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A Review of Assessment Methodologies for Offshore Windfarms

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Executive Summary

Background

1. The UK government has committed to obtaining 20% of the UK's energy from renewable sources by 2020 and to reducing CO_2 emissions by 80% by 2050. In June 2008, the Crown Estate launched its "Round 3" leasing programme for the delivery of up to 25 GW of new offshore windfarm sites by 2020. European Directives such as the SEA, Birds and Habitats Directives, together with the United Nations Law of the Seas require that states accept responsibility for assessing the effects of major offshore development on the environment.

2. COWRIE previously published guidelines for ship and aerial survey of marine birds for offshore windfarm assessments (Camphuysen *et al.* 2004). The purposes of the current review are fourfold:
   a. to assess the extent to which these recommendations have been followed;
   b. to identify any differences in interpretation of the guidance between sites;
   c. to test the practicalities of using high definition cameras during aerial surveys;
   d. to provide more rigorous guidelines for the type of analytical techniques that should be used.

Potential of high-definition cameras

3. Note that a recent workshop, conducted in July 2009, reviewed developments in high definition imagery approaches and provides more up to date information and recommendations than are given here. A full report of these findings can be found in Thaxter & Burton (2009); see Annex 1 for a summary.

4. High definition video cameras mounted on helicopters and aeroplanes to collect data during aerial bird surveys at sea were trialled by HiDef for COWRIE (Mellor *et al*. 2007; Mellor and Maher 2008). The principle of this survey method was to film so that seabirds could be counted and recorded at a later date.

5. In trials thus far, only a narrow strip transect of 30-40 m was filmed and counts were interpolated using kernel regression. Due to the high variability in count data, transects must thus be flown very close together if accurate and precise estimates of bird numbers are to be obtained. However HiDef have recently developed a compound camera that allows a strip transect of 200 m to be filmed and there are plans to trial this camera in the coming months. This may significantly improve the viability of this method, in terms of cost, time and data quality. Improved techniques for interpolating count data are also being developed by HiDef in conjunction with the Wildfowl and Wetlands Trust (WWT) and the University of St Andrews.

6. The methods currently used require a large amount of time to be spent reviewing images after the survey has taken place (this can take five times as long as the survey itself). Although methods are currently being developed to automate this task, it is unclear how reliable such automation will be and this must be tested.

7. The technique has not yet been directly compared to conventional aerial surveys, which needs to be done to ensure the comparability of data and to test methods of data analysis to ensure that valid population estimates can be made. However, this is planned for winter 2008/9 and once this has been done the potential use of this technique for future surveys should be re-assessed.

8. High-definition cameras have the potential to provide a useful tool for aerial seabird surveys, subject to satisfactory outcomes of the trials in winter 2008/9 and the development of a standardised technique. At the present time we suggest that the

methods and technologies are not sufficiently developed to allow recommendation of this technique but a suitable survey method may be achieved in the very near future and therefore this should be reassessed once the results of the winter 2008/9 are available to assess whether the technique has been refined and tested sufficiently for a standardised methodology to be recommended.

Review of boat-based and aerial survey methodologies

9. We reviewed eight Environmental Statements for offshore windfarms in detail and drew on information presented in several others and from technical reports to provide context and to give a more wide-ranging synthesis of the survey methodologies and analytical techniques that have been used.

10. Where reported in sufficient detail, both boat-based and aerial surveys generally followed the majority of the recommendations of Camphuysen *et al*. (2004). However, in some cases it was unclear whether all of the guidelines had been followed strictly as reporting of the methodology in Environmental Statements lacked detail. We stress that in future these details need to be provided in the Environmental Statement or alternatively supplementary technical information should be more readily available.

11. Boat-based surveys followed the majority of the recommendations of Camphuysen *et al*. (2004), except that some surveyors had developed an alternative method where the exact timings of bird sightings were recorded, rather than assigning birds to two-minute time intervals as recommended by Camphuysen *et al*. (2004). This improves the accuracy of locations assigned to each bird sighting but is incompatible with nature conservation databases so cannot be recommended at present. An improved method for carrying-out snapshot counts was also developed, whereby counts were conducted at regular distance intervals (measured using GPS) rather than at regular time intervals, which means that any slight variation in the speed of the boat (for example due to tide or currents) would not affect the distance between snapshot counts.

12. There were two recommendations of Camphuysen *et al*. (2004) that had not been followed in the majority of surveys. The first was that an area at least six times the size of the proposed windfarm should be surveyed. In most cases a smaller area than this was covered by boat surveys, but we deem this to be adequate. The second recommendation that was not followed by many of the surveys we reviewed was that two observers should be present per observation platform. There was no evidence that this had ever been done. We discuss this issue in detail in R23

13. Aerial surveys conducted for Round 1 and Round 2 windfarm applications were largely done by WWT, using standardised methodology that conforms to the recommendations of Camphuysen *et al*. (2004) and highly experienced observers. The only variations from the methods suggested by Camphuysen *et al*. (2004) were that flight altitude was 76 m (for practical reasons, as this equates to 250 ft which is easier to read from a standard altimeter (P. Cranswick *pers. comm.*) and that four, instead of the recommended three, distance bands were used.

Review of methodologies for analysing data

14. Both aerial and boat surveys were generally conducted for two years and throughout the year. The number of aerial surveys varied from one to 19. Boat-based surveys were generally carried-out monthly, but the total number varied from nine to 33. The nature of additional surveys varied considerably between windfarm applications, but often entailed desk-based reviews of existing data and/or radar studies to assess bird movements.

15. Maps of species abundances derived from aerial and boat surveys were generally presented as part of the baseline assessment to allow the relative importance of the

windfarm area to be determined in a regional context. Sometimes maps were presented for each survey and sometimes as cumulative totals. Generally shaded grids or variable sized dots were used to denote species densities, but occasionally smoothing techniques were used.

16. In most (but not all) assessments, actual counts of bird numbers were corrected to account for the area surveyed relative to that studied and for undetected individuals. Insufficient information was available to allow detailed assessment of how this was done in all instances. In the few assessments that reported methods in detail, totals derived from snapshot counts were corrected to account for the proportion of the study area sampled but not corrected to account for undetected individuals. These estimates were then added to Distance software derived estimates from line transects to derive total bird totals. The way in which unidentified species were handled, differed between assessments.

17. In most (but not all) instances, the standard "matrix" approach recommended by the BWEA and SNH was used to assess the significance of impacts. Using this method the magnitude of the impact for each ornithological feature is scored and cross-tabulated against the sensitivity of each feature to determine the significance of the impact. Options for mitigation were almost always discussed qualitatively.

18. Direct habitat loss was always assessed qualitatively and the significance of the impact was concluded to be very low in all instances. The magnitude of indirect habitat loss was sometimes assessed qualitatively and sometimes quantitatively. When assessed quantitatively, it was usually assumed that all individuals would be displaced from the windfarm and a buffer zone around this area. The proportion of regional populations displaced was then determined. The size of the buffer zone used varied from 800 m to 4 km. The definition of regional populations differed between studies, but often corresponded to numbers within three or more aerial survey blocks.

19. The magnitude of disturbance impacts during construction and decommissioning was always assessed qualitatively. The magnitude of disturbance during operation was sometimes assessed qualitatively and sometimes quantitatively. When assessed quantitatively, the approach was usually very similar to that used to determine the magnitude of indirect habitat loss impacts. Barrier effects were always assessed qualitatively.

20. The magnitude of collision risk impacts were sometimes assessed qualitatively, but usually quantitatively for key features using the Band (2000) model. In most instances insufficient information was available to determine how the number at risk was calculated (but at least in one instance, it is apparent that the method used was incorrect). Where it could be assessed, the number at risk was determined by determining the number of birds flying through the windfarm in the "at risk" zone and by assuming birds moved through the site continuously. The determination of the number of birds flying through the at risk zone, sometimes entailed measuring flight densities directly from snapshot counts and sometimes by assessing the proportion in flight recorded by aerial survey. The choice of avoidance rates varied between studies, with worst-case scenario rates varying from 0% to 99%, but were generally around 95%.

Refinement of survey of methodologies:

R1. For both aerial and boat-based surveys, observers should be assigned an ID code, and sea-states and viewing conditions should be recorded. This information can be used to account for differences in detection when undertaking analysis using Distance software. A checklist of standard information that should be recorded for surveys is presented in Appendix 1.

R2. Snapshot counts undertaken onboard boats, could be conducted at fixed distance intervals, not time intervals and the necessary systems should be in place to remind observers when to do these counts. A GPS and data-logger should be used to log the track of the boat at frequent time intervals.

R3. We agree with Camphuysen et al. (2004) that at least two observers should be used per observation platform (if continuous working hours are long, large numbers of birds are present or the weather is cold, an additional trained observer should be present on the boat to allow for observer rotation and rest periods thus ensuring two observers are always surveying).

R4. Observers should take appropriate breaks when viewing conditions are arduous. We recommend that observers focus their attention in the nearest distance band. In instances where significant numbers of divers and/or seaducks are present, a third observer should be deployed at all times to scan ahead of the boat looking for flushed birds.

R5. Although we agree with Camphuysen *et al.* (2004) recommendation that transects should not be placed more that two nautical miles apart, we recognise that this may be difficult for some of the larger Round 3 developments zones. If this is indeed the case, we strongly recommend that hydrographic data are collected simultaneously to bird data. This may allow bird densities to be more accurately predicted across the entire study area.

R6. Camphuysen *et al.* (2004) recommends that a high resolution grid should be deployed, covering an area at least 6 times the size of the proposed wind farm area. The nature of Round 3 windfarm is such that a different approach will be required. The windfarms will be located within development zones the location within and the proportion of the zones occupied by windfarms will be unknown at the time of survey. We therefore recommend that the entire development zone be surveyed, but there is no need to survey areas outside the development zone.

R7. We recommend that during aerial surveys, attempts are made to distinguish between birds in flight naturally and those that have been flushed by the aircraft.

R8. We also recommend that radar studies be used to quantify nocturnal migration volume if such movements through the windfarm area are suspected.

Recommended methodologies for analysing data:

R9. We recommend that surveys should be conducted over a minimum of two years throughout the year. As a rule-of-thumb and for planning purposes, we recommend that boat-based surveys should be carried out monthly and aerial surveys at least eight times per year (3 times in winter and 5 times in non-winter). However, to check the precision of estimates and thus determine whether sufficient surveys have been carried-out, we recommend that mean numbers should be plotted as a function of the number of surveys conducted.

R10. All data should be corrected to account for the area surveyed in relation to the study area. All data collected by aerial survey and transect data collected by boat-based surveys should be corrected to account for undetected birds. Snapshot counts should not be corrected to account for undetected individuals, but birds beyond 300 m (200 m for auks) should be incorporated into analyses. Unidentified birds should be accounted for by assigning them as positively identified species, based on the relative abundances of the species that they could be. Peak densities should be used to assess disturbance and habitat loss impacts, and mean densities (corrected for biases in the timing of surveys) should be used for collision risk assessment.

R11. We concur with the approach outlined in the IEEM guidelines for EcIA for marine and coastal projects, whereby expert judgement, guided by the best available information is used to determine the significance of impacts. However, there is a critical need to ensure a more standardised and quantitative approach within Environmental Statements. We therefore recommend the continued use of the matrix approach recommended by SNH and BWEA, whereby the magnitude of and sensitivity to impacts are cross-tabulated to quantitatively assess the significance of impacts as a means of backing-up expert judgement. However, we recommend that a further method is used to refine and interpret assessments: we highlight the need to incorporate sensitivity to the particular impact in question. We provide specific guidelines for incorporating such sensitivities.

R12. In the absence of more detailed information, we recommend that the magnitude of disturbance impacts should be determined by assuming all birds are displaced from the windfarm and species-specifically sized buffer zone and assessing the size of this population against relevant regional, national and international populations. We propose that published information on species' sensitivity to boat and helicopter traffic should be incorporated into the measure of species' sensitivity to disturbance.

R13. In the absence of more detailed information, we recommend that the magnitude of impacts due to habitat loss should be determined by assuming all birds are displaced from the windfarm and species-specifically sized buffer zone and assessing the size of this population against relevant regional, national and international populations. We propose that published information of the flexibility of species' habitat use be incorporated into the measure of species' sensitivity to displacement.

R14. We recommend that the magnitude of impacts due to barrier-effects should be determined using two criteria (1) the number of birds likely to be flying through the windfarm and (2) the extent to which the windfarm is likely to act as a barrier. We propose criteria to assign scores for each component and propose a matrix approach for assessing the overall magnitude. We propose that information on wing loadings should be incorporated into the measure of species sensitivity to barrier effects. We propose sensitivity scores for different taxa.

R15. We propose a standard method for calculating the number of birds at risk of collision in an offshore context that can be fed into the Band collision risk model. We also suggest some refinements that could be made to the model. We propose that the choice of avoidance rate be determined by published information on flight manoeuvrability and likelihood of collision and propose avoidance rates for different taxon. We recommend that annual collision rates are assessed against regional, national and international populations to determine the magnitude of collision impacts. We also recommend that published information on adult survival rates be incorporated into the measure of species' sensitivity to collision.

Recommended further research:

R16. One of the major difficulties in providing strict guidelines in relation to survey methodologies is that the necessary background research has yet to be undertaken. Given the size of round 3 development zones, there is a need to determine how precisely and accurately mean and peak estimates of bird abundances can be determined for sample efforts (survey frequency and duration and transect spacing) and to see whether modelling methods can be improved to provide better estimates. Possible methods for improving estimates include spatial-kriging or the incorporation of hydrographic data into models mapping species densities. We strongly recommend that further research be undertaken to explore these issues.

Glossary

Avoidance rate – the proportion of birds flying through a wind turbine that avoid colliding. Generally 1 – collision rate.

Barrier effect – an effect of resulting from birds altering their migration flyways or local flight paths to avoid a wind farm, thus increasing their energy expenditure.

Buffer zone – an area around a windfarm from which birds are displaced as a result of the windfarm's presence.

Collision risk – the proportion of birds flying through a wind turbine that collide with the blades or nacelle. Generally 1 – avoidance rate.

Detection function – the mathematical relationship between the likelihood of a bird (or any other object) being detected and distance from the observer. Typically it is assumed that the probability of detection is one at zero distance from the observer and declines to zero at some distance from the observer.

Displacement effect – an effect due to visual intrusion and disturbance during the construction and operation of windfarms, which results in the displacement of birds from areas within and surrounding the windfarm.

Distance band – when conducting aerial or boat surveys, surveyors attempt to estimate the distance of birds from the survey transect, so that Distance software can be used to calculate the proportion of birds detected. Because this cannot be done accurately, birds are assigned to distance intervals (e.g. 100 – 200m from the transect) or "distance bands".

Distance software – a software package that can be used to account for birds (or any other objects) that are undetected during surveys. It does this by assuming detection probability is one at zero distance from the observer and declines to zero at some distance from the observer. By analysing the relationship between the number of birds detected and distance form the transect (or observer), the shape of this "detection function" is calculated. This is used to calculate the proportion of birds detected and can thus be used to estimate overall density or abundance within a given area.

Kernel regression – this is a non-parametric statistical technique used to estimate the conditional expectation of a random variable. In the context of this report it is used to interpolate between surveyed areas to estimate bird densities in unsurveyed areas.

Line transect –a linear route along which observers record birds and at the same time, obtain the distance of the bird from the path. These results are used to determine the area covered and estimate the way in which detectability decreases from probability 1 to 0 as objects are further from the path.

Matrix – a rectangular table of numbers or abstract quantities that can be added and multiplied. In the context of this report the "matrix approach" is the process of cross-tabulating the magnitude of impacts with the sensitivity of impacts to determine the overall significance of an impact.

