likely frequency of weather events that may increase the potential for collision.

Diurnal patterns and tidal influences

Seabirds respond to offshore foraging conditions in various ways, but daylight and tidal influences are perhaps the most important factors for many birds to find and obtain prey. Diurnal rhythms may be such that a site is not used at all for some part of the day, with peak occurrences early morning, mid-day or just before sunset. Tidal currents influence distribution patterns greatly and seabirds may be expected to move in and out sites with the tide. For migratory seabirds, diurnal patterns in the intensity of migration require attention, for peak occurrences may take place at certain times of day.

Foraging areas
Specific feeding areas at sea are poorly known. There are obvious concentrations of seabirds at sea around their colonies, but at larger distances from colonies, or in the non-breeding season, the situation is often less clear. Predictable feeding concentrations of seabirds and marine mammals are known to occur at frontal systems, around banks or other elevations on the seafloor, over shellfish banks (seaduck) and around fishing fleets.

Factors explaining seabird distribution and abundance
Seabird distribution and abundance are governed on different time scales. There is a strong seasonal component that causes a large proportion of any population to be tied to specific areas in the breeding season (e.g. within flying range of colonies). Many seabirds move to specific areas to moult or winter, following broadly defined migration routes (offshore species) or more clearly defined narrow migration bands (coastal species). In the short run, fishing fleets or single fishing vessels will attract scavenging seabirds, but mainly at certain stages of the fishing process, e.g. when nets are hauled and by-catches and discards are put back into the sea (Camphuysen *et al.* 1995). Strong daily rhythms in movements have been observed in wintering offshore seabirds (Camphuysen 1999), while nearshore species such as gulls or cormorants often sleep on land and feed at daytime, at sea. Hence, abundance of a given species, at a given location at a given time will be a function of total numbers in the population, the time of year, and possibly the time of day, as well as less predictable factors such as presence of fishing vessels or approaching weather systems. Many factors need attention when seabird distribution patterns have to be understood, explained and perhaps even predicted. This includes information on habitat characteristics (e.g. water mass, geography, depth, distance to land, prey availability) as well as detailed information on the behaviour (habitat utilisation) of the birds studied.

Common Guillemots with young chicks, just prior to fledging (Farne Islands, summer 2003, CJ Camphuysen)

Survey techniques

In an effort to standardise observations, techniques have been developed that provide an index of relative abundance corrected for observer effort and detection probability and several methods may now be deployed during ship-based or aerial surveys, including **strip-transects**, **point** and **line-transect** techniques. Direct counts are very not practical to cover large areas of sea, because animals move, the water moves, the observation platform moves, and many of the smaller animals are highly inconspicuous or submerged part of the time. Even with smaller sites, sub-sampling is normally required rather than a direct count of the entire population in the study area, and the techniques listed above are the most appropriate (Buckland 1982; Buckland & Turnock 1992; Buckland *et al.* 1993; Sutherland 1996). Exceptions are direct counts of single, concentrated, large flocks of seaduck caused by a concentrated resource of food (Offringa & Leopold 1991).

Combinations of methods are possible onboard (large) research vessels, if sufficient numbers of observers can be accommodated to operate simultaneously and independently. It would be naïve to assume that several different techniques could be deployed simultaneously by a single observer or by a very small team of (2) observers without significant loss of quality. Most ESAS associated ship-based surveys and most aerial surveys have deployed strip- or line-transect counts as the only technique. Within ESAS, much of the ship-based work has been realised by a single observer. With few exceptions, modern surveys are performed by at least two observers teamed up to work one transect (four observers if a double transect is worked). Mark-recapture techniques have thus far seldom been used, but could work with studies of marine mammals.

Line-transect technique using parallel strips (ship and boat surveys)

Line transect versus strip-transect techniques – confusing terminology

It appeared that there is confusion with terms and to avoid further confusion, terms used in this document are explained here. Ship-based survey techniques for the North Sea have been described as **strip-transects** (Tasker *et al.* 1984). The method required that all birds along the transect are detected within a pre-set perpendicular distance (the strip width). The strip width needed modification when necessary, i.e. be made narrower during adverse sighting conditions. As soon as the method was published, it was modified by the main users, to allow correction factors to be calculated for birds that were missed. To do that, birds seen on the water were ranked in 5 distance categories (A-E); distances perpendicular to the observation platform. The term strip-transect was not completely abandoned, although the method was now a form of **line-transect** technique (Komdeur *et al.* 1992). Aerial survey techniques, described in this document, have always been described as line-transect counts, even although the methods used were essentially identical to ESAS ship-based surveys: parallel distance bands as perpendicular distance groupings of animals observed to allow for later correction of individuals missed at greater distances. To add to the confusion, line-transect methodology in the strictest sense requires exact measurements of the perpendicular distance to the track line for every sighting and this method has been used and will have to be used for marine mammal surveys. While ship-based and aerial seabird surveys group animals in distance bands, perpendicular distances to the track line are calculated much more precisely by recording angle (°) and distance (m) for every individual sighting in marine mammal surveys.

The objective of this review is to use a method to generate population density estimates (D) over small areas of the marine environment based on the most effective sampling methods. One approach to this is to sail or fly extended transects and describe the distributions of birds encountered by observers along these trajectories, usually in terms of bird encounters per unit area (e.g. n km^{-2}). Strip transect sampling involves travelling along such transects, counting all the birds encountered out to a predefined distance, effectively covering long linear corridors on either side of the observer (Buckland *et al.* 2001). Given k of such strips, each width $2w$ (w being the width of the area covered by one observer on either side of the count platform), each strip i has length l_i, hence the total length (L) can be denoted:

$$L = \Sigma^{k}_{i=1} l_i$$

The total number of birds counted in all the strips is n, denoted:

$$n = \Sigma^{k}_{i=1} n_i$$

Then density D is estimated by:

$$D = n/2wL$$

To create a density estimate surface, it would be possible to cut the strips into sections along each transect in order to define the encounter densities over the study area. However, the basic assumption is that all objects within the strip are detected. Usually, however, no relevant data are collected at the time of the survey to test this assumption. This assumption is unlikely to be met, unless the strips are restrictively thin, which may in turn be highly inefficient, since many observed objects would be ignored to ensure all near objects were detected (Burnham & Anderson 1984).

Line transect (distance) sampling has far greater appeal as a modification of strip transect sampling. Instead of counting all objects out to a given distance in a strip of defined width, the observer records the distance of each object from the track line, hence "Distance Sampling" (Buckland *et al.* 2001). In this way, all objects on or near the track line are detected, but the method allows for a proportion of the objects present at the time the observer passes to be missed, within a given distance *w*. In this case, as long as the observer ensures all objects on or near the track line are detected, true density can be estimated without bias from the detected objects. An analysis at species level is required, for species-specific differences exist in detectability.

This makes the method a more efficient use of data gathered by the observer, with large sample sizes for the same effort, especially when dealing with objects at low density. It also ensures unbiased density estimates, given that certain assumptions are met. The sampling design requires a number of random track lines, or a grid of track lines systematically positioned at regular intervals randomly superimposed on the study area. In this case, the encounter rate within a strip can be thought of in terms of an effective half-strip width of μ which represents the distance from the track line at which as many objects are detected beyond μ as are missed within μ of the track line. In this case, density D is estimated by:

$$D = n/2\mu L$$

To estimate the effective half-strip width μ necessitates the determination of the detection function $g(y)$, i.e. the probability of detecting an object given its distance y from the track line. This is derived from the population of object observations generated from the survey results, which will show in simple bi-plots the predictable reduction in detected objects with increasing distance from track line. In order to generate robust estimates of overall density, however, the method requires an assessment of g(0) (following the assumption in the model that objects on the track line are always detected; i.e. that $g(0) = 1$). In addition, the method also requires that (i) objects are detected at their initial position, prior to any movement in response to the observer and that (ii) distances to objects are accurately and consistently determined.

In most surveys, the detection probability decreases with increasing distance from the observer. Although the nature of the relationship between distance and the probability of detecting an object can vary considerably, it is relatively simple to model this relationship in such a way as to generate reliable estimates of true density. The process can also be simplified by "binning" observations. This means that rather than measuring the distance of every observation from the track line (for example using protractors and triangulation), observers can assign bird positions to bands of increasing distance from the observation platform. Even using binned data and when small percentages of the total number of objects are detected away from the track line, modelling offers a highly robust means of fitting detection functions (Buckland *et al.* 2001). Although there are a plethora of potential models that could be fitted to survey data, there is now a body of theory and experience behind such techniques. Furthermore, the use of likelihood ratio and goodness of fit tests, as well as Akaike's Information Criterion enables objective selection between suitable models (Burnham & Anderson 1998).

Such model-fitting provides the most statistically robust method of estimating bird densities over extensive bodies of open sea based on the results of aerial or ship-based survey, and fulfils all the requirements of the methods outlined above, as long as the underlying assumptions are met. In particular, the opportunity to generate estimates with variance precision estimates offers the basis to make comparisons in time and space between bird densities as are required in the environmental impact assessment method.

Line-transect techniques using individual distances to the track line for marine mammals
This technique, or the *true* line-transect technique, is most appropriate for recording rare, elusive objects, such as marine mammals. With the need to carefully assess perpendicular distance from the track line for every individual or flock observed, this method is not practical to record seabirds at sea, not even in areas with relatively low densities. Line-transect techniques have been described by Buckland (1985), Buckland & Turnock (1992), and Borchers *et al.* (1998).