Over-dispersed (data) – data for which the variance is greater than the mean. In the context of this report it is used to demonstrate that seabird numbers are highly variable.

Round 1, 2 or 3 – the three rounds in which The Crown Estate has leased offshore areas to industry for the construction of windfarms. Round 1 was launched in April 2001, Round 2 in July 2003 and Round 3 in June 2008.

Snapshot counts - instantaneous counts of flying birds conducted at regular intervals during ship-based seabird surveys.

Spatial kriging - this is a geo-statistical technique used to interpolate the value of a random variable. In the context of this report it is used to interpolate between surveyed areas to estimate bird densities in unsurveyed areas.

Zero-inflated (data) – data with a large number of zeros. In the context of this report, used to refer to the fact that species are often absent from surveyed areas.

Acronyms

BTO	British Trust for Ornithology
BWEA	British Wind Energy Association
CIA	Cumulative Impact Assessment
CO_2	Carbon dioxide
COWRIE	Collaborative Offshore Wind Research Into the Environment
EcIA	Ecological Impact Assessment
EIA	Environmental Impact Assessment
GPS	Global Positioning System
IEEM	Institute of Ecology and Environmental Management
Kph	Kilometres per hour
NGO	Non-governmental organisation
SNCO	Statutory Nature Organisation
SNH	Scottish Natural Heritage

Units

ft - feet

km – kilometre

knot – nautical mile

kph – kilometre per hour

m – metre

mph – miles per hour

sea state – World Meteorological Organisation sea state

Introduction

1.1. Background

Ever-increasing concern regarding climate change (as well as the limited sustainability of fossil fuel supplies) has led to mounting recognition of the need for renewable energy sources. For example, within the framework of the United Nations Climate Convention, industrial nations agreed in the 1997 Kyoto Protocol to reduce their greenhouse gas emissions by an average of 5% (compared to 1990) by 2012. In response to these agreements, the UK Government has committed to obtaining 10% of the UK's energy from renewable sources by 2010 and 20% by 2020. More recently the UK Government pledged to reduce CO_2 emissions by 80% by 2050 and in June 2008, the Crown Estate launched its "Round 3" leasing programme for the delivery of up to 25 GW of new offshore windfarm sites by 2020. This programme is expected to greatly increase the number offshore windfarms projects.

Although windfarms could be viewed as beneficial to wildlife because they contribute to reducing climate change, they are also of potential detriment as they may displace wildlife from favoured areas or cause collision mortality. The taxonomic group most likely to be affected in this way is birds (Exo *et al.* 2003; Garthe and Hüppop 2004; JNCC 2004; Desholm and Kahlert 2005) as aggregations of large numbers of seabirds may be found in UK offshore waters throughout the year (Skov *et al.* 1995; JNCC 2004). In the UK, all wild birds have a level of protection under the 1981 Wildlife and Countryside Act. Additionally, European inshore coastal and offshore marine waters support globally significant numbers of seabirds (Carter *et al.* 1993; Skov *et al.* 1995) and European Union Member States are obliged to protect populations of these species, under the EU Directive on the Conservation of Wild Birds (79/409/EEC, the Birds Directive) and the Ramsar Convention on Wetlands (Ramsar Convention Bureau 1988). These international agreements, together with the United Nations Law of the Seas (United Nations 1982) and the EU Directive on the Assessment of the Effects of Certain Plans and Programmes on the Environment (2001/42/EC, the SEA Directive) require that states accept responsibility for assessing the effects of major offshore development on the environment.

In order that comparable assessments are carried out at different sites, in 2004 COWRIE published a comparison of ship and aerial sampling methods for marine birds and guidance on their applicability to offshore windfarm assessments (Camphuysen *et al.* 2004). The purpose of the current review is to assess the extent to which these recommendations have been followed in surveys for Round 1 and Round 2 windfarm assessments, and to identify any differences in interpretation of the guidance between sites. Furthermore, recently a technique using high definition cameras during aerial surveys has been tested for its applicability to assessing bird populations. This review will also investigate whether this, or other novel survey techniques, could improve assessments of bird populations and therefore be recommended in the future. We also provide more rigorous guidelines for the type of analytical techniques that should be used when undertaking ornithological impact assessments and recommendations for information provision in Environmental Statements.

1.2 Objectives

The aim of this report is to review the assessments carried out for Round 1 and Round 2 windfarm applications, as well as other recent developments in the monitoring and assessment of bird numbers at offshore sites, in order to provide further recommendations for carrying out ornithological impact assessments. The specific objectives of the review are as follows:

- Review the potential value of high definition cameras to collect suitable data from aerial bird surveys, and make recommendations on the potential usage and effectiveness of this emerging technique.

- Compare the aerial and boat-based survey methods used for Round 1 and Round 2 windfarm applications to those recommended in Camphuysen *et al.* (2004), in order to determine whether the range of methods recommended in Camphuysen *et al.* (2004) are being used appropriately.

- Based on the results of the review, identify whether the Camphuysen *et al.* (2004) recommendations can be refined, or whether there are potential areas for improvement in the interpretation of the Camphuysen *et al.* (2004) guidance.

- Review the analysis of aerial and boat-based bird survey data used for Round 1 and Round 2 windfarm applications and identify value of methods used.

- Based on the data analysis review, recommend the most appropriate methods of data analysis and presentation.

2. Potential of high definition cameras to collect suitable data from aerial bird surveys

2.1 Context

Two trials of the use of high definition video cameras to collect data during aerial bird surveys at sea have been conducted for COWRIE by HiDef Aerial Surveying Limited (Mellor *et al*. 2007; Mellor and Maher 2008). The principle of this survey method is to use a high definition video camera mounted on a helicopter or aeroplane to record films of transects flown over the area of interest, so that the resulting pictures of those transects could then be used to count and identify seabirds at a later date. The aim of this technique is to provide data that can allow analyses of the spatial distribution of birds. It may decrease costs through reduced staff time for expert observers and coverage of a greater area in a shorter flying time. Using video to record observations also allows observers to identify and count birds at a later date rather than under time-pressure as may be experienced by observers recording birds in real time from the aircraft. This should help to minimise identification and count errors, providing the video is of sufficient quality, and provide a fully auditable output. If this survey technique allows an increase in aircraft altitude compared to conventional surveys it may also make it easier to use aerial surveys in existing windfarm sites, and could potentially reduce disturbance to birds during aerial surveys.

In this section we review the trials of the use of high definition video cameras that have been carried out in order to assess whether this technique can collect suitable data to quantify the numbers and distribution of birds in proposed offshore windfarm sites and compliment the data provided by established aerial and boat-based survey methods.

Note that a recent workshop, conducted in July 2009, reviewed developments in high definition imagery approaches and provides more up to date information and recommendations than are given here. A full report of these findings can be found in Thaxter & Burton (2009); see Annex 1 for a summary.

2.2 Assessment of high definition camera trials

2.2.1 Survey methodology

This survey technique uses a high definition video camera with a resolution of 1080x1920 pixels (around 2.1 mega-pixels) with a gyroscopic camera mount to stabilise the video camera against the movement and vibration of the aircraft and allow the use of high magnification lenses (Mellor *et al*. 2007). Videos are recorded onto digital tapes and there is also a GPS logger that records the geographic location of each frame taken by the video camera. The image width was fixed at 30 m – 40 m to enable recognition of smaller species, and the distances between adjacent transects were between 250 m and 500 m in the first survey (Mellor *et al*. 2007), and fixed at 300 m in the second survey (Mellor and Maher 2008), compared to 2 km in conventional visual aerial surveys.

The first trial (Mellor *et al*. 2007) was on a relatively small scale, covering an area of around 12 square kilometres. This trial used a helicopter to conduct the aerial surveys, but there were some problems with this, including difficulty in maintaining an accurate transect heading, as only a small number of GPS waypoints were used, and the lack of range of the helicopter. However, manoeuvrability of a helicopter may significantly reduce the time spent manoeuvring between transects, particularly in small survey areas, and therefore the use of helicopters, particularly at small sites, should not be ruled out (Mellor *et al*. 2007). Although a helicopter may be more likely to flush birds than a plane the use of high definition cameras allows surveys to be conducted from a higher altitude than conventional aerial surveys with visual observers, which may help to reduce disturbance and flushing of birds. The availability of helicopters for this type of survey may warrant further investigation at some of smaller sites. However, it should be recognised that aeroplanes will be much more effective than helicopters at covering the large areas that would need to be surveyed for Round 3.

The second, larger scale, trial (Mellor and Maher 2008) covered an area 20 km by 10 km using a similar high definition camera set up to the first trial, but mounted on an aeroplane rather than a helicopter. The aeroplane had a built-in GPS navigation system with the transects plotted into it and a colour display, which allowed the pilot to constantly assess and correct the accuracy of the transect heading during the flight. This set up significantly improved the accuracy of the transect heading compared to the helicopter, with the aeroplane staying within 30 m of the transect line for the majority of the time (the exact amount of time that the plane was more than 30 m from the transect line is not stated in the report but this is unlikely to be a major problem as the tracks followed by the plane could be presented in any survey report, as long as they were logged using GPS as is done in conventional aerial surveys). The aeroplane also provided a much more stable platform for the camera, which reduced the need to adjust the camera orientation (Mellor and Maher 2008).

Although the use of high definition video cameras to collect data in aerial bird surveys may reduce the staff time needed for expert ornithologists, a camera operator has to be present at all times during the aerial survey to control the camera, and a larger amount of air time may be needed as the area covered by an individual transect with a high definition camera is significantly smaller than in conventional aerial surveys, so a larger number of transects would be required. In both trials, the camera operators experienced difficulties with focussing the camera, particularly on calm seas where the lack of features made focussing difficult. Mellor and Maher (2008) suggest that a method for locking the focus (once it has been set) would be a significant improvement on their trial methods. Controlling camera orientation can also be difficult due to the rapidly moving image; a trained and experienced operator is required as accuracy improves with experience, and the work is tiring for the operator. Mellor and Maher (2008) suggest that a fixed-orientation camera would be a significant improvement on the technique used in their study and it would be worthwhile testing such a camera.

The altitude in high definition camera surveys can be much higher than conventional aerial surveys where observers fly at around 80 m. With the camera, the aircraft can fly between 400 m and 1000 m as the lens allows the focus and zoom to be adjusted so that a consistent field of view of around 40 m can be achieved, which is necessary to allow identification of seabird species given the resolution of the camera, although altitude can be limited by low cloud. The higher altitude may be beneficial in reducing the disturbance to birds during aerial surveys and therefore the number of birds that flush from the transect. This might be an important consideration when choosing methods for monitoring numbers of sensitive species in Special Protection Areas. The helicopter in the first survey flew at around 150 kph, while in the second survey the aeroplane flew at around 185 kph.

Footage is looked through in slow motion to identify birds. This is necessary because in real time an individual bird would only be on the film for less than half a second. This is the most time-consuming part of the work as it can take 5 minutes to go through 1 minute of footage (Mellor *et al*. 2007). However, the majority of this work can be conducted by a non-ornithologist who can identify those images where birds are present, then only the images with birds in them need to be looked at by an expert ornithologist. Moreover, the development of improved image recognition software may eventually allow this process to be semi- or fully-automated. The cost-savings in so doing would make this a worthwhile aim.

2.2.2 Survey outputs

The initial trial survey found only a small number of birds: eleven auks in six groups (i.e. six encounters), three Gannets *Morus bassanus* in one group, one Shag *Phalacrocorax aristotelis* and an unreported number of Herring Gulls *Larus argentatus* and Kittiwakes *Rissa tridactyla*.

However, in the second trial, a total of 823 birds were recorded, of which 760 were Common Scoter *Melanitta nigra* allowing for a much more robust analysis of distribution.

The analyses used in the trials assume that birds do not move between transects, because higher altitude avoids disturbance of birds. However, this does not allow for natural movement of foraging birds between transects and could therefore result in some bias in the resulting density estimates. A kernel regression technique is used to estimate the density of birds but does not appear to use any predictor variables other than location. Problems with the estimates derived using this technique could occur as count data for seabirds are likely to be highly over-dispersed and zero-inflated, which will affect the reliability of density estimates derived using standard techniques.

The population estimate for Common Scoter *Melanitta nigra* generated during the second trial of the high-definition camera method in March 2008 was compared to the population estimate from conventional aerial surveys of the same area conducted by WWT during the winters of 2004-2007. The population estimate from the WWT surveys was more than double that calculated from the high-definition camera survey. However, because the surveys were carried out at different times and covered different areas, it is unclear how much of the difference between the population estimates was due to real differences in the number of birds present, and how much was due to problems with the methods of data collection and analyses in either the conventional or the high-definition camera survey. It would be necessary to conduct a trial of the high-definition camera method at or close to the same time as a conventional aerial survey in order to test this effectively and to compare densities rather than abundances if different areas are surveyed. The ideal way to achieve this would be to have the camera operating in the same plane in which conventional surveyors are seated, with the camera operator seated next to the pilot. However, different operating heights for the different methods will make this ideal solution difficult to apply.

2.3 Recommendations

The full-scale trial of high definition video surveys (Mellor and Maher 2008) suggests that this survey method could be used alongside existing methods to improve monitoring of windfarm sites.

Using an aeroplane rather than a helicopter significantly reduced the cost of the survey. The GPS navigation system on the plane also allowed transect lines to be followed much more accurately than in the helicopter, where a waypoint GPS system was used, therefore if this technique is adopted aeroplane surveys would be preferable in most situations.

In both of the trial surveys, camera operators experienced difficulties with focussing the camera, and recommendations in Mellor and Maher (2008) to allow focus to be set to a pre-determined value based on altitude, to automate contrast control, and to use a fixed-orientation camera to reduce the burden on the camera operator have yet to be tested. Further trials to test these methods would be required before a standardised technique for the use of high-definition video during aerial bird surveys can be developed. It was also not possible to fix the focal length on the camera used during the full-scale trial (Mellor and Maher 2008), and future developments in camera technology that allow this may improve the efficiency of this survey method.

Super high-definition camera could be used in future (Mellor *et al*. 2007) and would enable a doubling of the transect width to around 60 metres. This would also mean that an individual bird would stay in frame for twice as long as with the existing high-definition camera, which requires a transect width of 30 metres, and so it would allow for increased air speed to be used, thus reducing the amount of air time, and therefore the cost, of the survey (Mellor *et al*. 2007; Mellor and Maher 2008). However this would require reduced exposure times to minimise motion blur - at the present air speed exposure times of 1/1000 or less are required in order to minimise motion blur. At the present time the air speed is limited by the available camera technology, but it is likely that future technological developments will produce cameras that allow for increased air speed to be used (Mellor and Maher 2008).

Because of the reduced width of transects covered by high definition video compared to those observed during conventional visual surveys, Mellor *et al*. (2007) suggest that approximately eight times as many transects would be required with high definition video surveys to cover the same area as a conventional aerial survey with ornithologists observing from the aircraft. One potential solution suggested by Mellor and Maher (2008) would be a multi-camera system, allowing several adjacent transects to be filmed simultaneously from the aircraft. The merits of such a system, particularly with respect to the degree of overlap or gaps in coverage, requires further investigation

In communications with HiDef Aerial surveying, we were informed that a compound camera has now been developed and tested which allows a strip transect with a width of 200 m to be surveyed (M. Mellor *pers. comm.*). Further trials of this system are planned during the winter of 2008-2009 which, if they can demonstrate that this technique is reliable, should dramatically increase the potential of this system for use in aerial bird surveys.

Mellor *et al*. (2007) suggest that an automatic bird detection system could significantly reduce the data processing time, as only those images with birds in would need to be watched by an observer, rather than using staff time to go through the video and identify those frames where birds were present. Again, this system has yet to be developed and tested for use.

The use of high definition video cameras during aerial bird surveys has some significant advantages compared to conventional aerial survey techniques. In particular, the ability to review images to aid identification is a major advantage, and the report on the second trial (Mellor and Maher 2008) states that all species or groups (e.g. auks) could be identified readily, with the exception of differentiation between the large gull species due to over-exposure of some images. However, there are some seabird species that were not present in the areas surveyed during the two trials and therefore the efficacy of the technique in monitoring all seabird species requires further testing. Despite this it is likely that identification or counting errors would be minimised compared to conventional aerial surveys, where due to high encounter rate and the speed of the plane the amount of time available for observers to identify and count birds is small and could lead to birds being assigned to species groups rather than identified to species level, and possibly some identification or count errors, or some cryptic birds being missed, even with experienced observers. The higher altitude that can be used in high definition video surveys compared to conventional surveys reduces the disturbance caused to birds during the survey, reducing the bias of counts as well as being beneficial to the birds themselves. The altitude used also allows planes to cover transects that overlap the coast, which may not be possible in built-up areas using conventional aerial surveys due to the low altitude of the plane. Although conventional surveys can still cover areas up to a few metres from the coast, even in built-up areas, this may be important in certain areas if large numbers of birds occur very close to the coast and could potentially be missed by conventional techniques.

Despite these advantages, there are still some aspects of the survey technique that need to be tested as described above, and some technical developments, before recommendations for a standardised survey technique can be produced.

It is also essential that a trial of the high definition camera survey is conducted at a comparable time to a conventional aerial survey in order that the comparability of these methods can be accurately assessed. Such a trial is planned during the winter of 2008-2009 (M. Mellor *pers. comm.*), and this may also allow further development of the statistical methods used to analyse data from high-definition camera surveys, which are currently being improved by HiDef in conjunction with WWT and St. Andrews University (M. Mellor *pers. comm.*). Methods of data analysis must be improved, and any modifications to the data collection method necessary to provide more suitable data for whatever analytical methods are developed, before a standardised survey method can be recommended.

It is also worth noting that ensuring that surveys conducted using high-definition cameras are directly (or indirectly through the application of correction factors) comparable with conventional surveyors will greatly improve the feasibility of post-construction monitoring. Most pre-construction surveys have been conducted using a flight height of c. 80m (as recommended by Camphuysen *et al.* 2004). The health and safety implications of flying at a height lower than the constructed turbines are such that using the present methodology, post-construction monitoring by aerial survey may not be feasible. Methods that permit higher flying may become the only way in which post-construction monitoring is feasible in the future. Similarly, it may be necessary to use a method that doesn’t disturb sensitive bird species in and around protected sites.

A thorough comparison of the cost of surveying an area using the high definition survey technique rather than conventional aerial survey also needs to be made, as although there is a reduction in the time spent by ornithologists on surveys, it would be necessary to fly a greater number of transects to adequately cover an area (due to the need for transects to be closer together because a much smaller area is covered by each transect than using conventional aerial surveys), and the time taken to review the images from the surveys will also add cost compared to conventional surveys. Although software may be developed to automatically detect those images that contain birds, which would reduce the time spent on reviewing images, the reliability of such software needs to be tested and there would still need to be time spent checking the images that contain birds to identify and record them.

However, with the rapid rate of development in technology and with some further trials of the methodology, it is likely that a standardised technique could be achieved in the relatively near future (HiDef have already developed proposals for a standardised method (M. Mellor *pers. comm*.)), and therefore the use of high-definition video should be monitored for possible inclusion in bird surveys of proposed windfarm sites in the next few years.

3. Comparison of aerial and boat-based survey methods used for Round 1 and Round 2 windfarm applications to those recommended in Camphuysen *et al.* (2004)

3.1 Context

In this section we review the methods for boat-based and aerial surveys of proposed windfarm sites recommended in Camphuysen *et al*. (2004) (see Table 3.1.1 and 3.1.2) and their use during Round 1 and Round 2 windfarm applications. We reviewed eight Environmental Statements (see Table 3.1.3) for offshore windfarms in detail and drew on information presented in several others and from technical reports to provide context and to give a more wide-ranging synthesis of the survey methodologies and analytical techniques that have been used. The aim is to assess whether the recommended methods have been used effectively, and if not, the reasons that the recommendations have not been followed. In addition to reviewing environmental statements, we also draw on the survey experience of authors of this report (principally DAS, but also IMDM) to determine the practicality of each technique.

Table 3.1.1 Summary of Camphuysen *et al.* (2004) guidelines for boat-based surveys.

Guidelines for boat-based surveys
Line transect methodology with a strip width of 300 m maximum
Subdivision of survey bands into 0-50 m, 50-100 m, 100-200 m, 200-300 m and 300 m +
No observations in sea state 5 or more
Survey time intervals 1 or 5 minutes
Ship speed should be 10 knots (range 5 - 15 knots)
Ship type: motor vessel with forward viewing height possibilities at 10 m above sea level (range 5-25 m), *not* being a commercial or frequently active fishing vessel
Ship size: stable platform 20 m - 100 m total length
Bird detection method: by naked eye as a default, except in areas with wintering divers
Two competent observers with range finders and GPS per observation platform
Observers should have adequate identification skills
Observers must be trained by experienced offshore ornithologists under contrasting situations and in different seasons
High resolution grid covering at least six times the area of the proposed windfarm
Survey grid lines at least 0.5 nautical miles apart, maximum 2 nautical miles apart
Cost effectiveness of surveys: improved if an Aquaflow is used to simultaneously log hydrographical information, and if combined with other surveys such as those of marine mammals, for which an additional specialist observer is required

Table 3.1.2 Summary of Camphuysen *et al.* (2004) guidelines for aerial surveys.

Guidelines for aerial surveys
Twin engine aircraft (for safety and endurance)
High-wing aircraft with excellent all round visibility for observers
Line-transect methodology should be used with sub-bands
Transects should be a minimum of 2 km apart
Flight speed 185 km h-1 at 80 m altitude
Subdivision of survey bands (44-163 m, 164-432 m, 433–1000m)
Use an inclinometer to measure declination from the horizon
Two trained observers, one covering each side, observations recorded continuously on a Dictaphone
GPS positions logged by computer at least every 5 seconds
Time of each bird sighting recorded to the nearest second, or within 10 seconds
No observations in sea states above 3 (small waves with a few whitecaps)
All waterbirds recorded to the best level of identification (species or group)
Sampling units are single birds or groups of birds within the three transect bands

Table 3.1.2 Summary of sites and literature used to determine whether Camphuysen *et al.* (2004) guidelines have been met.

Site	Reference
Gwynt y Môr offshore windfarm	RWE Group (2005)
Lincs offshore windfarm	RES (2007)
Kentish Flats offshore windfarm	EMU (2002)
West of Duddon offshore windfarm	Grünkorn *et al.* (2005); RSK (2006).
Greater Gabbard offshore windfarm	Banks *et al.* (2005); PMSS (2005); Banks *et al.* (2006)
London Array offshore windfarm	RPS (2005)
Race Bank offshore windfarm	Centrica (2009)
Thanet offshore windfarm	Royal Haskoning (2005); Jensen 2006

3.2 Boat-based surveys

Camphuysen *et al*. (2004) recommend that boat-based seabird surveys should use, “line-transects with sub-bands and with snap-shots for flying birds, and incorporating the full behaviour module recording detailed information on species, sex, age and where feasible, foraging behaviour and flying height. Whenever possible, hydrographical data, such as sea surface temperature, salinity, water depth should be continuously and synoptically monitored”. They recommended a number of specific techniques, and the use of each of these in surveys for Round 1 and Round 2 windfarm applications is detailed in the sections below.

The main recommendation that boat-based surveys should use line-transects with sub-bands and snapshots for flying birds was followed for all Round 1 and Round 2 assessments that we reviewed, except one where it was not clear whether or not snapshot counts had been carried out for flying birds.

Surveys of birds conducted for the Kentish Flats environmental statement (EMU 2002) recorded fully detailed information for each bird or group as recommended by Camphuysen *et al*. (2004). Similarly, for surveys of the Gwynt y Môr area (RWE Group 2005), the methods recommended by Camphuysen *et al*. (2004) were followed. The environmental statement for Gwynt y Môr states that some minor variations to the methods recommended by Camphuysen *et al*. (2004) were used, for example basing recording of bird flight heights on the mast of the boat (which was approximately 20 metres). It is not clear what other variations may have been used in this survey.

Bird surveys carried out for the Greater Gabbard offshore windfarm also followed the recommendation to survey on line transects with sub-bands, recording details of birds seen in the following hierarchy (which was set according to the aims of the survey): (1) numbers and species/taxon; (2) distance from the survey vessel; (3) flight height; (4) behaviour; (5) flight direction; (6) age; (7) sex of obviously dimorphic species; (8) moult status and (9) plumage. This survey also recorded snapshot counts every two minutes for flying birds (Banks *et al*. 2005).

Boat-based surveys on another site (RES 2007) also complied with the main recommendations of Camphuysen *et al*. (2004), with line transects for swimming birds, snapshots for flying birds, and numbers, flight height, direction, age, sex, plumage and behaviour recorded wherever possible (RES 2007).

Again, in surveys of the London Array, the main survey protocols suggested by Camphuysen *et al*. (2004) were followed (RPS 2005), and the recommendations were also followed in surveys of the Thanet offshore windfarm area (Jensen 2006).

3.2.1 Line transect methodology with a strip width of 300 m maximum

This method was followed by surveyors in all of the assessments that we reviewed. In surveys for the Kentish Flats environmental statements line transects with a strip width of 300 m were used as recommended by Camphuysen *et al*. (2004). This method was also followed in bird surveys for the Greater Gabbard offshore windfarm (Banks *et al*. 2005), the Lincs offshore windfarm site (RES 2007), the London Array (RPS 2005) and the Thanet offshore windfarm (Jensen 2006).

3.2.2 Subdivision of survey bands

Camphuysen *et al*. (2004) recommend subdivision of survey bands to allow corrections for missed individuals at greater distances away from the observation platform. Their recommended subdivision for swimming birds (with all distances measured perpendicular to the ship) is as follows:
A = 0-50 m
B = 50-100 m
C = 100-200 m
D = 200-300 m
E = 300+m or outside the transect

All of the assessments we reviewed used sub-divisions of the survey bands as recommended by Camphuysen *et al*. (2004).This method was followed in boat-based bird surveys for the Kentish Flats environmental statement (EMU 2002) and in surveys carried out of the Greater Gabbard offshore windfarm area (Banks *et al*. 2005). In the Greater Gabbard surveys, the distances of flying birds recorded during transect surveys were measured from the observer, rather than perpendicular to the transect line followed by the survey vessel, but for swimming birds distances were measured perpendicular to the transect line (Banks *et al*. 2005). However in another survey at the site of the Lincs offshore windfarm birds were recorded in the recommended distance bands, measured perpendicular to the transect line, regardless of whether they were swimming or flying (RES 2007). The same method was followed for surveys of the London Array area (RPS 2005) and for surveys of the Thanet offshore windfarm area (Jensen *et al*. 2006). It should be noted that the two approaches differed only insofar as the way in which distances of birds recorded in flight during transect surveys were recorded, however if these counts are used to assess the proportion of birds in flight this could be important as differences in the accuracy of the two methods could result in biased estimates of the ratio of flying birds to birds on the sea.

3.2.3 No observations in sea state 5 or more

None of the assessments we reviewed explicitly stated what sea states their surveys were carried out in, although many stated that surveys were not conducted in bad weather. For some sites the raw datasheets were available and in these we did not find any records of sea states 5 or more.

This was not explicitly stated in the Kentish Flats report (EMU 2002), but the report did state that recommended survey methods were followed, and that inclement weather prevented surveys from being carried out in one month, therefore it seems likely that this recommendation was followed. Similarly, in the report on bird surveys in the Greater Gabbard area (Banks *et al*. 2005) it does not explicitly state that surveys were not conducted in sea states of 5 or more, but does state that their surveys were "consistent with COWRIE recommendations (Camphuysen *et al*. 2004)", and also that surveys were not carried out in some months due to weather disruption, so again, it seems likely that the recommendation that surveys should not be carried out in sea state 5 or more was followed.

A report on surveys at the site of the Lincs offshore windfarm also did not state what states of sea surveys were carried out in (RES 2007), however, the report did state that the sea state was recorded during each survey and that in some of their surveys a larger ship was used that was more stable and enabled surveys to be conducted in "more challenging sea conditions" so that surveys could be completed in "a wide range of sea and weather conditions". This suggests that the recommendation to not carry out surveys in sea state 5 or more may not have been followed in this case, although this is not clear.

At the London Array, boat surveys were not conducted in bad weather conditions, but the report does not make it clear whether this means sea state 5 or more (RPS 2005). There is no information given in the ornithology addendum to the Thanet environmental statement as to what weather or sea state conditions boat surveys were conducted in (Jensen 2006).

We are also aware that there are instances in which weather conditions were suitable at the start of surveys but then deteriorated, but surveys were not abandoned. This is particularly likely to occur if weather deteriorates towards the end of a long trip. In so doing, any data collected may have been invalid.

3.2.4 Survey time intervals 1 or 5 minutes

Camphuysen *et al*. (2004) recommend that survey time intervals should be 1 or 5 minutes, with a range of 1 - 10 minutes. They suggest that longer time intervals are acceptable when lower resolution data are required, but short intervals are preferable in small study areas. The mid-positions (latitude and longitude) should be recorded or calculated for each interval.

All of the assessments we reviewed used survey time intervals within this range, except for two which developed an alternative method where the exact timings of bird sightings were recorded.

For the Kentish Flats assessment, surveys were divided into two minute time periods which falls within the range recommended by Camphuysen *et al*. (2004), and their locations recorded, as recommended. The Greater Gabbard surveys also used two minute time intervals, with water-borne birds recorded in each distance band over a two minute period. Two minute survey periods were also used in boat-based bird surveys conducted for the Thanet offshore windfarm area (Jensen 2006).

In surveys at the Lincs offshore windfarm this recommendation was not followed, but instead an alternative methodology was used where the exact timings of bird sightings were recorded, rather than recording them in one or two minute blocks, so that their locations could be assigned more accurately. Rather than using times to estimate the distance travelled, the distance was measured using the boat's onboard navigation systems and transects were carried out over a 500 m distance rather than a specific time (RES 2007). The exact timings of bird sightings were also recorded for a survey of the London Array area (RPS 2005). Although this method may improve the accuracy of bird locations it is incompatible with current nature conservation databases which assign data to time bins rather than distance bins and use these as sampling units in data analyses.

3.2.5 Snapshot counts

Snapshot counts should be instantaneous counts of flying birds conducted at fixed intervals along the transect. The timing of snapshot counts should be varied according to the speed of the boat, and aim to cover the entire area covered by the standard transect, but using instantaneous counts of birds in the air conducted at fixed intervals to avoid double counting.

During surveys of the Greater Gabbard, snapshot counts were conducted at two-minute intervals but counts lasted for 5-10 seconds rather than being instantaneous. While it may not be practical to count birds "instantaneously" in the field as it may take a few seconds to count birds, observers should attempt to count birds as instantaneously as possible, as prolonged snapshot counts could lead to biased estimates of the density of flying birds.

It was impossible to deduce from the environmental statement for the London Array whether snapshot counts were conducted; the report states that the exact times of any sightings of flying birds were recorded in the same way as swimming birds (RPS 2005), with the flight heights of each bird recorded as accurately as possible in order to assess the proportion of birds that were flying at the height of the proposed turbine blade, but does not state whether snapshot counts were also conducted.