Point-transect techniques
Strictly speaking, a point transect requires the observer to remain at one point for a fixed period of time to record the targets at distances recorded in terms of concentric zones around the point (Buckland *et al.* 1993, Sutherland 1996). For seabirds and marine mammals it is not a very practical method and it hasn't been deployed anywhere, except on vessels where considerable time was spent on stations. The results will never be very reliable, however, because the assumption that the behaviour of the animals observed is independent of the observer is almost always violated: marine mammals and seabirds have a strong tendency to 'check-out' stationary platforms for foraging opportunities. A variation of the point-transect method has been deployed in a large-scale project where fishery intensity needed to be measured at the same time as seabirds were counted with the strip-transect method (Camphuysen *et al.* 1995). At frequent intervals, all active fishing vessels were counted within a fixed *r* set on the radar screen (assumed detection probability = 1). Each snap-shot has geographical information and a known

surface area, allowing the calculation of densities (active trawlers km^{-2}) and it results in a coarse distribution pattern of fishing activity. This technique has not and should not be deployed for seabirds or marine mammals at sea.

However, in the specific situation, where seabird densities need to be assessed in a fixed area, such as a wind farm at sea, the technique may prove useful, specifically when an observation base is present within the park. Such a base could be a stationary ship (but see above for problems mentioned in relation to such a base). A base, such as a central 'command post' such as a power collection station, equipped with an observation platform, could prove to be useful, as such a base would be an integral part of the wind farm. Animals being attracted to that base, or indeed the wind farm, would simply be part of the equation. As such point transect methods have not been used before properly at sea, and in any case not in a wind farm setting, this is an option that could be explored in the future.

Seaduck and diver surveys: local modifications to ESAS database

Methodological deviations were sometimes put in place because for example counts of large seaduck or diver concentrations from ships could not be performed successfully with the strip-transect protocols deployed up until then (Offringa & Leopold 1991; Offringa 1993; Leopold *et al.* 1995; Durinck *et al.* 1993). These modifications meant that dedicated observers continuously scanned the sea area ahead of the ship with binoculars, to detect the take-off of usually very wary seaduck and divers well ahead of the approaching platform. Line-transect techniques (distance sampling) could still be deployed by measuring angles and distances to flushed birds ahead of the ship (Durinck *et al.* 1993), but total counts have also been used, e.g. on very large (tens of thousands) groups of seaduck.

Geographical accuracy

The advent and wide availability of navigation aids (such as global positioning systems [GPS]) enable the identification of the precise position of a moving observer with accuracy. This enables pilots and skippers to establish waypoints and fly or sail along predetermined track lines with a very high degree of accuracy. Such equipment also enables surveyors to localise observations of individual birds, or flocks of birds, with similar accuracy. This means that, rather than smoothed or amalgamated sampled densities over grid squares, the surveyor can plot with an increasing degree of spatial accuracy all encounters with birds. This has a number of immediate benefits, which need to be considered, and taken advantage of, in designing any survey protocol. Not least of these benefits is that the observational unit becomes a flock or individual bird (aerial survey) or a number of records within a short time interval (ship survey) with a precise location, rather than a pooled average density. This enhances the opportunity to relate bird distributions to oceanographic, bathymetric or other physical/biological features of their environment that could influence their distribution and which could potentially contribute to modelling distribution and abundance in time and space. It should be stressed immediately that to appropriately relate the distribution of birds to oceanographic (and most biological) features, such data should be collected simultaneously.

Because the mapping of individual birds and groups of birds can be very precise, with accumulated knowledge and appropriate replication of survey, the variations in abundance and distribution of seabirds can be defined in such a way as to define spatial and temporal patterns in abundance and distribution. In particular, such detailed mapping of flocks and individuals will demonstrate with considerable confidence where and when seabirds consistently occur, where they occur less frequently and areas where their occurrence is rare. Using even a very simple GIS platform, this would immediately enable the zoning of potentially damaging operations in time and space that would minimise any potential effects on seabirds given a composite overview of annual changes in their distribution in a given area. The ability to provide these data with some statistical rigour based on individual positions provides an important tool to zone areas of importance for seabirds as well as define those areas where the birds almost never occur.

Red-throated Divers in flight, Iceland, summer 2001 (CJ Camphuysen)

Ship-based seabird surveys

Strip- and line-transect techniques for seabirds
The standard strip-transect techniques used by the European Seabirds at Sea Database group (ESAS) have been outlined by Tasker *et al.* (1984). Modifications have been described by Komdeur *et al.* (1992), and what was called strip-transect technique thus far is basically identical to what is described as line-transect technique in the description of aerial surveys (see inset above under "Survey techniques"). The method involves a 300m wide band- or strip-transect operated on one side and ahead of the ship and short time-intervals (1, 5, or 10-minute periods) in a continuous series to sample short stretches of water with a known surface area, a known location and any other biological, geographical, or physical factors that could be associated by that area. To evaluate the bias caused by specific differences in detection probability with distance away from the observer, the transect is subdivided into narrower distance strata (A= 0-50m away from the ship, B = 50-100m, C = 100-200m, D = 200-300m, and E > 300m). A species-specific frequency distribution over these strata would indicate how many individuals were likely to have been missed in the furthest strata (Distance Sampling). All birds on water within 300m perpendicular to trackline of the ship are counted as 'in transect'. To avoid an overestimate of bird numbers in flight, a regular snapshot of flying birds over the transect and within 300m distance ahead of the ship is performed (frequency of snapshots depending on ship's speed; Tasker *et al.* 1984). Distance techniques, used to correct numbers of birds observed swimming to numbers believed to have been present on the water, cannot be deployed on birds in flight. Birds 'outside transect' are recorded either in a 90° or 180° scan ahead of the ship. Birds recorded in the scan are not used to calculate densities, and recording them has therefore a lower priority than recording birds in transect when abundance estimates are the main objective of a survey. Scan results may enhance assessments of age- and sex composition of certain populations or directions of flight by migrants and birds travelling to and from colonies simply by enlarging sample sizes and the scan accommodates sightings of rarer, highly mobile seabirds such as shearwaters, skuas, terns and migratory birds that would otherwise remain unrecorded, or flushed birds, e.g. divers and scoters.

Transect width is 300m by default, unless circumstances (sea state, visibility, small ship size) prevent the observers from doing so. However, it is recommended to discontinue systematic surveys in circumstances so poor that a minimum width of 200m cannot be maintained. Time-intervals deployed are variable, in response to specific needs. Tasker *et al.* (1984) proposed 10-minute intervals. Large-scale surveys are indeed usually performed with 10-minute intervals, but smaller scale surveys should be conducted with 5-minute or 1-minute intervals. For the preferred vessels and speeds deployed (see below), working on gradients over miles rather than tens or hundreds of miles, we would propose 5-minute intervals as a sensible default, 1-minute intervals for a more detailed approach. At a ship groundspeed of 10 knots (nautical miles per hour) a single 5-minute count would comprise an area of 1543 m x 300 m = 463,000 m^2 (50/60 of a nautical mile length, 300m width), whilst a 1-minute count would comprise an area of 309 m x 300 m = 92,650 m^2 (10/60 of a nautical mile length, 300m width). Each snapshot captures ± 300 m x 300 m = 90,000 m^2. For each time-interval a central geographical position (lat-long) is stored into the database. In most situations, this requires accurate logging of start- and end-positions, and a calculation of mid-positions afterwards.

Efficiency may be enhanced by operating two transects at the same time, one on each side of the ship. This will require extra observers, but no extra ship time. Sun-glare is a problem to take into account, as now both sides as opposed to the side with optimal light and sighting conditions need to be operated. Therefore, operating one transect (best side) is preferred over operating two transects for which usually one has much poorer light conditions. An advantage of operating two transects at the same time is, that with more surface area surveyed per count, chances of recording "false zero's" decrease, and more accurate assessments of low densities may be achieved. Small-scale differences in seabird densities may also be better assessed this way.

The method assumes that target species behave independently of the observers/the observation platform. Therefore, ship-followers should not be recorded as animals in transect and in fact should be kept aside at all times. To avoid problems with ship-followers it is important to maintain a minimum speed of the platform (> 5 knots). At low speed, ship-followers have a stronger tendency to fly ahead of the vessel. Strip transect counts are excellent for counting seabirds at sea and the method does not require a random distribution of target animals to be successful. A careful assessment of distances (at least within the 300m boundary should be carefully set and maintained) is essential to avoid over-or under-estimations.

Following the demands to evaluate sea areas in a context of offshore wind farm developments, the methods have been evaluated again and new modules were attached to the standard methods by a number of (independent) researchers around the North Sea (Exo *et al.* 2003; Garthe *et al.* 2003; Hüppop *et al.* 2003). It is these newly proposed modules plus the original methods for ship-based and aerial surveys at sea that are evaluated in the present study, to set standards for future work around the UK, and hopefully elsewhere in Europe.

Transect set-up recommendations for ship-based surveys

	Time intervals[1]	Band width	Subdivision	Observers	Snap-shot
Minimum	1 min	200m	A (0-50m) B (50-100m) C (100-200m) D (>200m)	2	200m
Maximum	10 min	300m	A (0-50m) B (50-100m) C (100-200m) D (200-300m) E (>300m)	-	500m
Recommended[1]	5 min	300m	A (0-50m) B (50-100m) C (100-200m) D (200-300m) E (>300m)	≥ 2	300m

[1]Scale dependent, 5-min intervals produce valuable data on the gradient level of several nautical miles, 10-min counts may be more useful at larger scales, 1-minute counts are preferred and recommended when a high level of accuracy is required in very small study areas or for example in combination with hydrographical observations. Note that (total) band width, as well as the number of observers double if two strip transects are to be operated simultaneously.

Behaviour of birds

A protocol has been provided to record behavioural aspects of the birds observed (Annex 1). Crucial are attempts to relate the presence of birds to any visible cues in the area (e.g. fishing vessels, front lines, floating matter, offshore installations, marine mammals) and to try and distinguish between birds that simply pass through an area (e.g. migrants, long-distance feeding flights) and birds that utilise a site for feeding, resting, or other activities. A careful recording of directions of flight, particularly in nearshore situations, will enhance the understanding of seabird movements in an area. Today's practice is to record flight directions in octants (1 = no direction, 2 = northward, 3 = NE, 4 = E, 5 = SE, etc; ESAS Database protocol, see Annex 1).

Flying height of birds

The distribution of flying height can be assessed during seabirds at sea counts from ships, by categorising any birds seen in flight to its altitude (classes used in Dutch studies are: 0-2m, 2-10m, 10-25m, 25-50m, 50-100m 100-200m, >200m; a system adopted from landbird migration monitoring programmes; Lensink *et al.* 2002). This provides an estimate of seabird numbers in flight per volume in different weather conditions; this is important when evaluating seabird numbers potentially in conflict with moving rotor-blades.

Training of observers, observer quality

A presumably large, but often neglected source of variation is inter-observer differences (van der Meer & Camphuysen 1996). Observers on board must be competent. Specifically, they must be well-trained both in terms of their identification skills as well as in their capacity to deploy the required survey technique (especially to record navigational data and deploy the snapshot technique for flying birds), and observers must have good eye-sight and be able to withstand rough seas and overcome sea-sickness. To become a competent observer, several boat trips under contrasting situations are required, normally involving several weeks of fieldwork under the supervision of a very experienced observer. Within ESAS, observers from different teams (internationally) are encouraged to try to organise joint cruises to be able to compare their work directly and to detect differences in interpretation of the prescribed methodology. Employing only experienced observers and frequent training will solve part of the problem of individual variation, but this source of variation (negative bias mostly) will in all likelihood be greatly reduced (no specific studies have been carried out on this topic), by using more than one observer to watch the same transect. Therefore, as recommend earlier, two observers should be employed on each side of the ship.

Avoiding attraction by birds

Vessels at sea attract seabirds, even if they do not provide food. As a default, attracted birds (normally defined as those remaining with the ship for more than 2 minutes) should be coded as such and kept out of the analysis of densities in an area. From commercial fishing vessels, sensible data on seabird distribution at sea cannot be obtained and working on fisheries research vessels is only feasible if fishing operations are wide apart and separated by prolonged sessions of full-speed steaming. It is strongly recommended *not* to use fishing vessels for offshore surveys that have accurate abundance estimates as a prime objective.

Additional data

Ship-surveys provide unique opportunities to obtain additional data. Vessels equipped with an Aquaflow could record characteristics of the surface water, such as temperature, fluorescence (chlorophyll), and salinity simultaneously with the bird counts. Water depth (depth sounder) and the presence of fish (acoustic survey) are further sets of data that will enhance the understanding of area usage by marine birds.

Recommended methodology, ship-type, and observers

Recommended census techniques for ship-based seabird surveys, as part of an EIA, are line-transects with sub-bands and with snap-shots for flying birds, and incorporating the full behaviour module recording detailed information on species, sex and age where feasible, foraging behaviour, flying height. Whenever possible, hydrographical data, such as sea surface temperature, salinity, water depth should be continuously and synoptically monitored. For a minimum set-up, the following techniques and qualifications are recommended.

- Line-transect methodology is recommended with a strip width of 300m maximum.
- Subdivision of survey bands to allow corrections for missed individuals at greater distances away from the observation platform (recommended subdivision for swimming birds: A= 0-50m, B= 50-100m, C=100- 200m, D= 200-300m, E= 300+m or outside transect; all distances perpendicular to the ship).
- No observations in sea state 5 or more to be used in data analysis for seabirds, data not usable for marine mammals above sea state 3.
- Survey time intervals are recommended to be 5 (1) min intervals (range 1-10m, longer time intervals are acceptable when less resolution of data is required), with mid-positions (Latitude, Longitude) to be recorded or calculated for each interval.
- Preferred ship's speed should be 10 knots (range 5-15 knots).
- Preferred ship type is a motor vessel with forward viewing height possibilities at 10m above sea level (range 5-25m), *not* being a commercial or frequently active fishing vessel.
- Preferred ship-size: stable platform, at least 20m total length, max. 100m total length
- Bird detection by naked eye as a default, except in areas with wintering divers *Gaviidae.* Scanning ahead with binoculars is necessary, for example to detect flushed divers.
- Two competent observers are required per observation platform equipped with range-finders (Heinemann 1981), GPS and data sheets; no immediate computerising of data during surveys to maximise attention on the actual detection, identification and recording.
- Observers should have adequate identification skills (i.e. all relevant scarce and common marine species well known, some knowledge of rarities, full understanding of plumages and moults).
- Observers must be trained by experienced offshore ornithologists under contrasting situations and in different seasons.
- A high resolution grid should be deployed, covering an area at least 6x the size of the proposed wind farm area, including at least 1-2 similar sized reference areas (same geographical, oceanographical characteristics), and preferably including nearby coastal waters (for nearshore wind farms only).
- Survey grid lines are recommended to be at least 0.5nm apart, maximum 2nm apart, and the grid should be surveyed such that time of day is equally distributed over the entire area (changing start and end time over the area to fully comprehend effects of diurnal rhythms in the area)
- The cost-effectiveness of the ship-based surveys are greatly enhanced if the vessel can be equipped with an Aquaflow (logging surface water characteristics including temperature, fluorescence (chlorophyll), and salinity logging hydrographical information simultaneously).
- The cost-effectiveness of the ship-based bird surveys can be greatly enhanced if combined with other surveys, such as those of marine mammals, for which a specialist observer and different methods will be required.
- The cost-effectiveness can be further enhanced by counting birds on both sides of the ship, i.e. cover two strips, for which additional observers will be required.

Conclusions

In attempting to draw together the various conclusions relating to the effectiveness of ship-based surveys, and in particular the approaches presented here, it is important to reconsider the objectives set for the method. These are summarised in Table 1.

Explaining seabird distribution in ecological terms is not just a scientific interest, but is essential to understand seabird occurrences from census data, to explain the (natural) variability of the data collected, or even to predict (future) occurrences (Maurer 2002; Scott *et al.* 2002). Ships work more slowly than aircraft, and therefore spend longer at sea. Whilst this may seem a disadvantage at first glance, seagoing vessels may offer better possibilities to record natural variability issues, such as tidal and diurnal patterns in seabird abundance resulting from shifts and patterns in area usage. Directions of flight and the (ecologically relevant) behaviour of seabirds can be studied in considerable detail, while (foraging) associations with for example fisheries, marine mammals, and oceanographical phenomena can be logged in great detail. These data enhance the possibilities for an ecological interpretation of the material collected and, hence, will be essential to evaluate the area studied for migrants, residents, (nearby) breeding birds, and winter visitors.

The cumulative distribution of encounters of individuals of given species can provide inference on foraging areas, but without detailed investigations of prey distributions, foraging behaviour and the conditions enhancing the availability of prey to foraging seabirds, there will be no difference with for example results from aerial surveys. The great benefit of ship-based surveys is the potential to collect data on foraging conditions (water masses, presence of prey) simultaneously (oceanography, acoustic survey, fisheries data) or near-simultaneously (benthic sampling) with foraging seabirds. In addition and in general terms, the incorporation of environmental covariates into spatial and temporal models to generate bird density surfaces can provide insight into the factors affecting birds abundance and distribution. The possibility to exclude non-residents (migrants) or non-foraging seabirds from actively searching and feeding seabirds will strengthen the analysis and will help with the interpretation of results.

As a contribution in the evaluation of collision risks, ship-based survey protocols can be easily modified as to collect data on the height of flight under different conditions. A three dimensional pattern of seabird distribution and abundance will result. Still, static measuring devices (such as infra-red movement triggered video surveillance and vibration detection equipment currently under development) are needed to measure the impact of windfarms more directly.

Table 1. Overview of effectiveness of ship-based strip-transect surveys, distance sampling, spatial and temporal modelling techniques in relation to specific tasks set under the process of environmental impact assessment of offshore windfarm development.

	Strip transects	**Distance sampling (line-transect)**	**Spatial modelling**	**Temporal modelling**	**Other approaches needed**
Seabird distribution	Good	Better	Best	Best	Validation (double platform or other)
Seabird abundance	Good	Better	Best	Best	Validation (double platform or other)
Migration routes	Reasonable	No improvement	Better	Better	
Migration flight Direction	Good	No improvement	Better	Better	
Seasonal migration	Good	No improvement	Better	Better	Combine with data collected at coastal sites (seawatching)
Weather effects	Reasonable	Better	Best	Best	
Foraging areas	Best	No improvement	Best	Best	
Factors affecting distribution and abundance, diurnal patterns and tidal influences	Best	No improvement	Best	Best	Foraging associations recorded, oceanographical data directly coupled
Prediction of collision risk	Information of height of flight collected	No improvement	No improvement	No improvement	3D radar studies of flight trajectories before/during/post- construction
Assessment of collision risk	No contribution	No contribution	No contribution	No contribution	Infra-red video; vibration detectors post-construction
Assessment of disturbance and habitat loss	Good	Better	Best	Best	

Aerial seabird surveys

One of the objectives is to achieve the mapping of bird density distributions at the highest possible spatial precision, without causing disturbance to the underlying pattern of distribution, and while using analytical techniques that derive workable precision estimates about density estimates. The techniques reviewed, presented and recommended in Komdeur *et al.* (1992) were developed for the general description of bird numbers and distribution in offshore waters on a macro scale. This type of approach was used with success to analyse numbers and distribution at flyway, regional and national scales (such as those presented by Durink *et al.* 1994, Pihl & Laursen 1996, Laursen *et al.* 1997). However, these methods were never developed to generate fine scale density estimates of smaller areas of open sea, nor were the data they generated of a form that could support the use of analytical tools that would enable statistical comparisons of time series. Such analysis is fundamental, for example, in a situation where it is necessary to compare before, during and after seabird distributions during the construction of an offshore windmill park. This chapter concentrates upon the rationale behind the adoption of best-practice aerial survey techniques, with reference where appropriate to other techniques.