Some experienced seabird surveyors have suggested that it is difficult to vary the timing of snapshot counts according to the speed of the boat, which can vary due to wind or tide during the course of a survey. To deal with this problem they used the onboard GPS system to flag up when the location for each snapshot count was reached. This methodology enabled the snapshot counts to be carried out at specified fixed distance-intervals, thus allowing for variation in the speed of the boat due to the tide.

In instances where boat crew are amenable, it may be possible that fixed intervals for snapshot counts are relayed to the observers by the crew of the boat using their onboard GPS, for example by using a portable transceiver. This will be more accurate than timing the survey to estimate the distance covered as the boat speed could vary due to wind or tide.

3.2.6 Ship speed should be 10 knots (range 5 - 15 knots)

This range of speeds is recommended because rare or cryptic species may be missed at higher speeds, but at lower speeds birds are more inclined to associate with the ship.

In all of the assessments where the ship speed was specified the range was within that specified by Camphuysen *et al*. (2004). Surveys on the Kentish Flats (EMU 2002) were conducted at ship speeds of 6 - 8 knots, which falls within the range recommended by Camphuysen *et al*. (2004). Similarly, surveys of the Greater Gabbard area were conducted at ship speeds within the recommended range (Banks *et al*. 2005). In a report of surveys at the Lincs offshore windfarm site, the ship speed used is not stated; the report simply says that the ship speed was recorded at every snapshot count every 500 m (RES 2007). Surveys of the London Array area were carried out at a speed of around 8 knots (RPS 2005) which is within the range recommended by Camphuysen *et al*. (2004). Likewise surveys of the Thanet offshore windfarm area were also carried out at a speed of 8 knots (Jensen 2006).

3.2.7 Ship type

Camphuysen *et al*. (2004) suggest that the ship should be a "motor vessel with forward viewing height possibilities at 10 m above sea level (range 5-25 m), *not* being a commercial or frequently active fishing vessel".

The ship type was not stated in the Kentish Flats environmental statement. For the Greater Gabbard, surveys were undertaken in a ship with an observation deck 8 m above sea level, which is within the range recommended by Camphuysen *et al*. (2004), although the report on bird surveys at this site did not state whether or not the boat was also a commercial or fishing vessel (Banks *et al*. 2005), although we know that it was not (M. Rehfisch *pers. comm.*). Similarly for surveys of the Lincs windfarm the ships used had observation decks more than 5 m above sea level as recommended by Camphuysen *et al*. (2004). However, this report did not state whether the boat used was a commercial or fishing vessel (RES 2007). Surveys of the London Array were conducted on a converted fishing vessel, with a viewing platform 5 m above sea level. The report on these surveys states that although this was at the lower end of the recommended range, the small size of the boat was necessary because of shallow waters and sand banks in the survey area that made navigation difficult in a larger vessel (RPS 2005). There is no information about the size of the boat used for bird surveys in the ornithology addendum to the Thanet offshore windfarm environmental statement (Jensen 2006), but the report does state that a specially constructed platform giving a viewing height of 5 m above sea level was used for observations.

3.2.8 Ship size: stable platform 20 m - 100 m total length

Many environmental statements do not state the size of the ship used in their methodology, for example the reports on surveys of the Kentish Flats (EMU 2002), the Greater Gabbard (Banks *et al*. 2005), the Thanet offshore windfarm (Jensen 2006) and the London Array (RPS 2005). However the report on surveys for a Lincs offshore windfarm states that the ship used was 21.3 m in length, which falls within the range recommended by Camphuysen *et al*. (2004).

3.2.9 Bird detection method

Camphuysen *et al*. (2004) recommend that bird detection should be "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." Camphuysen *et al*. (2004) additionally recommend that birds attracted to the boat (defined as those remaining with the boat for more than two minutes) should be recorded as such and left out of any analyses

The recommended method was followed in surveys of the London Array proposed offshore windfarm (RPS 2005). Surveys of the Greater Gabbard area also followed this methodology, with birds detected by the naked eye for the majority of the time during two minute survey counts, while at the end of each count scanning ahead with binoculars for divers was done at the same time as the snapshot counts of flying birds (Banks *et al*. 2005). Likewise the recommended detection method was followed for surveys of the Thanet offshore windfarm site.

In surveys of the Lincs offshore windfarm site, observers regularly scanned ahead with binoculars, not only for divers but also for other species such as sea ducks which were known to flush at long distances (RES 2007). Divers and scoter can flush at very long distances: up to 2 km (Kaiser 2002; Kaiser *et al.* 2006). It is therefore likely that many of these birds could be missed by boat surveys unless additional effort is expended looking for these birds.

Camphuysen *et al*. (2004) recognise this problem and stress that in instances where divers or seaduck are expected, an additional observer should be deployed.

We suggest that the recommendation of Camphuysen *et al*. (2004) to scan ahead with binoculars for divers should be extended to include sea ducks.

3.2.10 Two competent observers with range finders and GPS per observation platform

Camphuysen *et al*. (2004) state that "two competent observers are required per observation platform equipped with range-finders, GPS and data sheets; no immediate computerising of data during surveys to maximise attention on the actual detection, identification and recording".

The reason that Camphuysen *et al*. (2004) suggest that two observers should be used is to reduce inter-observer bias if the two observers survey the same transect at the same time. It also allows additional information (for example behavioural information) to be collected and helps to reduce the effects of swamping if large numbers of birds are encountered. *Camphuysen et al*. (2004) suggest that there should be two observers on each side of the ship (i.e. four in total) if transects are being conducted on both sides of the ship at the same time.

In surveys of the Greater Gabbard area, two trained observers were present on the observations deck, but each watched a separate transect on opposite sides of the ship (Banks *et al*. 2005). Although the observers frequently swapped sides in order to minimise observer bias (Banks *et al*. 2005), the two observers were always on opposite sides from each other and therefore this does not strictly comply with the recommendation of Camphuysen *et al*. (2004) which suggests that using more than one observer to watch the same transect should reduce observer bias.

Surveys carried out in the area of the Lincs windfarm followed the recommendation to always have two competent observers present, with distance bands continuously verified using range finders and GPS, although, as for the Gabbard survey only one observer surveyed each transect as two transects were operated simultaneously on opposite sides of the boat (RES 2007).

A team of three experienced observers was used for the majority of surveys of the London Array site (RPS 2005).

Surveys of the Thanet offshore windfarm site used one observer to conduct snapshot counts, while the other observer recorded all other birds on both sides of the ship (Jensen 2006). This deviates from the recommendation of Camphuysen *et al*. (2004) that two observers should record data for the same transect.

3.2.11 Observers should have adequate identification skills

Camphuysen *et al*. (2004) state that all relevant scarce and common marine species should be well known by observers, and that they should have some knowledge of rarities, and a full understanding of plumages and moults.

Banks *et al*. (2005) state that in surveys for the Greater Gabbard, two trained observers specialising in boat-based bird survey were present at all times. This suggests that the observers had adequate identification skills. In surveys of the Lincs offshore windfarm site (RES 2007), observers were all highly experienced ornithologists with excellent bird identification skills. The environmental statement for the London Array states that all observers were experienced ornithologists who were able to identify all species accurately (RPS 2005).

No information is given regarding the competence of observers who conducted surveys on the Thanet offshore windfarm site (Jensen 2006).

3.2.12 Observers must be trained by experienced offshore ornithologists under contrasting situations and in different seasons.

In surveys conducted for the Greater Gabbard environmental statement, two trained observers were used to conduct the surveys (Banks *et al*. 2005), although it is not stated exactly what training these observers had received. In the report on surveys of the Lincs offshore windfarm site it does not state whether observers had been trained by experienced offshore ornithologists, but does state that the observers were themselves highly experienced ornithologists (RES 2007). Similarly, it is not stated in the London Array report (RPS 2005) what training observers had received, but does state that they were experienced ornithologists. No information regarding the training or competence of the observers is given in the report on surveys of the Thanet offshore windfarm site (Jensen 2006).

3.2.13 High resolution grid covering at least six times the area of the proposed windfarm

Camphuysen *et al*. (2004) recommend that a high resolution grid, covering an area at least six times the size of the proposed windfarm should be deployed and including at least 1-2 similar sized reference areas with similar geographical and oceanographical characteristics, and for nearshore windfarms including nearby coastal waters.

Most of the surveys that we reviewed covered an area slightly less than six times the area of the proposed windfarm. This recommendation of Camphuysen *et al.* may need to be reviewed for Round 3 surveys, where the area to be covered is likely to be significantly higher than Rounds 1 and 2. Although it may be ideal to cover six times the area of the proposed windfarm this may not be practical in all circumstances. For all sites the area covered by aerial surveys was much greater than that covered by boat surveys, and therefore it may be appropriate to suggest that although both aerial and boat surveys should be conducted, perhaps the area six times the size of the windfarm could be covered by aerial surveys.

In the boat-based surveys for the Kentish Flats Environmental Statement (EMU 2002), a control site of comparable (though slightly smaller) size to the footprint of the proposed windfarm was surveyed, in addition to a buffer zone around 3.5 times the size of the windfarm site. This means that the total area surveyed for this impact assessment was around 5.5 times the size of the proposed windfarm, so slightly smaller than the minimum area of six times the size of the proposed windfarm as recommended in Camphuysen *et al*. (2004).

Similarly, for the Greater Gabbard Environmental Statement, the windfarm area comprised between 20% and 30% of the entire study area covered by boat-based surveys (in different surveys), and therefore the study area was again less than six times the area of the proposed windfarm (Banks *et al*. 2005).

The report on surveys of the Lincs offshore windfarm area is not clear as to whether the area covered by boat-based surveys was at least six times the area of the proposed windfarm (RES 2007), however looking at maps of the transect routes relative to the windfarm site, which are presented in the report, it does not appear as if the area covered was more than six times the size of the windfarm footprint. However, a high resolution grid was used for all of the surveys in this area (RES 2007).

For the London Array, boat surveys covered the windfarm area and a 2-6 km buffer around it (RPS 2005), but not a control area.

At Thanet offshore windfarm site, only the windfarm plus a buffer zone of 1 km, and a control site approximately half the size of the windfarm area, were surveyed by boat (Jensen 2006), falling well short of the recommendation of Camphuysen *et al*. (2004).

3.2.14 Survey grid lines at least 0.5 nautical miles apart, maximum 2 nautical miles apart

Camphuysen *et al*. (2004) recommend that the grid should be surveyed so that time of day is equally distributed over the area by changing the start and end time so that diurnal rhythms can be understood.

The surveys carried out for the Kentish Flats environmental statement (EMU 2002) and surveys of the Thanet offshore windfarm site used transects spaced at approximately 1 km intervals, which is within the recommended range, although towards the lower end of the range. However this is not a bad thing as it likely to improve the coverage compared to surveys conducted at higher intervals. For the Greater Gabbard Environmental Statement, transects were spaced at 1.8 nm, again within the range recommended by Camphuysen *et al*. (2004). The report on surveys of the Lincs offshore windfarm location (RES 2007) does not specifically state the distance between transects, but does provide a scale map which appears to show that transects are around 3 km apart, which is within the range specified by Camphuysen *et al* (2004) (converting their recommended range of suitable distances between transect lines of 0.5 to two nautical miles into kilometres provides a range of 0.92 – 3.7 km). On the London Array site, spacing between transects was 2 km (RPS 2005), which is within the recommended range.

3.2.15 Cost effectiveness of surveys

Camphuysen *et al*. (2004) suggest that the cost-effectiveness of ship-based surveys can be enhanced if an Aquaflow is used (to simultaneously log hydrographical information), and if combined with other surveys such as those of marine mammals, for which an additional specialist observer is required. They additionally suggest that the cost-effectiveness can be further enhanced by counting birds on both sides of the ship (to cover two strips simultaneously), which requires additional trained ornithologists.

In the Greater Gabbard area, surveys recorded some additional hydrographic and biological information (including water depth and fish recorded on an echo sounder), and birds were counted on both sides of the ship (Banks *et al*. 2005), but although sightings of marine mammals were recorded these were not done by an additional specialist observer, and additional trained ornithologists were not used to cover both sides of the ship, but rather the two observers split up to cover one side each (Banks *et al*. 2005).

No additional data other than water depth, and environmental variables affecting visibility, were recorded during boat surveys of the Lincs offshore windfarm area (RES 2007) but observers recorded birds on two transects simultaneously on either side of the boat (although only one observer covered each side of the boat). Likewise in surveys of the London Array site only bird surveys appear to have been carried out on the boat, rather than combining with recording of other biological and hydrographic data (RPS 2005), but again surveys were conducted on both sides of the boat simultaneously where possible. There is no evidence of any combination with recording of other variables in the report on boat-based bird surveys of the Thanet offshore windfarm site (Jensen 2006).

3.2.16 Additional survey methods used during Rounds 1 and 2 not covered by Camphuysen *et al*. 2004

A survey of Gwynt y Môr (RWE Group 2005) used a boat-based radar study, carried out over five days during February, to assess the extent of dawn and dusk movements of Common Scoter *Melanitta nigra* in the area around the study area. These surveys combined visual observations by trained ornithologists with the use of the ship’s radar, and a similar approach may be appropriate in other surveys in areas where the dawn and dusk movements of birds is a concern.

Radar was also used in surveys of the Lincs offshore windfarm location (RES 2007), but in a different way from in Gwynt y Môr. At the Lincolnshire site land-based radar, located on the coast, was used to monitor the migration of passerines and waterbirds in areas close to the coast (within range of the radar).

In the Greater Gabbard area, special 'migration watches' were conducted during boat based surveys in April-May and August-November, in order to record migrant passerines and wildfowl passing through the survey area, and their height above sea-level, so that the likelihood of migrant birds colliding with any future turbines could be assessed (Banks *et al*. 2005).

3.3 Aerial surveys

The techniques recommended by Camphuysen *et al*. (2004) and their use in Round 1 and Round 2 windfarm surveys are detailed below, along with whether or not these recommendations have been followed in a series of surveys for proposed windfarm environmental statements.

The majority of aerial surveys for Round 1 and Round 2 windfarms have been carried out by the Wildfowl and Wetlands Trust using standardised methods that comply with the guidelines of Camphuysen *et al*. (2004). The only real difference is that four distance bands were used rather than the three recommended by Camphuysen *et al*. (2004). However this can only improve the quality of distance sampling analyses and therefore the resulting population estimates.

In the sections below we review the information given in environmental statements.

3.3.1 Twin engine aircraft (for safety and endurance)

The type of aircraft used for surveys of the Gwynt y Môr proposed windfarm area is not stated in the environmental statement (RWE Group 2005), although it may be in the ornithological technical report (ERM 2005) which we were not able to obtain for this review. Similarly the aircraft used was not stated in the ornithological survey report for the Greater Gabbard offshore windfarm (Banks *et al*. 2005). For surveys of the Lincs offshore windfarm site (RES 2007) the aerial surveys were carried out in a Partenavia PN68 aircraft, the type recommended in Camphuysen *et al*. (2004). The environmental statement for the London Array clearly states that a twin-engined aircraft was used to conduct aerial bird surveys for safety reasons (RPS 2005), as does the statement for the Thanet offshore windfarm (Jensen 2006).

Although not all of the environmental statements are clear as to the type of aircraft used, as the majority of surveys were carried out by WWT using Ravenair's aircraft, which comply with Camphuysen's recommendations, we know that this recommendation has been followed.

3.3.2 High-wing aircraft with excellent all round visibility for observers

The type of aircraft used for surveys of the Gwynt y Môr proposed windfarm area is not stated in the environmental statement (RWE Group 2005), although it may be in the ornithological technical report which has not been obtained. It was also not stated in the report of surveys of the Greater Gabbard area (Banks *et al*. 2005), although this survey did state that methods suggested in Camphuysen *et al*. (2004) had been followed, and it is clear from the report that surveyors had a good view of the sea surface from the aeroplane (Banks *et al*. 2005), so it seems likely that this recommendation was followed. Surveys of the Lincs offshore windfarm (RES 2007) were carried out using the type of high-wing aircraft recommended by Camphuysen *et al*. (2004), a Partenavia PN68. A Partenavia P68 aircraft was also used for surveys of the Thanet offshore windfarm site (Jensen 2006).

Although not all of the environmental statements are clear as to the type of aircraft used, as the majority of surveys were carried out by WWT using Ravenair's aircraft, which comply with

Camphuysen's recommendations and have good all round visibility, we know that this recommendation has been followed.

3.3.3 Line-transect methodology with sub-bands

All of the surveys followed this recommendation, for example this recommendation was followed for surveys of a proposed windfarm area at Gwynt y Môr (RWE Group 2005), and also for surveys of the Greater Gabbard area (Banks *et al*. 2005), the Lincs offshore windfarm site (RES 2007), the London Array (RPS 2005) and the Thanet offshore windfarm site (Jensen 2006).

3.3.4 Transects should be a minimum of 2 km apart

Camphuysen *et al*. (2004) suggest that this distance should avoid double-counting while allowing the densest coverage feasible. This methodology was followed by all of the surveys we reviewed, although the minimum distance of 2 km tended to be used rather than any wider spacing.

In aerial surveys for a proposed windfarm development at Gwynt y Môr this recommendation was followed, and transects were 2 km apart (RWE Group 2005). Equally in aerial bird surveys of the Greater Gabbard area transects were separated by 2 km (Banks *et al*. 2005), and at the Lincs offshore wind farm site (RES 2007), the London Array (RPS 2005) and the Thanet site (Jensen 2006) the same methodology, with transects 2 km apart, was followed.

3.3.5 Flight speed 185 km h^{-1} at 80 m altitude

In surveys conducted by WWT (the majority of Round 1 and Round 2 surveys) the flight speed of 185 km h-1 was used but the altitude was 76 m rather than 80 m. This is for practical reasons because 76 m equates to 250 ft, which is easy to read from a standard altimeter on the plane (P. Cranswick *pers. comm.*). In practice the altitude may vary slightly (between 225 and 275 ft) as it may not be possible for the pilot to maintain an altitude of exactly 250 ft (P. Cranswick *pers. comm.*).

The recommended speed and altitude were used for surveys of the London Array (RPS 2005). For the surveys of the Greater Gabbard proposed windfarm, the report states that these recommendations were followed precisely and the flight speed was 185 km h^{-1} and the aircraft flew at an altitude of 80 m (Banks *et al*. 2005). However as these surveys were conducted by WWT it is likely that their standard of 76 m altitude was followed but has been mis-reported.

For the Gwynt y Môr environmental impact assessment aerial survey transects were flown at an altitude of 76 m rather than 80 m (RWE Group 2005), although this should be comparable with the method recommended by Camphuysen *et al*. (2004). This altitude was also used for surveys of the Thanet site (Jensen 2006). Aerial surveys carried out at the Lincs offshore windfarm site were conducted at a speed and altitude close to that recommended in Camphuysen *et al*. (2004), but not exactly as recommended, with the flight speed in these surveys being 200 km h^{-1}, rather than 185, and the altitude being 76 m.

3.3.6 Subdivision of survey bands to allow calculation of detection probabilities

The recommended subdivision ranges in Camphuysen *et al*. (2004) are as follows:
44-163 m (60-25° declination from the horizon at 80 m altitude)
164-432 m (25-10° declination from the horizon at 80 m altitude)
433-1000 m (10-4° declination from the horizon at 80 m altitude)

In aerial bird surveys of the Greater Gabbard proposed windfarm area there was additional subdivision of the second survey band suggested by Camphuysen *et al*. (2004), so that in their survey birds were recorded in one of four bands as follows: Band A = 44-163 m, B = 163-282 m, C = 282-426 m and D = 426-1000 m (Banks *et al*. 2005). The exact same four distance bands were also used for surveys of Lincs offshore windfarm site (RES 2007), the Gwynt y Môr proposed windfarm area (RWE Group 2005) and the Thanet offshore windfarm site (Jensen 2006), although in the report on the Thanet surveys it appears to suggest that distances to each bird or group were estimated and observations were subsequently grouped into distance bands, however this should not affect any analyses of the data provided distances were estimated accurately, particularly near the divisions between bands.

Although the aerial surveys of the London Array recorded birds in different distance bands, these bands were rather different from those recommended by Camphuysen *et al*. (2004), instead being 49-174 m; 175-459 m and more than 460 m (RPS 2005).

We were unable to assess how accurately observers are assigning birds to the distance bands as no data were available to test this. This is an important consideration because if observers are inaccurate in recording which distance bands birds are in then the resulting estimates of density will be biased. Conversely, if observers are able to estimate distances very accurately it may be feasible to have a greater number of smaller distance bands, which could improve the accuracy of density estimates. It would be worthwhile to consider this issue in future reviews.

3.3.7 Use an inclinometer to measure declination from the horizon

Many of the environmental statements do not state whether an inclinometer was used; only three state that an clinometer was used. However as the majority of the surveys were carried out by WWT using standard recommended methods it is likely that a clinometer was used in all surveys. It was not stated in the environmental statement (RWE Group 2005) whether an inclinometer was used during aerial surveys of the area around the Gwynt y Môr proposed windfarm, however the report did state that records had been positioned using appropriate tools, and the details of whether an inclinometer was used may be in the ornithological technical report (ERM 2005) which we did not obtain. The environmental statement for the Thanet offshore windfarm also does not state whether a clinometer was used in aerial surveys, although in this case it seems likely that a clinometer was not used as the text states that the distances of birds from the plane were estimated (Jensen 2006).

In aerial surveys of the Greater Gabbard proposed windfarm area a clinometer was used to allocate birds to the distance bands (Banks *et al*. 2005) as recommended in Camphuysen *et al*. (2004). This was also done in surveys of the Lincs offshore windfarm site (RES 2007) and surveys of the London Array (RPS 2005).

3.3.8 Two trained observers, one covering each side, observations recorded continuously on a Dictaphone

As the majority of aerial surveys for Round 1 and Round 2 were conducted by WWT the standard method using a Dictaphone would have been followed. WWT observers are well trained and among the most experienced in the UK at these types of surveys, therefore the quality of observations should be consistent and high.

Surveys for the proposed Gwynt y Môr offshore windfarm development used two trained observers, with one covering either side of the aircraft. The environmental statement does not mention whether observations were recorded on a Dictaphone, but does state that they were recorded accurately (RWE Group 2005). As these surveys were carried out by WWT the standard methodology using a Dictaphone would have been followed.

Banks *et al*. (2005) state that surveys of the Greater Gabbard proposed windfarm were carried out by trained staff from the Wildfowl and Wetlands Trust, and that one observer counted from each side of the aircraft and continuously recorded observations on a Dictaphone as recommended by Camphuysen *et al*. (2004). These recommendations were also followed by surveyors conducting aerial surveys of the Lincs offshore windfarm site (RES 2007) and the London Array (RPS 2005).

Trained staff from the Wildfowl and Wetlands Trust carried out surveys of the Thanet offshore windfarm site, but the report presented in the addendum to the environmental statement for this site does not make it clear whether both sides of the aircraft were monitored, but does state that a Dictaphone was used to record sightings (Jensen 2006)

3.3.9 GPS positions logged by computer at least every 5 seconds

The environmental statement for the proposed Gwynt y Môr offshore windfarm states only that records were positioned using appropriate GIS tools and software, but details of how positions were logged during the survey may be detailed in the ornithological technical report (ERM 2005). GPS positions were also logged regularly during aerial surveys of the Greater Gabbard area, although it is not clear from the report whether positions were always logged every five seconds, since the report states that, “the precise location of the plane was downloaded regularly from the GPS onto a laptop computer (e.g. every five seconds)” (Banks *et al*. 2005). It is not clear from this whether the five second example was kept to on all occasions or not. However, in surveys for the Lincs offshore windfarm (RES 2007) and the London Array (RPS 2005) this recommendation was followed, with the GPS position always logged every 5 seconds. There is no mention of whether GPS was used, and if so how often positions were logged, in the report on surveys of the Thanet offshore windfarm area (Jensen 2006). However this information may be in the Appendix to the environmental statement which was not available to us.

3.3.10 Time of each bird sighting recorded to the nearest second, or within 10 seconds

Camphuysen *et al*. (2004) suggest that a watch attached to the window of the plane is the ideal method to record timings.

It is not stated whether this method was used in aerial surveys for many of the environmental statements, such as the Gwynt y Môr environmental impact assessment (RWE Group 2005), but all those conducted by WWT should have followed this methodology, as this is standard WWT practise. In the report for the Greater Gabbard surveys it is not clear how precisely the timing of sightings were recorded (Banks *et al*. 2005), and neither is this clear in the report on surveys of the Lincs offshore windfarm site (RES 2007), nor in the report on surveys of the Thanet offshore windfarm site (Jensen 2006), but we presume that all of these surveys followed the prescribed methodology as they were carried out by WWT.

In surveys conducted for the London Array environmental statement, the report states that time of each bird sighting was recorded to the nearest second using a watch synchronised with the GPS. This may be a better method than recording birds to the nearest 10 seconds as an aircraft can travel a long distance in 10 seconds. It may be advisable to change the recommendation of Camphuysen *et al*. (2004) to state that the time of each bird sighting should be recorded to the nearest second (and remove the alternative of recording birds within 10 seconds), assuming that this is practical in all survey situations.

3.3.11 No observations in sea states above 3 (small waves with a few whitecaps)

It is not stated whether this recommendation was followed in surveys for the Gwynt y Môr environmental statement (RWE Group 2005), or in the environmental statement for the Thanet offshore windfarm (Jensen 2006). Similarly, in the report for the Greater Gabbard area it is not explicitly stated what conditions surveys were carried out in, although it does state that the recommendations of Camphuysen *et al*. (2004) were followed. This is also the case for the London Array (RPS 2005) The report on the Lincs offshore windfarm does not specifically state what sea states the surveys were carried out in, but does state that surveys were carried out in good weather with wind speeds of less than 15 knots, suggesting that this recommendation was followed in this instance (RES 2007).

3.3.12 All waterbirds recorded to the best level of identification (species or group)

For the Gwynt y Môr environmental statement this method was followed, with the species, number of birds in the group, behaviour and distance band recorded for each observation (RWE Group 2005). This was also done in surveys of the Greater Gabbard area (Banks *et al*. 2005), the London Array (RPS 2005) and the Thanet offshore windfarm (Jensen 2006). This method was also followed in surveys of the Lincs windfarm site (RES 2007) but in all cases a precautionary approach was followed so that only those individuals that were seen clearly were recorded to species level, with other birds being recorded to the best level of identification possible, for example "pale-backed gull" (for Herring *Larus argentatus* or Common Gull *L. canus*).

3.3.13 Sampling units are single birds or groups of birds within the three transect bands

This method was followed for the Gwynt y Môr environmental impact assessment (RWE Group 2005), and also for the Greater Gabbard surveys (Banks *et al*. 2005), surveys at the Lincs windfarm location (RES 2007), the London Array (RPS 2005) and the Thanet offshore windfarm (Jensen 2006).

3.4 Conclusions

In many cases insufficient details have been given in environmental statements to assess whether the guidelines of Camphuysen *et al*. (2004) have been followed. In future it is important to stress that these details need to be provided and that reports should state even what may seem like obvious details of their methodology. One possible solution would be for all reports to have a standardised form (see Appendix 1) listing all the recommendations and stating specifically whether each one has or has not been followed. If the recommendations have not been followed, then a reason why this was impractical, or why an improved method was used, should be described in detail.

Where sufficient details are available, it appears that the recommendations of Camphuysen *et al*. (2004) have generally been followed in both boat-based and aerial surveys, but we have to rely on the reporting. There is little proof of whether certain recommendations, such as using competent observers, are followed. One solution for this problem could be to include a list of observers as an appendix to environmental statements, including details of their previous experience (e.g. number of previous boat-survey hours) and any training or qualifications they have received.

4. Can the recommended survey methods of Camphuysen *et al.* be refined?

4.1 General Recommendations

Boat-based and aerial surveys still provide complementary data, as suggested by Camphuysen *et al.* (2004), and both should be carried forward to Round 3. As a refinement to the Camphuysen method, we recommend that for both aerial and boat-based surveys, sea states and a clearly defined score of viewing ease are recorded at the start of each transect and at any time during the transect if this changes. To aid analysis, we also recommend that the observers are assigned a identification code, which could be incorporated as a covariate in Distance analyses (see section 6).

4.2 Boat-based Surveys

The major recommendations of Camphuysen *et al.* (2004) regarding boat-based bird survey methodology have been followed in surveys for Round 1 and Round 2 windfarm applications. However, it is often not clear in technical reports or environmental statements whether all of the recommendations have been followed. For example, the maximum sea state on which surveys were conducted is rarely stated in reports, and it is therefore unclear whether some surveys may have been conducted in rougher seas than recommended by Camphuysen *et al.* (2004). Another potential deviation from the methods recommended by Camphuysen *et al.* (2004) is that surveys are often conducted with only one observer recording birds on each side of the boat, rather than two observers recording the same transect as suggested by Camphuysen *et al.* (2004) to minimise observer bias. Furthermore, in some reports the level of training of the observers carrying out the surveys is not stated, and it is therefore unclear whether experienced, competent, trained observers are always used to conduct these surveys (although in many cases reports do say that competent trained observers were used).

We recommend that for all boat surveys, a checklist of recommendations is completed and supplied in the appendices of Environmental Statements. Any deviations from the recommendations should be justified in detail.

In terms of additional methods that could be recommended for Round 3 surveys, we recommend the following:

(1) With regards to the frequency of snapshot counts, we recommend that observers capitalise on improvements in GPS technology. Boat speeds can vary considerably with tide and current. Thus methods based on time-intervals do not enable accurate georeferencing of birds. Where ship navigating crew are amenable, we suggest that snapshots could be conducted at fixed distance intervals (e.g. 300 m) rather than fixed time intervals. An effective method used for several of the assessments by Econ Ecology (e.g. RES 2007), was to have the ship's navigator contact the observers using handheld transceivers when the snapshot location had been reached.

(2) With regards to the deployment of observers, we agree with Camphuysen *et al.* (2004) that at least two observers are required per observation platform. However, their roles need to be more clearly defined. There are several advantages to deploying additional observers. Firstly, more observers are likely to see more birds thus improving the accuracy and precision of density estimates, and ensuring that assumptions regarding all birds at zero distance from the transect being seen are more likely to be met. Secondly, in instances where there is a large number of birds, one observer may be swamped if he or she is required to scribe and observe at the same time. If a third trained observer is present on the boat this can allow observers to rotate and take breaks (with two observers on the observation platform and one taking a break at any one time); this can reduce

tedium and enhance concentration. This is particularly necessary if days are particularly long or weather conditions harsh. Indeed, under such circumstances the employment of an additional observer to allow rotation may be required for health and safety reasons (so there should be three trained observers on the boat or four if divers and seaducks are present, with one resting at a time). However, there is a problem if their roles are changed intermittently without documenting such changes. Usually when analysing data using Distance software, a global detection function is assumed (i.e. detection probability is thought to remain constant throughout the survey). Where the roles of observers change, this will not be valid. For example if one observer switches to scribing or goes indoors to warm-up[1] then probabilities of detection will decline (unless a third is present to rotate with). Thus we recommend the following:

i. A minimum of two observers are present per observation platform
ii. Three observers are present per observation platform if seaduck and divers are likely to be present within the survey area
iii. An additional observer should be available on the boat to allow them to rotate, rest and warm up indoors as necessary (for example if days are long or weather conditions are cold). Any changes in the number or identity of observers used should be clearly documented and each combination is considered as a potential covariate when undertaking analysis using Distance software.