This part of the desk study is less of a review of aerial surveys than a justification of the methods adopted by the National Environmental Research Institute (NERI) in Denmark, simply because of the scarcity of information relating to different techniques. Wherever possible, some justification for the methods adopted are offered where there are appropriate experiences in the literature, but all too often there is little published to offer guidance on the best techniques available.

Transect bands

Experience suggests that assigning sample unit observations to one of three transect bands in the time available to process and record the information seems to be as much as can be dealt with under normal circumstances. Sub-division into further bands does provide benefits, especially with regard to generating density estimates for distance sampling. However, it is recommended that any further subdivision of bands is done on the basis of distances which equate to declination angle units of 5° or 10° apart to greatly aid the speed involved in checking distances using the inclinometer. It is also essential that any such further subdivision is carefully considered and subject to trials in the field, given that it must still be possible to assign all observations to these bands even at greatest rates of encounter. It is suggested that transect bands are identified by alphabetic codes to avoid confusion with flock numbers or registrations of time intervals.

Using the NERI system and the Partenavia P-68 observer aircraft (see below), transect bands A, B and C (defined below) are covered on both sides of the aircraft. Use of the inclinometer, to measure vertical declination from the horizontal (i.e. 0°) is encouraged at all times, to enable the observer to confirm the correct categorisation of birds or flocks in the correct transect bands. This method has been found to be better than using tape or striations on the bubble windows of survey aircraft or other methods such as wire tracers mounted externally (e.g. on wing struts see Figure 7.9 on p.261 of Buckland *et al.* 2001). The latter techniques necessitate flying without roll or yaw and protracted periods where the observers do not move their head relative to the markers. All data gathering assumes that there is a “dead angle” underneath the aircraft that the seated observers cannot cover, here considered to be an angle greater than 60° from the horizontal. Given a normal flight altitude of 250 feet (80m), the transect bands are defined as follows:

Band	Boundary distances (in m.) perpendicular out from track line	Declination in degrees from the horizontal
A	44-163	60-25
B	164-432	25-10
C	433-1000	10-4

Time is read from the watch, which is preferably attached to the window of the plane in an appropriate position to allow the observer unhindered access to read the time whenever necessary. It is only necessary to record minutes and seconds, recording the hour only when changing from one to the next. It is, of course, essential that the stopwatches be synchronised with the GPS used. Time should be recorded as often as practically possible. It may become necessary to pool more than one observation of birds under the same time record. The guiding principal should be that the more frequent the time recordings are, the greater the accuracy obtained in the final analysis.

The position assigned to each observation is made under the assumption that the time is recorded at the precise moment the observation passes abeam of the aircraft on the transect strip. This is normally the case, but if for reasons of observation density, recordings are made where this assumption is not met, and birds are recorded at times after the point of encounter, this fact should be noted on the tape.

Choice of airframe

One major prerequisite for the suitability of a particular aerial platform is that the aircraft flies at a speed slow enough to enable the onboard observers to count and identify birds over the widest area possible. In general terms, this means normal operational flying speeds of 250 km h^{-1}, and preferably less. With their ability to fly slower, helicopters offer the opportunity to fly transects at a greater range of speeds than fixed wing platforms. Whilst the cruising speed for most small helicopters at sea level is around 200 km h^{-1} (e.g. 230 km h^{-1} for an Aerospatiale SA 330 Puma, 200 km h^{-1} for a Bell 212, and 167 km h^{-1} for an Aerospatiale SA 318 C Alouette-Astazou), operational direct line flight speeds can be reduced yet further without compromise to safety. Unfortunately, a second major prerequisite on the method of data collection is the major assumption of many aerial survey methods is that birds are first detected by the observer in a distribution that is undisturbed. Helicopters are associated with intense noise, both high and low frequency, which is detectable at long distance and tends to be highly disruptive to waterfowl generally (Miller 1991, Mosbech & Glahder 1991, Holm 1997). Although habituation is known to occur under certain circumstances (Kahlert et al 1996, Holm 1997), this is unlikely to occur in the case of occasional surveys over large areas of marine waters. This disturbance of the detected distribution from the “natural” distribution creates considerable difficulties for the accuracy and precision of population estimates. Although attempts have been made to correct for the overestimation in numbers that invariably results, in practice, it is extremely difficult to calibrate for the disruption caused by the aircraft (e.g. Linklater & Cameron 2002).

Microlight aircraft also offer low survey speeds for wildlife surveys (e.g. Murn *et al.* 2002), but the combination of low speed and noise is also highly disruptive, the platform lacks necessary endurance and the associated safety hazards of operations at sea rule this out with regard to aerial survey for offshore wind farm developments. Safety and aircraft endurance is also a constraint on airframe – although a Piper Cub has a potential cruising speed of 110 km h^{-1}, normal fuel tanks and loading only offer an endurance of 4 hours. This greatly restricts operations and the safety margin, especially with regard to diversions in the case of engine or other mechanical failure. The same restrictions apply to most single-engine aircraft, and flight safety rules in Europe effectively restrict operations in the offshore zone to twin-engine aeroplanes. For this reason, surveys in most western European countries have increasingly been carried out using twin-engine aircraft, most commonly high-wing aircraft that ensures best all round visibility for observers. Extensive experience has been obtained in Denmark in seabird surveys conducted from a high winged, twin-engine Partenavia P-68 Observer, designed for general reconnaissance purposes. Although other aircraft would undoubtedly be suitable for the purpose, the bubble windows in the side of this aircraft and the Plexiglas nose of this particular type make this aircraft eminently suitable for the task of aerial survey (see Figure 1). JNCC has been using a normal Partenavia P-68 (e.g. Dean et al. 2003) around the UK.

Figure 1. Partenavia P-68 Observer aircraft. Note the plexiglass nose for pilot and front seat observer, and bubble windows on both sides of the aircraft in the rear passenger panels (see on open door to right).

Survey flight speed and altitude

The question of the appropriate flight speed and altitude is an intractable one to some extent, representing as it does a compromise between competing requirements placed on sampling. Flight speed is set to some degree by the nature of the aircraft, which is in turn determined by factors other than survey protocol (e.g. safety and endurance). Extensive previous experience with aerial survey, aircraft availability, high wing design, bubble and Plexiglas windows all confirmed the Partenavia as the natural choice for this work in Danish waters, but other factors may conspire in favour of other aircraft under other conditions. Optimal speed is a trade off between visibility and the time needed for adequate observation and rapid passage over birds sitting on the sea. Whilst there is therefore no good reason for flight speed to be set at 185 km h^{-1}, subsequent experience has shown this to be a suitable level in terms of operational expediency and the ability of observers to record observations in good time.

Following the results of test flights in the Kattegat in August 1999, flight altitude during surveys was standardised at 80m at a cruising speed of 185km h^{-1} (Kahlert *et al.* 2000). This enables rapid approach to birds sitting on the sea, causing minimal disturbance, since the aircraft is over and to some extent beyond birds sitting on the sea before many react. Flying similar tracklines with the same aircraft at 150m dispersed birds at up to 2 km distance ahead of the plane, especially displacing birds into flight along the transect line. Since a fundamental assumption of the distance sampling technique is that birds are detected before or at the moment they react to the approaching plane, this makes 80m much more suitable than higher altitudes above the water surface for counting seabirds. There is no doubt that the optimal flight height is likely to vary with species and it is unlikely that there is a perfect combination of flight speed and altitude that offers best opportunities to survey all seabird species, but the experience of several years now is that this platform is as good as any alternative. There is no doubt that this issue would merit further experimentation to verify the best possible techniques, but it is important to maintain survey conditions as constant as possible under the circumstances. In reality, the use of distance sampling offers a robust method for estimation of bird densities, such that even if very small proportions of the numbers of a particular species present are detected (but critically including all on the trackline), the “loss” of observations resulting from flying “too” fast makes little difference to the precision of the estimates generated.

Data collection and observer training

During surveys, two observers, one covering each side of the aircraft, record all observations continuously on dictaphone, giving information on species, number, behaviour, transect band and time. Concentration needs to be maintained over extended periods of flying, and observers need to be able to maintain vigilance and avoid becoming drowsy. Prior to a survey, new observers must be introduced to technical equipment such as GPS, the PCs and the software used, dictaphones, inclinometers, stopwatches, etc and become proficient with their use, so that reactions become automatic. All observers require training in the recording routines, and new observers will need easy access to a graphic copy of recording protocol during flight, covering the methods for recording birds as well as human activities and environmental variables. There is no time during data collection for discussions about how to handle data or undertake unfamiliar tasks. Species identification of birds from an aircraft is a skill unfamiliar to most ornithologists and can take some time to acquire. Although observers must naturally have a good basic ornithological experience, particularly with coastal waterbirds, even the best observers need some guidance with specific identification difficulties involved with the unfamiliar experience of birds viewed from above.