(3) With regards to the competence of observers, we agree with Camphuysen *et al.* (2004), that observers must be well-trained both in terms of their identification skills as well as in their capacity to deploy the required survey technique. However, we wish to emphasise the particular need for observers to be good at estimating distances. For this reason, and because the accurate estimation of distances is one of the key assumptions of analysis using Distance software, it is important that observers are able to estimate distances fairly accurately, and should make regular use of distance measurement devices.

(4) With regards to transect spacing, we agree with Camphuysen et al (2004) that, if possible, these should be spaced a maximum of two nautical miles apart. If transects are spaced further apart than this, only a very small proportion of the study area is sampled. Given the variability in count data, this scaling process can be problematic if only a small proportion of the area is sampled, largely because it becomes very likely that seabird hotspots will be missed. In the context of Round 3, some of the Development Zones are extremely large and far out to sea. It has yet to be determined whether covering these entire areas using closely spaced transects can be achieved for logistical reasons. More research is required to establish the trade-offs between the accuracy and precision of density estimates and transect spacing and whether it is better to space transects widely or sample smaller areas. The possibility of using better methods than assuming that the area surveyed is representative of the entire study area (i.e. scaling counts by proportion of area surveyed to derive totals) should be explored. There may be scope for adopting spatial kriging methods or to construct habitat association models using hydrographic data.

4.3 Aerial Surveys

As the aerial survey programmes for Round 1 and 2 assessments have been mostly conducted by a single organisation: the Wetlands Advisory Service of the Wildfowl and Wetlands Trust (WWT), the recommended methods of Camphuysen *et al.* (2004) have followed in the majority of aerial surveys carried out for Round 1 and Round 2 windfarm applications, with relatively

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[1] Authors of this report have spoken to a number of experienced boat surveyors. All have emphasised the difficulty of undertaking surveys in cold conditions. Even when dressed warmly and equipped with a survival suits, surveyors have in the past contracted hyperthermia

little deviation or new techniques used. Consequently there may be no need for new recommendations for aerial surveys to be published. However, some minor deviations from the recommended methods have been recorded (usually where aerial surveys were undertaken by other organisations, although in some instances the discrepancies may also be reporting errors). These, and their potential benefits for future surveys, are described below.

Line transect methodology, with sub-bands, was used in all of the surveys that we were able to obtain information for, but there were some discrepancies in the size and number of sub-bands used. In particular, some surveys split up the sub-bands into finer detail than suggested by Camphuysen *et al.* (2004). Using a greater number of sub-bands can improve the fit of detection functions and lead to a more accurate estimate of density. However, Maclean *et al*. (2006) found that increasing the number of distance bands used results in no perceptible reduction in the error associated with estimating detection functions using Distance software and that greater precision is best achieved by increasing the number of transects flown over any given area, thus increasing the frequency with which birds are encountered. Finally, environmental statements and technical reports rarely state explicitly whether aerial surveys were always carried out in sea states of three or less. While we assume that surveys were not undertaken in these conditions, sea states should be systematically recorded (see general recommendation above).

We propose only on refinement to the Camphuysen *et al.* (2004) method with regards to aerial surveys. We recommend that, if possible, observers should distinguish between birds in flight that have been flushed by aircraft, and those that would have been in flight in any case. Collision risk modelling requires accurate estimates of the proportion of birds present within an area that are in flight. The current method, which does not distinguish between actually flying and flushed birds, will overestimate this proportion.

4.4 Other Survey Techniques

Some assessments have use radar to detect dawn, dusk or nocturnal movements of species of concern (e.g. RWE 2005; RES 2007). This method is the only way in which large movements of birds that might occur outside survey periods can be detected. Most mass movements of birds during the migration period occur at night (Elkins 1983) and boat surveys occur during the data. Thus we recommend that radar studies should always be conducted if mass migratory movements through the windfarm area are suspected. It is beyond the scope of this report to provide details of the merits of remote techniques. This subject will be dealt with in a separate forthcoming report commission by COWRIE.

5. Review of methods of analysis

5.1. General approach

5.1.1. Data sources

In order to conduct a comprehensive review of the analysis methods that were used for Round 1 and Round 2 windfarms, we made use of as many information sources as was possible within the timeframe of this study. We were able to access Environmental Statements for eight windfarms (Emu 2002; PMSS 2005; Royal Haskoning 2005; RPS 2005; RWE Group 2005; RSK 2006; RES 2007) plus one additional site, which is not yet in the public domain and has therefore been referred to as the "Commercially Sensitive Site" without making reference to the specific site in question nor the consultancy responsible for producing the statement. It should be noted however, that although a reasonable number of Environmental Statements are in the public domain, these often lack the necessary detail for an adequate assessment of analytical approaches. Often the details used may be contained in technical reports and appendices, which were not always available to the authors of this report.

We were only able to access a limited number of these technical reports (Banks *et al.* 2005; Grünkorn *et al.* 2005; Banks *et al.* 2006; Jensen 2006), but we contacted some of the consultants responsible for undertaking the analyses directly, for further details. Thus, for windfarms where additional information was available, more detailed assessments have been made. However, the lack of detailed information has constrained the extent to which detailed assessment of analysis techniques can be carried-out, and this limitation should be taken onboard when reading the review.

5.1.2 Review process

We review the analyses methodologies associated with five components of baseline assessment and six components of impact assessment. Because the precise methodology used for one component often has direct relevance for subsequent components, we present our review by assigning a section to each windfarm rather than to each component of the assessment process. However, to allow readers to gain an overall picture of the types of approaches that have been used for each component of the assessment, we devote a final synthesis section which assesses each component more generically.

We considered the following components of baseline assessment: aerial survey duration and frequency, boat-based survey duration and frequency, the way in which densities are presented and the way in which numbers and densities were calculated. We also briefly outline any studies that have been conducted in addition to aerial and boat-based surveys as these often have implications for the way in which the impact assessment has been performed. However, we focus primarily on the analytical techniques associated with boat and aerial surveys, as the majority of other surveys are specifically designed to meet key requirements of the impact assessment process, unique to each site. A review of the analyses techniques used is thus not necessarily particularly useful for future studies, as the techniques used are wholly dependent on the survey deployed, which are individually tailored to each site. However, we can identify major flaws in the approaches used.

We considered the following components of impact assessment: the general approach used, impacts associated with direct habitat loss, impacts associated with disturbance during construction, operation and decommissioning, impacts associated with indirect habitat loss, impacts associated with barrier effects and impacts associated with collisions. Our review focuses primarily on the impacts associated with the erection of wind turbines. It does not consider the impacts associated with onshore works due to grid connection, as this was considered to be outside the scope and remit of this study. Additionally, we do not consider the analytical methodologies associated with cumulative impact assessment, as these were reviewed in detail in a separate study (Maclean and Rehfisch 2008). Nevertheless, one of the major concerns flagged-up in this study was the lack of common approaches used in different studies, which makes the assessment of cumulative impacts much more difficult. One of the intended purposes of this report is to provide stricter guidance on how analyses should be carried-out, thus helping to ensure compatibility across studies. However, another of the concerns raised in the cumulative impact assessment reports was the lack of common outputs across studies. It is thus our intention to provide stricter guidance on how impact assessments should be reported also.

5.2 Gwynt y Môr Offshore Windfarm

5.2.1 Baseline

Information source: RWE Group (2005)

Aerial survey duration and frequency: surveys were undertaken in July and August 2004, between November 2004 and February 2005, and again in May 2005.

Boat-based survey duration and frequency: monthly boat-based surveys were undertaken between February 2003 and March 2005.

Other surveys: A combined survey using ship radar and trained observers was undertaken to assess movements of scoter at dawn or dusk. Each survey lasted c. three hours with two hours of daylight and one hour of darkness. The radar boundary was initially set to 3–4 km, but was revised to approximately 8 km. The detailed data derived from the radar study were not used for impact assessment in the environmental statement, but anecdotal information from observers was used to assist the description of scoter distribution and behaviour. Counts of species recorded from headlands and reported in bird reports were consulted.

Distribution: Distribution maps of raw boat and aerial observations were produced. The data were offset – i.e. the locations of birds were more precisely georeferenced by referring to the distance bands in which they were recorded.

Calculation of numbers: for key species (scoter and red-throated diver) aerial data were used to estimate the numbers and densities of birds present in months with peak observations. Distance software (Buckland *et al.* 2001) was used to account for undetected birds. Best estimates rather than upper confidence limits were reported. The findings were cross-validated with the boat-based survey data to ensure consistency or identify any differences. In some instances inconsistencies did occur, but were given limited consideration in impact assessment. For example, boat-based surveys sometimes recorded high numbers (particularly of common scoter) within the windfarm area, but aerial surveys did not. No attempts were made to account for birds under water. For key species, kriging techniques were used to produce density maps.

5.2.2 Impacts

Information source: RWE Group (2005)

General approach: information collected and evaluated during the baseline surveys was used to identify potential impacts. The assessment of the significance of the potential effects was based on an approach developed by the British Wind Energy Association (BWEA) and Scottish Natural Heritage (SNH), and involved three phases. The first entailed establishing the bird species and populations at risk. The second entailed evaluating the significance of the potential impacts to at-risk species and populations from direct and indirect habitat loss effects and from collision risk. Positive effects are also considered. The third entailed considering options for mitigation measures where a significant impact on the species or populations would result. Significance of effects on bird species outwith Natura 2000 sites were assessed using a matrix approach in which the magnitude of the effect (as determined by its intensity and extent in space and time) and the vulnerability of the species to change caused by the development and its ability to recover the value, were cross-tabulated to assess the significance of the impact.

Where designated features of Natura 2000 sites, such as Special Protection Areas (SPAs) were affected, attempts were made to (1) determine whether the proposal is directly connected with or necessary to site management for conservation, (2) determine whether the proposal was likely to have a significant effect on the site either individually or in combination with other plans or projects and (3) appropriately assess the implications of the development for the site in view of that site's conservation objectives. Conservation objectives were considered to include the following: (1) to avoid deterioration of the habitats of the qualifying species, or significant disturbance to them, (2) to ensure the integrity of the site is maintained and (3) to ensure for the qualifying species, that their populations and distributions and the extent, structure and function and distribution of their supporting habitats are maintained.

Direct habitat loss: impact assessed qualitatively and assumed to be low or negligible for all species.

Disturbance: impacts were assessed qualitatively and were assumed to be low or negligible for all species. The impacts were justified as being minimal based on anecdotal information available as a result of the construction of the nearby North Hoyle Offshore Windfarm. Temporary disturbance to birds was considered to have low impacts on populations of Common Scoter due to lower energetic costs of the localised redistribution. Some mitigation measures were proposed to minimise long-term redistribution. Disturbance to other species was not considered in detail.

Indirect habitat loss: impacts were assessed qualitatively and assumed to be low or negligible for all species. Specifically for Common Scoter, this was justified as the main feeding area was thought to be to the south. Nevertheless, during one of the boat-based surveys, numbers considerably in excess of the national importance threshold were observed within the windfarm footprint area. This was not discussed in detail.

Barrier effects: impacts were assessed qualitatively and assumed to be low or negligible for all species. No reference to the results of the radar study was made.

Collision risk: impacts were assessed qualitatively and assumed to be low or negligible for all species. It was argued that formal collision risk modelling was unnecessary, as the majority of birds were recorded flying under 20 m and the main feeding flock occurred closer to the shore than the proposed windfarm. Nationally important numbers of scoter were recorded flying at heights over 20 m, albeit not within the wind farm area. This was argued to be unimportant. It was recognised that birds may be displaced from feeding areas by strong winds. Data from bird reports were used to show that strong westerly to north westerly winds result in large numbers being displaced and flying past headlands. It was argued that under these conditions, birds were pushed closer to shore and would therefore be at lower risk of collision with the offshore windfarm. The possibility of strong easterly or south-easterly winds pushing birds offshore was not considered.

5.3 Lincs Offshore Windfarm

5.3.1 Baseline

Information source: RES (2007)

Aerial survey duration and frequency: seventeen aerial surveys covering the site were carried out between November 2003 and March 2006.

Boat-based survey duration and frequency: 33 surveys were conducted between March 2004 and March 2006.

Other surveys: the Central Science Laboratory (CSL) Bird Detection Radar system was deployed continuously day and night for two periods of 5 days in October 2004. The purpose of deploying the radar was to observe bird movements, including passerines.

Distribution: distribution maps of raw boat and aerial observations are included in the report. Data were georeferenced approximately – no attempt was made to offset the location of counts based n the bands in which they were recorded.

Calculation of numbers: for all species for which sufficient counts were recorded to permit analysis, numbers (and densities) were reported for both boat-based and aerial surveys. Where appropriate, counts were corrected to account for undetected birds using Distance software (Buckland *et al.* 2001). Boat-based estimates were derived by multiplying the density of birds by the area of the entire study site or windfarm and buffer area. Densities were determined by adding together the calculated density of birds in flight (assessed using snapshots) and birds on the water (assessed using transects). For aerial surveys no distinction was made between birds in flight and those on the water. Best estimates are reported for all individual surveys. The peak counts are also reported with confidence limits. Discrepancies between boat and aerial-derived estimates are discussed. No attempts were made to account for birds under water.

5.3.2 Impacts

Information source: RES (2007)

General approach: information collected and evaluated during the baseline surveys were used to identify potential impacts. Impacts were assessed assuming the 'worst case scenario' i.e. a layout based on a greater number of smaller turbines (83 x 3 MW), which has the potential to cause a greater number of collisions as well as maximum disturbance and displacement of birds from the site. The level of significance of impacts was assessed using matrix analysis, which combines the sensitivity of the species and the magnitude of any negative effect. The process was based on the Environmental Assessment Regulations (1999) and on the Institute of Environmental Assessment Guidelines (1995). The definitions of sensitivity and magnitude followed those developed by Scottish National Heritage (SNH) and the British Wind Energy Association (BWEA) (Percival *et al.*, 1999).

Direct habitat loss: not considered, but inevitably smaller than indirect habitat loss.

Disturbance: assessment of the vulnerability of species to construction (i.e. boat traffic) was determined by adapting Garthe and Hüppop (2004) and using their five-point score combined with the sensitivity of the species (using the matrix approach) to give the overall likely significance of the impact. No account was taken of the actual number likely to occur within the windfarm area, but results were discussed qualitatively.

Indirect habitat loss: three measures were used to determine the magnitude of the effect and then incorporated into standard matrix analysis to determine the significance of the impact: (1) how flexible the species is in its habitat use as given in Garthe and Hüppop (2004), (2) the proportion of birds specifically using the site (measured as feeding) and (3) the proportion of birds using the site in relation to its area in a regional context (defined as the areas of aerial zones).

Barrier effects: impact assessed qualitatively and assumed to be low or negligible for all species. No reference to the results of the radar study was made.