Estimating the numbers of individuals in flocks is a challenge that many observers will be familiar with beforehand. However, these skills need honing in situations where flocks are viewed from above, often under unfavourable viewing conditions. Computer count simulation programmes can greatly assist observers to check their ability to estimate flock size. After each survey, the performance of inexperienced observers needs to be assessed. Species identification is one particular issue that should be checked against the other observations on track, but also an observer’s ability to designate observations in the correct transect bands, using the inclinometer to check judged distances, should be evaluated. New observers must be taken along on a survey with the sole aim of training and getting used to count conditions. Komdeur *et al.* 1992 suggested that it takes 150–200 hours of flying to become proficient in using aerial survey methods. We suggest this is unnecessarily demanding to be set as a standard for new aerial surveyors and suggest a minimum of 30 hours flying time, depending on individual skills, would be sufficient for most observers, accompanied and assessed by an experienced, qualified surveyor.

Spatial precision and recording protocols

The objective is to gain the maximum possible precision in recording the position of birds or groups of birds in the open sea. This is achieved using a Global Positioning System (GPS), recording the precise position of the counting observers if necessary every second. This enables the establishment of a relationship between bird observations and a time sequence, which can then be used to relate a single observation to a precise position in time and space. Pre-planned transect end points may be entered into the aircraft GPS as waypoints used in the navigation of the aircraft along the transect tracks.

Birds are assigned to three transect bands each side of the aircraft by use of an inclinometer, used to determine angles below the horizon, measured abeam from the flight direction of the aircraft. Beneath the Partenavia P-68 observer aircraft, a band 44 m wide on either side of the flight track cannot be seen by seated observers and should therefore be excluded from analysis. For other planes, this dead angle needs to be carefully assessed. Bird observations are assigned to transect bands based upon their distance from the track line beneath the plane and for the Partenavia P-68 observer aircraft as: 44-163 m (band A), 164-432 m (band B) and 433-1000 m (band C). To be able to incorporate differential detectability in the analysis of results from aerial surveys, the response of observed birds to the aircraft were assigned to the categories: sitting (on the water), diving, flushing or flying.

During aerial surveys, a computer logs latitude, longitude and time from a GPS (preferably differential GPS) at five-second intervals. The accuracy of GPS longitude and latitudinal must be about 10 metres. After the completion of a survey, tables of observation/count data and flight track data have to be created from the transcription of the dictaphone tapes. In situations where high densities of birds are encountered, some observations may have a common time reference. Grouping of observations should not extend over a period of more than 10 seconds, to keep overall positional accuracy within *c.* 250m of actual, but could potentially in cases of grouped observations, for 10 seconds extend to 500m.

Data format

Throughout survey flights, all observations should be recorded onto a dictaphone tape. Each tape could start with information on type and call sign of aircraft, survey area identifier, date, observers, etc. for future reference. General details of the weather conditions, visibility, sea state should be reported onto tapes and then modified as often as this changes after the initial definition. The start of the flight along each transect line should be identified by recording the precise time at which each waypoint was passed, followed by the records of birds along its length, concluding with time at which the aircraft completed the transect. Any changes in observation conditions should be recorded between transects. Ideally, every observation record should contain the following data: species, numbers, response behaviour (i.e. in flight, flushed, swimming or diving), transect band, and time to the nearest second.

Species

All waterbirds should be recorded and in cases where identification to species is not possible they should be recorded to the best level of accurate identification, i.e. "small gull", "small diver", "auk", etc. Under this general heading, all human activities in offshore waters should be recorded as well. These observations may contribute to the patterns of observed bird distributions, and therefore offer a simple, but often effective variable that contributes to modelling avian distribution patterns. These observations could include static features, such as gill net markers, gas platforms, etc., which are indicators of human activity as well as more conventional moving vessels such as fishing boats, ships, ferries, wind-surfers, etc. Observations of marine mammals should be recorded too, preferably with a measure of the vertical angle to the animal abeam of the track line. However, all ancillary observations and records of this nature should only be recorded if there is no cost to the accuracy or precision of recording the primary species for which the survey was designed.

The unit sampled is either a single bird or a group of birds, insofar as all other information relates to this sample unit. In situations where a small discrete group of birds straddles one or more transect bands (see below) observations should be assigned to the transect band in which the mid-point of the flock is situated. In the case of species such as eider and common scoter, large aggregations of birds may occur over extensive areas with no discernible flock structure (as viewed from the point of view of the observer in the aircraft). In this case, the flock should be separated and assigned into the three transect bands as if they were separate sample units (even though they may represent members of one flock "unit" when seen at a greater spatial scale). As far as possible, observations should not be amalgamated into larger units before they are recorded on the Dictaphone, since it is important to try as far as possible to retain the most fine-grained spatial scale when recording each sample unit.

It is inevitable that the survey aircraft will displace some birds. Furthermore, the response of individual birds to the aircraft has a considerable effect on the detectability of the individual. Since distance sampling makes the assumption that birds are undisturbed at the point at which they are first detected, it is important that if the need arises, it is possible to carry out analysis on data that exclude, for example, birds flushed or flying. For this reason, all records of birds should have information on response behaviour, and under the normal protocol, four different responses are recognised and recorded: sitting, diving, flushing, and flying. In order to maintain the rhythm of observations, it is essential that these behaviours are recorded for every observation. When transcribed, these behaviours are converted to a numeric code for analysis (see below).

Constraints on counting conditions

Survey results are highly sensitive to weather conditions. Surveys should not start when wind speed exceeds 6 m/s when detectability of birds is severely reduced. High wind speeds create greater sea surface featuring (e.g. white wave tops, greater shadowing), which means that observers are more likely to fail to see birds than under more optimal conditions. This becomes critical for the survey when observers are unable to detect all birds in the closest transect band to the aircraft. At regular intervals (and at least at the start of every transect line) sea state and an assessment of light conditions (glare) should be recorded. Additional recordings should be made whenever conditions change along the transect line. All recordings should be followed by a time recorded from the watch.

Sea state describes the sea surface conditions from mirror calm (0 Bft), through tiny ripples (1), small waves (2; no whitecaps), small waves (3; with few whitecaps), moderate waves (4; numerous whitecaps), larger waves with whitecaps forming bands (5), and large waves with dominant whitecaps forming broad bands (6). At sea states above 3, there is no point in undertaking surveys, the data quality will be poor. Glare is recorded as the angle of the sun to the flight direction, with a subjective assessment of intensity (i.e. low, moderate or high). The times at which encountered bouts of precipitation started and stopped should also be recorded, as these may impede visibility.

Observers should also record the times when land (including sand and mud exposed at low tide) is encountered within the transect bands (start and stop times).

Current methods of data presentation and analysis

The objective with current research programmes at NERI is to develop spatial modelling tools that enable the construction of continuous density estimate surfaces for single bird species over large areas of shallow sea. These surfaces will be of a suitable geographical resolution that enables a comparison of densities present before, during and after the construction of a windmill farm in the study area. Specifically, differences in the density estimates generated will (in combination with associated statistical precision) enable the calculation of the avoidance effect, not just within the confines, but also around the periphery of the wind farm to the distance dictated by the behavioural responses of the species concerned.

However, until these techniques are fully available, it is difficult to convert the aerial counts into estimates of bird density in any sub-sections of the study area, because of the detection probability functions associated with the counts at the time of the flights. For this reason, and because different sea areas are covered in different survey flights, to date, bird numbers have been presented in the form of birds encountered per unit km surveyed, or as total numbers encountered during a survey (see for example Kahlert *et al.* 2000). The high level precision achieved with the positions of all observations gives confidence in using this sample of actual observations to be used to interpret the overall distribution of birds in the general area. In particular, the encounter rate (i.e. the numbers of birds counted per unit length of transect effort) offers a robust interim measure of the relative densities of birds and their distribution throughout a count area.

Potential future developments

Double Platform

Further development along a number of lines of enquiry could be continued, particularly with respect to estimating detection probability using the methods of Borchers *et al.* (1998). The double-platform analysis methods can allow effective strip width to be estimated as a function of any number of covariates without the traditional line-transect assumption that all organisms in the observers' path are detected. There remains much scope for further development of such techniques to look in depth at factors affecting effective strip width. While glare from the sun and sea states can greatly affect visibility and have a dramatic effect on effective strip width, an effort to quantify this important variable has to be made, for example by analysing the results with the sun intensity and sea state as quoted in categories during the surveys. Using the GIS platform we can calculate the angle between the individual observer's core search angle relative to the angle of the sun, and thus get a value of the search condition in the transect bands.

Spatial modelling

Great advances have been made in developing statistical techniques that permit seabird density to be modelled as smooth functions of space, time and other variables, using the data gathered continuously along transect lines. The first phase has involved the identification of areas of consistently high seabird density, but the next challenge is to incorporate a temporal element to determine whether such patches of high density persist over time, i.e. incorporating inter- and intra-annual (i.e. inter-seasonal) effects into the modelled distributions. Further development should incorporate human activity as a source of deviance in the model from distributions predicted by the environmental covariates.

Recommended methodology, airframe characteristics, and observers

For a minimum set-up, the following techniques and qualifications are recommended.