Collision risk: formal collision risk modelling was carried-out for all species thought to be sensitive, but using a precautionary approach to account for uncertainties regarding collision/avoidance. The collision risk model used to estimate mortality rates of birds passing through the site was based on that developed by SNH and BWEA (Percival *et al.* 1999, Band 2000), with several amendments made to increase accuracy of the output and applicability to the offshore scenario. These amendments were (1) a small error in the integration part of the original spreadsheet was corrected, (2) a numerical integration over all possible incident angles (0° to 90°) was included as the original model assumes that the bird is always flying into the rotor at 90° degrees incident angle and the profile of the rotor blade embedded in the original model was changed to a profile more relevant for offshore turbines. The number of birds at risk of collision was calculated by assuming densities of birds in flight were constantly passing through the site. This value was derived from snapshots during the boat-based surveys. Given that at least some birds are likely to have been flushed by the survey boat, this is likely to over-estimate the number in flight and would thus be precautionary. Because many species occurred at low density, records in Band E were included to increase sample size. Band E has no upper limit on distance, so it is impossible to scale the area sampled by snapshots relative to the entire area. Consequently, the area sampled by snapshots was considered to be that within Bands A - D, which is a precautionary approach. The number passing through the site was calculated by assuming that densities were constantly maintained, by determining mean flight speeds from literature and by assuming that birds moved through the windfarm area in random directions (needed to calculate mean passage length).

5.4. Kentish Flats Offshore Windfarm

5.4.1 Baseline

Information sources: EMU (2002)

Aerial survey duration and frequency: one aerial survey was conducted in January 2002. The desk-based review (see other surveys) refers to earlier aerial surveys.

Boat-based survey duration and frequency: nine surveys were conducted between October 2001 and April 2002.

Other surveys: prior to commencing site specific surveys of the Kentish Flats proposed windfarm site, a desk based review of the existing knowledge of the area, concentrating on bird data for the offshore area, was undertaken in order to identify the key issues and species for the subsequent site specific studies.

Distribution: no distribution maps were presented in the Environmental Statement, but it was stated that data were subsequently plotted to produce maps showing the distributions of all birds recorded during each visit and accumulated distribution maps for divers, wildfowl, seaducks and terns. These plots were not available to the authors of this report.

Calculation of numbers: methodological details were given in a supporting technical document, which was not available to the authors of this report. The Environmental Statement states that methods for extrapolated bird population estimates for the proposed windfarm area and buffer zone were based on the standardised methods. It is not clear whether raw counts were corrected using Distance software or whether they were corrected to account for the area surveyed relative to that studied, although one would assume that such corrections were made. Numbers were reported as integers with no upper and lower confidence limits, but for each individual boat-based survey. Aerial survey data for key species were displayed in figures. It seems unlikely that attempts were made to account for birds under water as this is not standard practise.

5.4.2 Impacts

The analysis methods used for impact assessment were not available to authors of this report.

5.5 West of Duddon Sands Offshore Windfarm

5.5.1. Baseline

Information sources: Grünkorn *et al.* (2005); RSK (2006).

Aerial survey duration and frequency: 19 surveys were conducted between August 2002 and March 2006.

Boat-based survey duration and frequency: 15 surveys were conducted between May 2004 and September 2005.

Other surveys: a desk-based review of existing information about offshore birds at West of Duddon Sands Offshore Windfarm was undertaken. Radar surveys were also conducted. Data on flying birds were obtained from an anchored vessel using vertical and horizontal radars in combination with visual and acoustic observations during the period 1st October – 29th October 2005. Visual observations and acoustic detection were carried-out for 15 minutes every hour, during daylight for visual observations at night for acoustic detection. Radars operated continuously. For cross-referencing, coordinated surveys of key onshore sites that were known, historically, to be important migration destination and stop-over sites were conducted on alternate days during the period of radar survey.

Distribution: No distribution maps were presented. Raw counts recorded during both aerial and boat-based surveys for the windfarm + one km buffer, windfarm + two km buffer and for the entire aerial survey block and all boat data are presented in a table.

Calculation of numbers: methodological details were given in a supporting technical document, which was not available to the authors of this report. It is stated that raw boat-based survey data were corrected to compensate for coverage and distance related detection errors, but the methods of doing so could not be assessed. Only peak counts were reported in tables. For one species: Manx Shearwater, an indication of variability between survey periods is given. All figures are reported as integers without indication of confidence intervals.

5.5.2 Impacts

General approach: information collected and evaluated during the baseline surveys was used to identify potential impacts. An overview of the ornithological importance of the site and the main potential impacts were discussed qualitatively and sensitivities were presented in a table. Although the approach taken is rather more discursive than the conventional matrix approach, the nature of the discussion follows a very similar logical framework insofar as definitions of sensitivity and magnitude followed those developed by Scottish National Heritage (SNH) and the British Wind Energy Association (BWEA) (Percival *et al.*, 1999).

Direct habitat loss: the impact were assessed qualitatively and assumed to be low or negligible for all species. It was argued that relatively small areas of sea-bed would be permanently lost due to the construction of turbine foundations, installation of scour protection and cable installation and that only Common Scoter, which were recorded in low numbers, are benthic foragers and would thus be affected.

Disturbance: the impacts on designated features of the candidate SPA in which the windfarm is located are considered qualitatively. On the basis of this discussion it is concluded that the risk of disturbance during construction was very low and consequently, the effect is considered to be of negligible significance. The risk of disturbance during operation was also assessed qualitatively. It is noted that high numbers of Guillemot were recorded within the windfarm footprint and buffer are and that these are considered moderately sensitive to disturbance (Garthe and Hüppop 2004). It was argued that the impacts would be low as there was little evidence of the area being particularly favoured by guillemots nor of major displacement during or after the construction of other windfarms. It is also noteworthy that the peak numbers estimated within the windfarm and buffer area only constitute c. 0.1% of the national population.

Indirect habitat loss: the impacts resulting from indirect habitat loss were considered qualitatively. It was noted that high numbers of some species, notably Manx Shearwater were recorded by boat-based surveys and moderately high numbers within the windfarm footprint and buffer. It was argued that, since most species do not specifically prefer the area in which the windfarm is to be located, and the proportion of available habitat occupied by the windfarm relative to the East Irish Sea as a whole was relatively small, the displacement effect would be low.

Barrier effects: impact assessed qualitatively and assumed to be low or negligible for all species. The radar study (Grünkorn *et al.* 2005), were referred to as justification.

Collision risk: concerns about the migration of Pink-footed Geese and Whooper Swans migrating through the windfarm area are discussed. The SNH collision risk model (Percival *et al.* 1999, Band 2000) was deployed to show that a very large number of flights through the windfarms would be required for Pink-footed Geese and Whooper Swans in order for there to be a significant level of mortality even at conservatively low avoidance rates. The detailed result of the radar study (Grünkorn *et al.* 2005) were cited to indicate that there was a low likelihood of significant mortality of migratory species arising from collision with turbines at the windfarms, either alone or in combination. The likely collision-risk on most species was assessed qualitatively. However, because Lesser-black backed Gulls were observed flying at turbine heights more than other species, collision rates were assessed for this species using the Band *et al.* (2000) model for a range of avoidance rates. The precise method of how the number of birds at risk was calculated was not available to the authors.

5.6 Greater Gabbard Offshore Windfarm

5.6.1. Baseline

Information sources: Banks *et al.* (2005); PMSS (2005); Banks *et al.* (2006)

Aerial survey duration and frequency: eight surveys were conducted; four between November 2004 and February 2005 and four between November 2005 and March 2006.

Boat-based survey duration and frequency: 22 surveys were conducted between February 2004 and April 2006. An additional nine surveys were disrupted (mostly by weather).

Other surveys: a migration watcher was deployed onboard ships during April-May and August-November surveys in order to record migrants (including passerines) passing through the proposed windfarm area

Distribution: distribution maps representing raw counts derived from aerial and boat-based surveys are shown for each winter period. Average distributions, smoothed using kriging techniques are also presented. The kriging technique deployed is somewhat sensitive to the recorded size of individual flocks. No attempt to offset data, i.e. to map locations of birds based on bands in which they were recorded was made.

Calculation of numbers: for all species for which sufficient counts were recorded to permit analysis, numbers (and densities) are reported for all boat-based and aerial surveys. Upper and lower confidence limits are also presented.

Boat-based estimates were derived by adding together the calculated density of birds in flight (assessed using snapshots) and birds on the water (assessed using transects). Counts of birds on the water were corrected using Distance software to account for undetected birds. For aerial surveys no distinction was made between birds in flight and those on the water in the presentation of total densities. No attempts were made to account for birds under water.

5.6.2 Impacts

General approach: information collected and evaluated during the baseline surveys were used to identify potential impacts. The assessment of significance was done using the standard matrix approach in which the sensitivity of species and magnitude of impacts are cross-tabulated to determine the significance of the impact. The approach used was based on the Environmental Assessment Regulations 1999 and Institute of Environmental Assessment guidelines (IEA 1995) and follows the methodology developed by Scottish Natural Heritage (SNH) and the British Wind Energy Association (BWEA) (Percival *et al.* 1999).

Direct habitat loss: impacts due to direct habitat loss were discussed qualitatively, but briefly. Inevitably smaller than indirect habitat loss.

Disturbance: disturbance impacts associated with construction were considered separately from that during operation. The disturbance impacts were considered together with indirect habitat loss and barrier effects and are reported in detail for each species. The sensitivity of each species was defined following Scottish Natural Heritage (SNH) and the British Wind Energy Association (BWEA) (Percival *et al.* 1999) guidelines, in which sensitivity is quantified depending on whether the species is a designated feature of a Natura 2000 site or whether numbers within the windfarm footprint and buffer area occur in nationally important numbers for example. Magnitudes were assessed by assuming a worst case scenario, in which all birds would be displaced from an area equivalent to the windfarm and four km buffer and that none would be able to successfully settle in these areas. The significance of the impact was then assessed using the standard matrix approach. Results are also discussed within the context of sensitivities reported in Garthe and Hüppop (2004).

Indirect habitat loss: the indirect habitat loss impacts were considered together with disturbance and barrier effects and are reported in detail for each species. The significance of impacts was determined in the same way as for disturbance impacts.

Barrier effects: the barrier effects were considered together with disturbance and indirect habitat loss impacts and are reported in detail for each species. The significance of impacts was determined in the same way as for disturbance impacts.

Collision risk: collision risk was assessed for all species using the Band *et al.* (2000) model. A worst case scenario of turbines with a maximum rotor diameter of 150 m was assumed. Bird dimensions were derived from Robinson (2005) and bird speeds were taken from Campbell and Lack (1985) and Pennycuick (1997). Lesser Black-backed Gull speed is not given in either source, but was assumed to be the same as Herring Gull. The percentage of birds flying at turbine blade heights was assessed using data collected during boat-based surveys. The unit of time used to derive hourly and monthly mortality was considered to be the length of time taken for one bird to cross the width of the windfarm, flying at a representative speed and was considered the most appropriate, as it assumes a conservative approach with a continuous stream of birds through the area (i.e. each bird that flies through the windfarm area is replaced by another). Birds were assumed to be flying perpendicular to turbine blades, but as a precautionary approach, the longest diagonal across the windfarm was selected as the distance. Results were reported for a range of avoidance rates and for flight speeds 10% lower than that recorded.

5.7 London Array Offshore Windfarm

5.7.1. Baseline

Information source: RPS (2005).

Aerial survey duration and frequency: 11 surveys were conducted between August 2002 and December 2004.

Boat-based survey duration and frequency: 29 surveys were conducted between October 2002 and February 2005.

Other surveys: a desk-based study was undertaken in which data from the RSPB, the Wetland Bird Survey (WeBS), the JNCC Seabird Colony Register, the Seabird 2000 national seabird survey, the JNCC Seabirds at Sea Atlas and relevant local bird reports and county avifaunas were collated to supplement the field survey data, in particular to explore longer-term trends.

Distribution: maps are presented as aggregated raw abundances for each winter period for both boat-based and aerial surveys. No attempt to offset data, i.e. to map locations of birds based on bands in which they were recorded was made. Maps are presented for key species: divers, Common Tern, Fulmar, Gannet, Common Scoter, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull, Kittiwake, Sandwich Tern, Guillemot, Razorbill, Great Crested Grebe, Cormorant and Eider.

Calculation of numbers: analyses took account of both the proportion of the study area covered by aerial and boat-based surveys and the proportion of birds present actually detected (Buckland *et al.* 2001). Peak corrected counts for the windfarm area + one km buffer are presented for each species. Individual counts recorded during each aerial and boat-based survey are presented graphically for key species (same species as those for which distribution maps are presented) and for all species in the appendix.

5.7.2 Impacts

Information sources: RPS (2005).

General approach: information collected and evaluated during the baseline surveys were used to identify potential impacts. The full range of impacts was assessed to the extent possible, including direct, indirect and secondary impacts, both temporary and long term and adverse and beneficial. The assessment methodology follows that developed specifically for bird impacts on windfarms by the British Wind Energy Association (BWEA) and Scottish Natural Heritage (SNH). Using this approach, the sensitivity of a species is cross-tabulated against the magnitude of the expected impact to determine the significance of the impact.

Direct habitat loss: the impact of direct habitat loss was discussed qualitatively and was dismissed as being negligible for all species, given that the take of habitat would be very low in relation to the availability.

Disturbance: disturbance impacts during construction and decommissioning were considered qualitatively and it was argued that these could be minimised by ensuring activities likely to result in disturbance are not carried-out during the period of key seabird activity (mid-November to March). Disturbance impacts were assessed by assuming a worst-case scenario in which all birds within one km of the windfarm are displaced. It is suggested that this one km buffer is an appreciably greater distance than any suggested displacement of any birds from existing studies. More recent studies in Denmark have highlighted that displacement can occur at distances up to four km from windfarms (Petersen *et al.* 2004; 2005), although complete displacement within this area is unlikely.

Indirect habitat loss: displacement effects due to indirect habitat loss were determined by producing maps that indicate the mean and peak proportion of the regional populations hosted by each two km x two km grid cell using a method termed "interaction with proportional distribution". This was calculated by summing distance corrected estimates of the number of birds recorded in each cell during all aerial surveys and dividing this number by the number of surveys. The cells were then ranked in descending order and colour coded into four categories, such that the cells in each category collectively host 25% of the regional population. The maps were then used to calculate the proportion of the population with which the windfarm and buffer interact. The method potentially offers a valuable visual tool for assessing which areas are important or considering alternative windfarm locations. However, as a tool for quantitatively calculating the proportion of the population contained within or interacting with the windfarm area and buffer, it has its limitations. Conceptually it does not differ substantially from calculating the mean and peak proportions of the regional population occurring within the windfarm and buffer more directly. Additionally, the precision of the result may be constrained when a low number of cells collectively constitute one of the categories.

Barrier effects: barrier effects were considered qualitatively. It was noted that there may be a significant effect, adding further to the likely significant effect from other impacts.

Collision risk: collision risk assessment was carried out for the key species that occurred regularly in the study area in nationally important numbers: red-throated and black-throated divers. Further consideration was given to possible collision issues arising for other species and estimates are given for several other species. Flight densities were derived from mean boat-derived estimates of overall density, multiplied by the proportion noted to be flying as recorded by aerial surveys. Results also accounted for predominant wind directions and sensitivity analyses were undertaken. Actual estimates of collision were not presented. Instead, the threshold avoidance rates that would need to be assumed for a significant impact to occur are reported. The significance of impacts is reported for several avoidance rates and it is often concluded that these are very high.

5.8 Race Bank

5.8.1. Baseline

Aerial survey duration and frequency: 14 surveys were carried out between November 2004 and August 2006.

Boat-based survey duration and frequency: 25 surveys were carried out between December 2005 and November 2007.

Other surveys: additional surveys focused on collecting visual tracking data of adults of one of terns, particularly focusing on determination of the flight direction and calculating the passage rate of adults leaving and entering breeding areas, recording the type and size of prey returned to the colony, primarily to provision chicks and assessing the relative distribution of potential prey at sea in inshore areas.