- Twin-engine aircraft (for safety and endurance)
- High-wing aircraft with excellent all round visibility for observers (e.g. twin-engine Partenavia P-68)
- Line-transect methodology is recommended with sub-bands.
- Transects should be a minimum of 2 km apart to avoid double-counting whilst allowing the densest coverage feasible
- Flight speed preferably 185 km h^{-1} at 80 m altitude
- Subdivision of survey bands to allow calculations of detection probabilities (recommended are 44-163m, 164-432m, 433-1000m, with a declination in degrees from the horizon being 60-25°, 25-10°, and 10-4° respectively for the Partenavia P-68 at 80m)
- Use of an inclinometer to measure declination from the horizon
- Two trained observers, one covering each side of the aircraft, with all observations recorded continuously on dictaphone

- GPS positions are recorded at least every 5 seconds (computer logs flight track)
- The time of each bird sighting should be recorded, ideally to the nearest second, but within 10 seconds accuracy, using a watch attached to the window of the plane.
- No observations in sea states above 3 (small waves with few whitecaps)
- All waterbirds should be recorded to the best level of identification (species or group)
- Sampling units are single birds or groups of birds within the three transect bands

Conclusion

In attempting to draw together the various conclusions relating to the effectiveness of aerial surveys, and in particular the approaches presented here, it is important to reconsider the objectives set for the method. These are summarised for convenience in Table 2.

Advantages/disadvantages of using an aircraft as a platform for bird surveys in open offshore areas can be summarised under different headings. The speed of aircraft guarantees a rapid, simultaneous coverage of large areas, to provide a snapshot of distribution and density. A disadvantage of this is that due to short observation time there will be identification problems, reduced count accuracy, and loss of species. In addition, there is little time for supplementary observations (sex, age, behaviour, etc.). With the flying height of aircraft, a good perspective over an extensive area is provided, and an extended detectability gradient. The downside is that there is no additional information on biological, hydrographic or other environmental parameters collected simultaneously, although GPS registrations enable subsequent analysis of bird distributions in relation to such parameters obtained by other methods. The use of skilled observers and constant methods are essential for reliable data collection, just as with ship-based surveys, and so require trained, competent observers and suitable aircraft. In stable weather conditions, aerial surveys can rapidly cover huge areas. Surveys are highly weather dependent (high cloud, good visibility) and extended bad weather is highly disruptive. An advantage of the use of aircraft is that a switch between different study areas in event of poor weather in one or other can be made with relative ease. Aircraft are relatively cheap per unit area covered, but expensive overall if extensive coverage is required.

Aircraft are able to survey for most seabird species without causing excessive disturbance, at least prior to the arrival of the aircraft. This is not the case for ships which may disturb red-throated divers and common scoters at considerable distance ahead of the vessel, necessitating extensive use of binoculars to permit detection and some compromise of the survey methods.

The acquisition of information about migration routes, direction or height of flight, detailed spatial and temporal distribution require intensive radar and direct observation in the vicinity of a proposed wind farm development to determine bird use of the area and to predict collision impact probabilities under a range of differing temporal (day/night) and weather conditions. Similarly, assessment of actual collision risk and collisions after construction necessitates static measuring devices (such as infra-red movement triggered video surveillance and vibration detection equipment currently under development). Aerial platforms are not, therefore, appropriate for these aspects of wind farm EIA.

The cumulative distribution of encounters of individuals of given species can provide inference on foraging areas, but without detailed investigations of prey distributions and availability to foraging seabirds, the technique requires more detailed studies to confirm predator-prey interactions. Similarly, in general terms, the incorporation of environmental covariates into spatial and temporal models to generate bird density surfaces can improve model output and give insight into the factors affecting birds abundance and distribution, but it requires detailed ecological investigations to determine ultimate factors affecting bird distributions.

Aircraft offer great possibilities for adequate surveys in shallow areas or in waters with subsurface reefs and sandbanks, where seagoing research vessels are hindered or have no access at all. Aerial surveys are essentially very fast (high speed) and therefore relatively cheap, compared to ship-surveys, for covering relatively large sea areas.

Table 2. Overview of effectiveness of aerial transect methods, distance sampling, spatial and temporal modelling techniques in relation to specific tasks set under the process of environmental impact assessment of offshore windfarm development.

	Aerial transects	Distance sampling	Spatial modelling	Temporal modelling	Other approaches needed
Seabird distribution	Good	Better	Best	Best	Validation (double platform or other)
Seabird abundance	Good	Better	Best	Best	Validation (double platform or other)
Migration routes	Poor	No improvement	No improvement	No improvement	3D Radar

	Aerial transects	Distance sampling	Spatial modelling	Temporal modelling	Other approaches needed
Migration flight Direction	Poor	No improvement	No improvement	No improvement	3D Radar
Seasonal migration	Poor	No improvement	No improvement	No improvement	3D Radar
Weather effects	Reasonable	Better	Best	Best	3D Radar
Foraging areas	Reasonable	Better	Best	Best	3D Radar
Factors affecting distribution and abundance, diurnal patterns and tidal influences	Reasonable in conjunction with other data	Better	Better	Better	Extensive research linking food availability and predation risk (including disturbance)
Prediction of collision risk	No contribution	No contribution	No contribution	No contribution	3D radar studies of flight trajectories before/during/post-construction
Assessment of collision risk	No contribution	No contribution	No contribution	No contribution	Infra-red video; vibration detectors post-construction
Assessment of disturbance and habitat loss	Good	Better	Best	Best	

Northern Gannet in flight, Wee Bankie area, summer 2003 (CJ Camphuysen)

Transect sampling design

Systematically arranged parallel transect lines
There are considerable advantages to the systematic coverage of open water habitats. Such featureless open water is naturally characterised by a range of physical and environmental factors that are likely to influence the abundance and distribution of the birds, but about which little can be inferred from the surface without taking measurements. A sampling approach that covers large areas of such habitat could be constructed on a random basis, but this process often results in clumping of transect lines which may actually bias the data collection. Preferentially, the sampling design should comprise a grid of systematically spaced line transects, randomly placed within the study area. Such a series of parallel lines has logistic advantages, in the sense that the ends of each transect can be entered into the GPS as a series of waypoints, travelled (sailed or flown) in succession across the study area, with relatively short turning and transit between the end of successive lines.

Grid orientation
The most statistically efficient study design is a set of line transects running perpendicular to major environmental axes. In the case of survey for coastal seabirds, which tend to sort themselves according to food availability and water depth, the dominant environmental gradients are those running perpendicular to the shore (i.e. increasing depth out to sea). For this reason, it usually makes sense to plan the transects to run to and from the coastline out into deeper water. Using a set of line transects parallel to the coast may result in considerable sampling bias (contra: Baptist & Wolf 1991; 1993). However, in areas where deep estuarine channels extend out from the coast, the most significant environmental gradients may not be oriented parallel to the coast. Careful planning of transects is necessary, using charts and other suitable information sources, in order to reduce variance between transects.

Transect intervals
In any analysis, such as distance sampling, the sampling unit is a single transect, not individual observations. Hence, there should be enough transects in each study area to generate confident estimates of numbers. Although it is impossible to define “how many is enough” without an extensive pilot study, ideally there should be around 20 transects in each separate study area. The other constraint upon line transect spacing is the distance to which seabirds are displaced, and hence the extent to which substantial double counting could occur. It is assumed that transects at less than 1 km intervals will run a high risk of double counting, while intervals of 2 and 3 km will reduce this risk.

Diurnal variation
Diurnal patterns in seabird behaviour (e.g. foraging activity, tendency to roost, migration intensity) are prominent in most species, with important consequences for spatial patterns measured in relatively small areas. Transects should therefore be sampled such that peak occurrences are unlikely to be missed and this requires site-specific reviews of existing knowledge and a design of transects flown or sailed that doesn’t just include the most suitable time of day for researchers, ship’s crews and pilots, but does take diurnal patterns in the study objects (seabirds at sea) into account.

Seabird behaviour

The behaviour of seabirds, where properly understood, gives vital information on the use that the animals make of the area surveyed. Foraging, feeding, and roosting or resting seabirds utilise an area in a radically different way than passage migrants and distribution patterns can be explained in terms of area utilisation based on behaviour aspects rather than on plain densities. Behaviour can only be observed from rather slow-moving observation platforms such as ships, while aerial surveys are not expected to produce significant results. A comprehensive protocol for behaviour recording and subsequent computer coding has been adopted by ESAS in recent years (Camphuysen & Garthe 2001). Annex 1 lists the codes currently in use by NIOZ; for a full description of the rationale and an explanation of the codes see the publication mentioned at:

http://wwwold.nioz.nl/en/deps/mee/projects/impress/publications.htm

The behaviour recording protocol is implemented without actually changing the core ship-based survey methods, so that historical data (abundance and distribution) can still be combined or compared with more recent surveys.

Actively foraging Northern Gannets, North Sea, summer 2003 (photo C.J. Camphuysen)

Conclusions

Using spatial and temporal modelling techniques to estimate bird density over certain areas of open sea offers the best method for statistically detecting differences in the distribution and abundance of these birds before, during and post-construction of offshore wind farms. The advantage of using distance sampling to estimate bird densities based on bird surveys in open offshore areas is that it is a reasonably simple method which enables an estimation of bird densities incorporating covariates (such as light conditions, sea state, observers) in detection probabilities, with high precision and with confidence intervals to permit comparisons. The use of distance sampling and spatial modelling enables the use of environmental covariates to generate population estimates with greatly improved precision. Hence, the method is also robust as a means of deriving factors explaining seabird distribution and abundance. When the line-transect methods are deployed as described in this document, both aerial and ship-based surveys provide the data required. The main differences between aerial and ship-based surveys are:

(1) Accuracy for species identification (lower with aerial surveys, higher with ship-based surveys)

(2) Time needed to survey large area (shorter with aircraft, longer with ship-based surveys)

(3) Access to shallow sea areas (potentially unlimited for aircraft, restricted for vessels)

(4) Disturbance of some inshore species, such as Red-throated Divers and Common Scoter (less with aerial surveys, higher with ship-based surveys).

Consequent and accurate recordings of flight directions, height and flocking behaviour will provide insight to migratory pathways and for example colony movements associated with colony location. This is feasible only from ships. It should be realised that the precise mapping of migratory pathways will require considerable amounts of data, and that a more prolonged stay within the study area will result in more robust data. Consequent and accurate recordings of bird behaviour will provide essential insight in the ways of utilisation of an area by the respective species (e.g. as a feeding ground, as a stop-over during migration, as a roosting site, on transit only) and this is important information before, during and post-construction of offshore wind farms.

Delegates at the COWRIE workshop, held in Aberdeen, November 2003, were asked to compare the strengths and weaknesses of aerial and ship-based surveys, for application in offshore wind farm EIAs.

It was agreed that, having reached some agreement on the recommended methodologies to be employed for both platforms, there was little point in comparing the accuracy of the two approaches. The meeting was in agreement that the use of the two platforms was complementary, in so far as ship- and aerial-based counts fulfilled different objectives. Hence, these were not an “either-or” option, but rather tools to be used to obtain different forms of data to inform the EIA process. For this reason it was agreed that a matrix was to be produced which attempts to develop further the simple strengths and weaknesses associated with each method provided in the main document (see above). In this matrix, the relative strengths and weaknesses of the recommended boat and aircraft count platforms has been summarised to achieve specific objectives likely to arise from the needs of EIAs.

The first tier of EIA necessitates collation of year-round baseline information for the proposed wind farm area and a larger contextual area, such as the UK strategic areas for wind energy development, (e.g. literature search, preliminary exploration of existing ESAS and seawatching data, evaluation of colony information and waterfowl censuses in the area), and baseline aerial and/or ship-based surveys, to determine spatial and temporal occurrence of birds in the area. Ideally, the baseline data will inform the next stage of the EIA process and the objectives of any further investigation. For example, surveys may identify offshore concentrations of terns, but explain nothing of the breeding colonies from which they originate. Such information requires a deeper level of investigation, at which point it becomes necessary to evaluate the two different platforms in order to fully assess their relative suitability to meet the specific goals of the more detailed investigations.

Rather than offer a set of prescriptions, or a decision tree, it was decided to provide a tabulation of the relative ability of aerial or ship-based counts to meet certain objectives likely to arise in an EIA. In Table 3, we list as many survey and/or monitoring objectives arising from EIA casework as we have been able to accumulate from our present experience. Table 3 aims to provide a clear objective, with an associated score (ranging from * for survey platform fulfils the objective to a limited degree, to *** for the best ability to fulfil the objective. These scores are based, where possible, on published sources and demonstrated ability of either platform to provide the necessary information. Footnotes have been provided as appropriate where clarifications or caveats are required for each objective.

Table 3. Survey and/or monitoring objectives arising from Environmental Impact Assessment casework and the suitability of aircraft or ships for offshore surveys.

SURVEY/MONITORING OBJECTIVE	AIRCRAFT	SHIP
1. Physical features relating to survey area		
Cover complex,low coastlines, skerries	***	*
Cover shallow water	***	*[1]
Survey extensive areas of open water	***	***
Survey restricted areas of open water	*[2]	***
Survey distant offshore waters	*	***[3]
2. Complementary data, other than bird abundance and distribution		
Achieve instantaneous gathering of complimentary oceanographic data (e.g. temperature, salinity profiles, fish distributions, etc.) during bird surveys	*[4]	***[5]
Define seabird flight lines (e.g. commuter routes between colonies and feeding grounds)	*	**
Describe migration routes/pathways	*	**[7]
Age/sex determination	*	***
Behavioural observations (Annex 2)	*[6]	***
Describe diurnal, tidal and other ephemeral patterns in bird distributions		**[8]
Describe feeding patterns	*	***
Define foraging areas	*	***
3. Logistic and other constraints		
Avoid time/tide constraints	**	*
Intensive coverage of small areas	*[2]	***
Simultaneous coverage over large areas	***	*
Ability to take advantage of short spell of good weather conditions	**	*
4. Species surveys – distribution and abundance (demonstrated ability; published sources)		
Survey diver abundance (*Gavia* spp.)	***	**
Survey grebe abundance (*Podiceps* spp.)	**	**
Survey Fulmar	***	***
Survey shearwaters	***	***
Survey storm-petrels	*	***
Survey Gannet	***	***
Survey seaduck	***	**
Survey gulls	***	**
Survey terns	**	***
Survey auks	**	***
Migrant species of other groups		*[7]
5. Species groupings – identification to species (* = most unidentified, *** = nearly 100% identified)		
Identify divers to species	**	***
Identify grebes to species	*	***
Identify auks to species	*	***
Differentiate Velvet Scoter and Common Scoter	**	***
Differentiate Lesser-black-backed and Great Black-backed Gulls	*	***
Differentiate Herring and Common Gulls	**	***
6. Other subjects relating to contributions to EIA		
Evaluation of collision risk	[9]	[9]
Predicting collision risk		[9]*

[1]In waters less than 5-10 m, vessel draft can restrict access of boats, so special, flat-bottomed vessels may be required
[2]Aircraft less suitable on grounds of cost-benefit
[3]Less efficient for extensive areas and long transit movement
[4]Only using modelled or remotely sensed data
[5]Assuming suitable on-board equipment and expertise
[6]Only at the level of flying/diving/swimming/flushing
[7]Radar techniques more appropriate than either platform
[8]Still requires radar or infra-red/light intensifier equipment to gather night time data (radar could be implemented on ship if stabilised)
[9]Neither platform offers any basis for recording collisions and population damage resulting from this, both identify some of the species most prevalent (and therefore most at risk) in the immediate area, a flying height recording protocol on board vessels will provide information on birds that are particularly sensitive.

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Annex 1

Recording seabird behaviour (applicable for ship-based surveys only)

A protocol has been provided to record behavioural aspects of the birds observed. Crucial are attempts to relate the presence of birds to any visible cues in the area (See “ Associations and direction of flight”), e.g. fishing vessels, front lines, floating matter, offshore installations, or marine mammals and to try and distinguish between birds that simply pass through an area (e.g. migrants, long-distance feeding flights) and birds that utilise a site for feeding, resting, or other activities. A careful recording of directions of flight, particularly in nearshore situations, will enhance the understanding of seabird movements in an area.

Behaviour codes		Behaviour
30	Holding fish	Foraging
31	Without fish	
32	Feeding young at sea	
33	Feeding, method unspecified	
34	Wading, filtering or probing	
35	Scooping prey from surface	
36	Aerial pursuit	
37	Skimming	
38	Hydroplaning	
39	Pattering	
40	Scavenging	
41	Scavenging at fishing vessel	
42	Dipping	
43	Surface seizing	
44	Surface pecking	
45	Deep plunging	
46	Shallow plunging	
47	Pursuit plunging	
48	Pursuit diving, or bottom feeding	
49	Actively searching	
60	Resting or apparently asleep	General
61	Coursthip display	
62	Courtship feeding	
63	Copulating	
64	Carrying nest material	
65	Guarding chick	
66	Preening or bathing	
67	*[still free for future use]*	
68	*[still free for future use]*	
69	*[still free for future use]*	
70	Wheeling or swimming slowly	Cetaceans
71	Escape from ship (rooster tail)	
72	Swimming fast, not avoiding ship	
73	Breaching clear out of the water	
74	At the bow of the ship	
75	Apparently feeding: herding behaviour	
76	Apparently feeding: other behaviour	
77	Calf at the tail of adult	
78	Calf swimming freely in herd	
79	Basking, afloat	
80	Spy-hopping	
81	Lob-tailing	
82	Tail/flipper slapping	
83	Approaching ship	
84	Only blow visible (whales)	
85	Only splashes visible (dolphins)	
86	Acrobatic leaps	
87	Sexual behaviour	
88	Play	
89	Sailing	
90	Under attack by kleptoparasite	Misfortune, disease
91	Under attack (as prey) by bird	
92	Under attack (as prey) by mar. mammal	
93	*[still free for future use]*	
94	*[still free for future use]*	
95	*[still free for future use]*	
96	Entangled in fishing gear or rope	
97	Oiled	
98	Sick, unwell	
99	Dead	

Associations and direction of flight		
1	Flying, no apparent direction	Direction of flight
2	Heading N	
3	Heading NE	
4	Heading E	
5	Heading SE	
6	Heading S	
7	Heading SW	
8	Heading W	
9	Heading NW	
10	Associated with fish shoal	Associations
11	Associated with cetaceans	
12	Associated with front	
13	Associated with line in sea	
14	Sitting on or near floating wood	
15	Associated with floating litter	
16	Associated with oil slick	
17	Associated with floating seaweed	
18	Associated with observation base	
19	Sitting on observation base	
20	Deliberately approaching observ. base	
21	Associated with other vessel	
22	Associated with or on buoy	
23	Associated with offshore platform	
24	Sitting on offshore platform	
25	Sitting on marking pole or stick	
26	Associated with fishing vessel	
27	Associated with or on sea ice	
28	Associated with land (e.g. colony)	
29	Associated with sand banks	
50	MSFA participant, no further details	MSFAs
51	MSFA participant, joined by others	
52	MSFA participant, joining flock	
53	MSFA participant, scrounger type	
54	MSFA participant, solitary diver	
55	MSFA participant, beater	
56	MSFA participant, social feeder	
57	Type II MSFA participant	
58	Type III MSFA participant	
59	*[still free for future use]*	

Collection behavioural data

(1) Direction of flight (codes 1-9) The rationale behind records of direction of flight is that (sea-)birds move from A to B on purpose. Searching (foraging) birds may seem to move more or less randomly over the sea. Birds coded with a direction of flight must have a distance code 'F' by default, while marine mammals travelling about may combine a 'direction of flight' code with an indicator of swimming ('A'-'E' or 'W') by default. Nine codes are reserved for direction of flight, including 1 (no apparent direction) and 2-9 (octagon, N → NW). For specific areas, such as while recording seabird movements near colonies (flying to and fro), directions of flight may be of great interest (*cf.* Schneider *et al.* 1990; Camphuysen *et al.* 1995).

(2) Associations (codes 10-29) Fairly often, we can actually see where the birds are heading for, or why they are on a given spot: for example a feeding frenzy, a fishing vessel, or the breeding colony. In those cases, it is of greater significance to code their goal (association) rather than their direction of flight. Therefore, within the same database field, and with priority over direction of flight, codes for 'associations' of seabirds with certain surface phenomena are proposed.

Association codes have been devised for birds associating with near-surface fish shoals or marine mammals, with floating objects such as wood, rubbish, oil slicks, or sea weeds, with fronts in sea (often indicated by distinct lines separating two water masses or concentrations of flotsam), with the own observation base (by default not in transect), with buoys, markers, other vessels, offshore installations, sea-ice or with land. A group of birds flying towards a distant fishing vessel can now be coded as flying with a F under distance, and as associated with fishing vessel with code '26'. The behaviour field (see below) should now be left blank, to separate the approaching birds from actual scavengers around the ship, either 'searching' for prey, actually feeding, or perhaps resting near the ship (see behaviour codes below). Similar combinations can be made for e.g. birds flying towards land, or birds flying in association with or towards a front, overruling the 'direction of flight' code that would not have been particularly informative.

(3) Foraging behaviour (codes 30-49) Types of foraging behaviour were characterised following Ashmole (1971), but with some modifications such as the split use of *'scavenging'* for birds feeding at fishing vessels and birds scavenging on a corpse, plus a distinction between *'surface seizing'* (few, large prey) and *'surface pecking'* (many, tiny prey). For use in shallow seas, *'wading'* (and filtering or probing for prey) and *'scooping'* (as in pelicans) were added. Contrary to Ashmole, there is no separation between wing- and feet-propelled diving, because we do not want to code what we cannot actually see. One of the most interesting aspects of test-cruises was, that certain seabirds did not always feed the way they should have done typically according to text books, but may change feeding techniques in particular situations. An approaching ship will trigger escape reactions of seabirds on the track line. Aerial species may simply fly off, but pursuit diving species such as auks may dive to escape from the vessel. It is up to the observer to discriminate between 'feeding dives' (code 48) and 'escape dives' (no code), but in case of doubt we recommend to refrain from coding. Of particular interest is the coding of 'searching' seabirds (code 49). The idea is, that seabirds actually 'foraging' (looking for prey) in a given area can be separated from those that are just there, even although the latter might use a sudden feeding opportunity. Potential feeding areas don't necessarily show off by the presence of actively feeding seabirds; prey density may for example be low or prey may be difficult to detect. Although any migrating seabird may interrupt swift flight to pick up a prey encountered by coincidence, any observer familiar with birds at sea will agree on the concept of separating actively searching individuals from birds that simply move about. Searching albatrosses and petrels circle consistently over certain patches (Veit & Prince 1997), with the head constantly pointing down or sideways. Searching Northern Gannets and terns may follow straight lines, but while peering down constantly. Shearwaters may settle and alight repeatedly, moving apparently randomly over an area, constantly reacting on one another. Auks extensively peer under water (they may do that also when disturbed by a ship, perhaps as a check of a route to flee). Gulls circle and hover repeatedly during their searches, skuas looking for options to kleptoparasitise 'stalk' and fly low before preparing their attacks. All those (and more examples) can be coded with 49, but it does not harm to make additional notes on paper for future reference.

(4) Complicated associations: multi-species (foraging) assemblages (codes 50-59) All birds, whether swimming or flying, that operate 'together' or stay tight in a particular area or in a particular movement are marked as distinct 'flocks'. Flocks comprising more than one species are called 'multi-species (feeding) associations' (MSFA's). Recent studies have shed some light on composition, structure and dynamics of MSFAs of seabirds (Sealy 1973; Hoffman *et al.* 1981; Porter & Sealy 1982; Maniscalco 1997), and on the specific role of different species in mixed-species assemblages (Bayer 1983; Grover & Olla 1983; Chilton & Sealy 1987; Hunt *et al.* 1988; Mahon *et al.* 1992; Camphuysen & Webb 1999; Ostrand 1999). MSFA's may be formed around fishing vessels (scavenging seabirds), in association with cetaceans and around sources of more natural prey (fish, plankton, carrion). Many MSFA's are formed by surface feeding or shallow plunging seabirds over concentrations of prey driven to the surface by underwater predators (predatory fish, cetaceans, seals or seabirds). Current knowledge suggests that these flocks represent an important behavioural mechanism in the exploitation of resources of food that are ‘normally’ out of reach for surface feeding seabirds. There is a great demand for additional observations and quantifications, which we might fill in by careful descriptions and systematic coding of what can be seen at sea during routine cruises.

Camphuysen & Webb (1999) evaluated the available literature and terms and categorisations of the role of seabirds (or marine mammals) in multi-species feeding associations. Important categories are (1) *initiators* or *producers* (birds that actually start the feeding frenzy by locating a food patch), (2) *joiners* or *scroungers* (birds streaming into patches discovered by others) and (3) *divers* or *beaters* (often the triggers of MSFA formation). To categorise a bird correctly according to their system, individuals need to be followed and watched for some time, sparsely available in standard cruises. Prior knowledge of existing group structures and (potential) dominance hierarchies might help in understanding and recognising what is going on (See Camphuysen & Webb 1999, and Camphuysen & Garthe 2001 for further details).

(5) General behaviour (60-69) Besides foraging, seabirds can engage in a variety of other activities that one may wish to record. Particularly nocturnal feeders may sleep a lot during the day, while birds that have just joined a feeding frenzy often rest on water, incapable as they even may be to fly away (code 60). Mostly during spring, seabirds frequently perform courtship displays at sea (code 61), including courtship feeding (62), copulation (63; e.g. Atlantic Puffins *Fratercula arctica*), the handling of nest material (64), or chick guarding (65). Other coded activities include preening and bathing (66).

(6) Marine mammals (codes 70-89) Most seabird observers under ESAS record marine mammals, perhaps as a matter of lower priority but still, as if they were birds. To facilitate a rapid description of observed behaviour, we propose 20 behaviour codes that would suit most needs.

(7) Misfortune, disease and death (codes 90-99) Ten codes are reserved for 'birds under stress', including deceased individuals. Entangled, oiled, otherwise 'sick' or even dead animals may be encountered in places and seabirds under attack by other animals can be coded with the system provided below.

Height of flight Additional database field can be reserved to record the flying during seabirds at sea counts from ships, by categorising any birds seen in flight to its altitude. Classes used may be (from Lensink *et al.* 2002):

0-2m	very low over the water
2-10m	undulating flight or just below the horizon (with observer eye-height at *c.* 10 m asl)
10-25m	at or just above the horizon
25-50m	well above the horizon*
50-100m	flying high*
100-200m	flying very high*
>200m	great height*

*Requires pre-survey training for example on land with reference heights in the landscape.

Recording prey

Finally, as one of the most difficult tasks at sea, it may be possible to recognize prey caught or targeted by seabirds at sea. The ultimate record does not only include place, species, age and plumage, but also association, behaviour, and prey (and all that preferably within transect). Prey data are stored in a separate column in the birds file under ESAS and several of a potential of 100 codes (0-99) are attributed to various prey, summarised as follows: **Fish prey** (10) fish, no further details, (11) small fish, unidentified (ca. bill length), (12) medium fish, unidentified (ca. 2-5x bill length), (13) large fish, unidentified, difficult to handle, (14) sandeel ball, (15) clupeoid ball, (16) unidentified fish ball, or (17) capelin ball at surface, (20) gurnard, (21) herring or sprat, (22) sandeel, (23) gadoid fish, (24) flatfish, (25) regurgitated fish after aerial pursuit, (26) salmonid, (27) capelin; **Miscellaneous prey** (30) small particles, unidentified, (31) large object, unidentified, (32) jellyfish, (33) squid, (34) worm (e.g. *Nereis*), (40) crustacean, unidentified, (41) swimming crab, (42) starfish, (43) sea urchin, (45) bivalve, unidentified, (46) mussel; **Carrion and corpses** (50) carrion or big corpse, unidentified, (51) seal carcass, (52) whale carcass, (53) bird carcass, (54) litter, rubbish, (55) regurgitated unidentified prey after aerial pursuit, (56) bird kill (e.g. Bonxie), (57) excrements (e.g. from whales); **Discards and offal** (60) fishery waste, unidentified, (61) discarded roundfish, (62) discarded flatfish, (63) discarded offal, (64) discarded benthic invertebrate, (65) discarded starfish, (66) discarded crustacean (e.g. shrimp)