Distribution: for key species, distribution maps of combined raw counts derived from boat-based surveys are produced for each survey season (but not each individual survey). Combined totals derived from all aerial surveys are also produced for these key species. Data were "offset" – i.e. locations of birds more precisely estimated, based on bands in which they were recorded.

Calculation of numbers: numbers were calculated by adding together the calculated density of birds in flight and those on the water. For birds in the water, counts were corrected using Distance software to account for the proportion undetected. Raw counts were used for birds in flight as it was assumed that birds in flight are easy to detect. Counts were corrected to account for the proportion of area surveyed relative to that studied. Numbers within the windfarm area and windfarm and buffer area are presented for all species and groups. For key species, seasonal patterns of the number of birds estimated to be present were presented graphically.

5.8.2 Impacts

General approach: information collected and evaluated during the baseline surveys were used to identify potential impacts. Impacts upon birds were assessed assuming the 'worst case scenario' i.e. maximum number of turbine placements that can be accommodated within the within the windfarm site area and assuming a layout that has the potential to cause the greatest number of collisions as well as maximum disturbance and displacement of birds from the site. The level of significance of impacts was assessed by cross-tabulating species sensitivities with the magnitude of any negative effect separately in relation to construction and decommissioning, and operation. The process was based on the Environmental Assessment Regulations (1999) and on the Institute of Environmental Assessment Guidelines (1995). The definitions of sensitivity and magnitude followed those developed by Scottish National Heritage (SNH) and the British Wind Energy Association (BWEA) (Percival *et al.*, 1999). Sensitivities were based on conservation status and the importance of the population in an international, national or regional context. These are justified in detail.

Direct habitat loss: not considered separately from indirect habitat loss (which is inevitably greater).

Disturbance: assessment of the vulnerability of species to disturbance during construction and decommissioning was performed using the scale developed by Garthe and Hüppop (2004). Where additional evidence was available, the potential magnitude was discussed in the context of the species distribution within the proposed site and the strategic area and using evidence from other operational windfarms to arrive at a predicted magnitude of effect. The impacts of disturbance during operation were not considered separately from indirect habitat loss.

Indirect habitat loss: the standard approach was adopted whereby the proportion of birds utilising the site relative to the regional population is quantified to determine impacts. Additionally, information on the flexibility of the species in relation to its habitat use and specifically the proportion actually using the site for feeding were considered to determine the magnitude of impacts. Information on habitat use flexibility was determined from Garthe and Hüppop (2004) and the region population was defined as that derived from aerial surveys in three blocks.

Barrier effects: barrier effects were determined qualitatively. Several site-specific parameters were considered as well as facts such as whether birds on the proposed site were actively selecting a route through it by commuting to and from breeding colonies and feeding areas. For migrating birds, a judgment was made as to whether the airspace above the site and buffer provided a particular combination of wind speed and direction or perhaps a direct route to a known specific land-fall site.

Collision risk: The collision risk model used to estimate mortality rates of birds passing through the site was based on the Band model (Band *et al.* 2000), with due consideration given to the appraisal of the model by (Chamberlain *et al.* 2005). The approach used to assess the number of birds at risk followed a methodology developed by Folkerts and Perrow (2007). This approach entails assuming that birds pass through the site continuously. The number of birds at risk of collision is then calculated by assessing the density of birds in flight from snapshots conducted during boat-based survey and determining the proportion flying at heights swept by the rotor blades and proportion of the windfarm cross-sectional area swept by the blades. The collision risk modelling was precautionary in as much as a worst-case scenario for the layout, number of turbines and turbine dimensions was assumed.

5.9 Thanet Offshore Windfarm

5.9.1. Baseline

Information sources: Royal Haskoning (2005); Jensen (2006)

Aerial survey duration and frequency: Four aerial surveys were undertaken between November 2004 and March 2005. Four more aerial surveys were undertaken between November 2005 and February 2006.

Boat-based survey duration and frequency: 12 monthly surveys were undertaken between November 2004 and October 2005. An additional six surveys were undertaken during the winter of 2005/06.

Other surveys: in addition to boat-based and aerial surveys a literature review was undertaken. This included reference to aerial and boat-based data undertaken in the Thames Estuary prior to October 2004, a review of data in the European Seabirds at Sea (ESAS) database and other ornithological data from the North Sea (e.g. Skov *et al.* 1995) and estimates of numbers and locations of breeding seabirds derived from the Seabirds 2000 survey (Mitchell *et al.* 2004).

Distribution: distribution maps are presented for each aerial survey for key species and groups: divers, auks, Kittiwake, Common Gull, Herring Gull, Lesser Black-backed Gull, Great Black-backed Gull, Common Scoter, wildfowl and waders. Data are presented as two km x two km grid cells, with the value of each cell, the raw count from that grid.

Calculation of numbers: peak counts from aerial and boat-based surveys are reported. Numbers presented in the Environmental Statement were not corrected for under-detection using Distance techniques. It was argued that Distance correction was not possible as distance band analysis had not been made available by the WWT's Wetland Advisory Service or DTI. The report refers to correction factors published in Stone *et al.* (1995), but it appears that correction factors were not applied in most instances. It was ostensibly argued that this was because correction factors can only be applied to larger datasets. In an attempt to minimise under-counting only data from Bands A-C were incorporated into density estimation. However, there is no mention of any correction factor applied to account for the proportion of the area covered by surveying in Bands A-C relative to the entire area.

5.9.2 Impacts

General approach: the impact assessment is qualitative in nature. The assessment of significance differs from the standard matrix approach in which the sensitivity of species and magnitude of impacts are cross-tabulated to determine the significance of the impact as recommended by SNH and BWEA (e.g. Percival *et al.* 1999).

Direct habitat loss: assessed qualitatively and argued to not impact birds because of the small area of seabed lost relative to availability elsewhere.

Disturbance: impacts during construction were assessed qualitatively and assume to be low. The impacts during operation were also assessed qualitatively, with detailed discussion of key species, notably divers. Raw peak counts derived from boat-based surveys are compared to national importance thresholds and numbers within other windfarm areas to justify that the impact is likely to be very low. It appears that attempts were not made to account for undetected birds and to correct for the area surveyed by recording birds in Bands A-C, relative to the total area of the windfarm.

Indirect habitat loss: considered together with disturbance.

Barrier effects: assessed qualitatively and argued to have minimal impact.

Collision risk: collision risk was assessed using the Band *et al.* (2000) model using raw counts of birds present within Bands A-D. Five avoidance rates, ranging from 0% to 99% were considered. Details of the method used to calculate the number of birds at risk were not available to the authors of this report. The collision estimates are considerably lower than those reported in other studies with similar assumptions regarding avoidance and similar numbers of birds exposed to collision (e.g. Banks *et al.* 2005; RSS 2005; 2006; see Appendix 2). Without details of the method, it is not possible to determine why such discrepancies may exist. It is worth noting however, that the 'worst-case scenario' avoidance rate of 0% would lead to a substantially higher estimate of collision mortality than if more typical worst-case scenario avoidance rates of e.g. 95% were assumed (Chamberlain *et al.* 1996). Thus any of the assumptions that could have lead to surprisingly low estimates of collision mortality relative to those reported in other studies, are likely to be at least partially offset by highly precautionary avoidance rate used (see Appendix 2).

5.10 Synthesis

5.10.1. Baseline

Aerial survey duration and frequency:

The number of aerial surveys conducted varied between windfarm, from just one (Emu 2002) to 19 RSK (2006). For all except one site, aerial surveys were undertaken for a minimum of two years, with surveys in both summer and winter for most sites, but only during winter for a small number of sites. In instances where surveys were only conducted during winter, the species most likely to be adversely impacted by the windfarm in question were most abundant during the winter period. At all sites where aerial surveys were conducted only at one time of year, boat-based surveys were carried-out throughout the year.

Boat-based survey duration and frequency:

The number of boat-based surveys varied from nine (Emu 2002) to 33 (RES 2007). With the exception of Kentish flats, surveys were conducted over two years. In most instances, surveys were conducted approximately monthly throughout the year.

Other surveys:

The nature of other surveys varied considerably between windfarms. In some assessments (e.g. Emu 2002; Royal Haskoning 2005; RPS 2005; Jensen 2006; RSK 2006), the results of desk-based studies were reported in the Environmental Statements. For other sites it is highly likely that similar studies were conducted, but as part of the scoping assessment. Typically such studies reviewed data collected as part of the Wetland Bird Survey (Austin *et al.* 2008), the JNCC Seabird Colony Register, the Seabird 2000 national seabird survey (Mitchell *et al.* 2004), the JNCC Seabirds at Sea Atlas and relevant local bird reports.

Additionally, in several assessments (e.g. RWE Group 2005; Grunkorn *et al.* 2005; RSK 2006; RES 2007), radar studies were deployed. Typically Bird Detection Radar systems were deployed continuously for several days during peak migration periods or to assess movements of key species that had the potential to be adversely affected by windfarms. To enhance species identification, such studies were generally conducted alongside visual or acoustic studies in which trained observers surveyed for set periods during the operation of radar systems. At the Greater Gabbard (PMSS 2005; Banks *et al.* 2005; 2006), migration was assessed by deploying a special migration observer onboard the boat for the surveys conducted during the migration period. For one assessment (RSK 2006), coordinated surveys of key onshore sites that were known, historically, to be important migration destination and stop-over sites were conducted on alternate days during the period of radar survey to permit cross-referencing.

At Scroby Sands, which is located adjacent to the most important UK breeding site for Little Terns *Sterna albifrons*, the Great Yarmouth North Denes Special Protection Area (SPA), radio-telemetry was used to track activity and foraging patterns, to illustrate habitat use and to indicate susceptibility to windfarm collisions (Perrow *et al.* 2006). Similar studies were conducted for another species at a commercially sensitive site.

Distribution:

Several approaches have been used to map and display the distribution and abundance of birds. For all windfarms, the area covered by these maps is considerably larger than that of the windfarm. This allows the densities of birds occurring within the windfarm area to be placed in context, particularly with regards to establishing whether the windfarms and buffer areas host particularly high densities in comparison to surrounding areas. The precise methods have differed somewhat. For most windfarms, raw aerial and boat data are mapped, with no attempt made to account for undetected birds using Distance software. This approach is adequate for providing comparisons of relative densities between areas.

The precise methods of displaying densities differ. In some instances, the counts have been more precisely georeferenced using the distance band and side of the boat or plane in which the observation was recorded and offsetting their location accordingly. In other instances, observations are assigned to the transect line or more usually, two km x two km grid cells. The number of maps displayed also differs between studies. Some only present maps for a few key species, whereas others present maps for all relatively abundant species. Similarly, in some instances only cumulative or mean densities are presented, whereas for others individual maps are presented for each survey or season. In most instances, maps have been presented using scaled dots or shaded grid cells to represent densities. However, for some baseline assessments (e.g. Banks *et al.* 2005; RWE Group 2005; Banks *et al.* 2006), maps have been smoothed using kriging approaches. In the baseline and impact assessments for the London Array (RPS 2005), the mean and peak proportion of the regional populations hosted by each two km x two km grid cell was displayed by colour coding cells into four categories, such that the cells in each category collectively host 25% of the regional population.

Calculation of numbers:

The method used to the number of individuals of each species is broadly similar across assessments. The level of detail presented in Environmental Statements is not always sufficient to allow adequate evaluation of the precise methods used and the technical reports and appendices in which the precise methods were described, were not always available to the authors of this report. In almost all instances, raw counts of birds in the water for boat-based surveys and all counts for aerial surveys have been corrected to account for undetected birds using Distance sampling techniques (Buckland *et al.* 2001) and for the proportion of area surveyed relative to the study area (although there is one notable exception). In some instances, where birds were too infrequently encountered to permit Distance analyses, correction factors derived from Stone *et al.* (1995) have been used to account for undetected birds. It is not always clear whether the birds in flight recorded using 'snapshot-counts' from boats were corrected using Distance software. Where methods are described in detail these counts were not corrected, because doing so appeared to give unrealistically high density estimates (e.g. Banks *et al.* 2005; 2006). The possible reasons and implications of this are described in more detail in the guidelines section. In almost all instances, species that could not be identified are assigned to separate categories and numbers are reported separately. The way in which this has been handled in the impact assessment varies between studies. In some studies, the unidentified birds have been excluded from analyses. In others, unidentified birds have been added to the totals of the species they are most likely to be, or assigned proportionally to one species or another based on the abundance ratios of positively identified individuals. The implications of and assumptions surrounding the various ways in which treating unidentified birds is discussed in the guidelines section.

5.10.2 Impacts

General approach: in most instances, the general approach to impact assessment is based on the method developed and recommended by the BWEA and SNH (Percival *et al.* 1999). This approach is based on the Environmental Assessment Regulations 1999 and Institute of Environmental Assessment guidelines (IEA 1995). There are three phases: (1) establishing the bird species and populations at risk, (2) evaluating the significance of the potential impacts to the species and the populations and any positive effects and (3) options for mitigation measures where a significant impact on the species or populations would result. The establishment of bird populations at risk generally draws heavily on data collected as part of the baseline survey, although the final species list is often refined through consultation with relevant statutory bodies and with the RSPB. The evaluation of the significance of potential impacts generally entails the use of the standard recommended matrix approach (Percival *et al.* 1999), whereby species sensitivities are cross-tabulated against the magnitude of impacts to derive the significance of impacts. The sensitivity of species is generally assessed based on whether birds present are designated features of Natura 2000 sites or have some other conservation significance and on the importance of the population in an international, national or regional context. The magnitude of impacts has been assessed in a variety of ways. In many instances these are assessed qualitatively or are assessed quantitatively only for key species. However, quantitative assessments are sometimes performed and these are described in more detail in the relevant sub-sections below. Options for mitigation measures are almost always discussed qualitatively and generally focus on measures that might minimise impacts rather than on quantifying the mitigation needed to compensate for losses.

Direct habitat loss: in all instances where direct habitat loss has been assessed, the assessment has been qualitative and it is generally concluded that, due to the small area of seabed that would be lost, such impacts are negligible. The justification for this is that the magnitude of impacts associated with indirect habitat loss is much greater.

Disturbance: disturbance impacts are generally assessed separately for the construction phase, the operation phase and the decommissioning phase (although the impacts during construction and decommissioning are often thought to be similar and are assessed together). Disturbance impacts during operation are usually considered alongside indirect habitat loss and as such, the impact assessment measures are discussed in more detail in this section. In some instances, disturbance impacts during operation have been considered separately by assessing the impacts within the context of individual species' vulnerabilities to disturbance. Where such assessments have been performed, the quantification of vulnerability usually derives from data presented in Garthe and Hüppop (2004).

Indirect habitat loss: the impacts associated with indirect habitat loss are often considered alongside those associated with disturbance during operation. For many of the studies, the assessment of the magnitude of the impact is essentially qualitative, although numbers recorded during the baseline surveys are usually presented to provide context. However, in some instances quantitative analysis to assess the magnitude of the impact has been undertaken (e.g. Banks *et al.* 2005; PMSS 2005; RPS 2005; Banks *et al.* 2006; RES 2007). The approach has generally been to assume that all birds within the windfarm area and a specified buffer are displaced and would suffer 100% mortality. The number of birds displaced is then assessed against regional, national or international populations to place this figure in context. There are slight variations on this approach used in some assessments. For example, in one assessment (RPS 2005), a method termed "interaction with proportional distribution" was used (method described in detail above) and in others (e.g. RES 2007), the significance of impacts was also determined by assessing the impacts within the context of individual species' flexibilities of habitat use. The quantification of habitat use flexibility usually derives from data presented in Garthe and Hüppop (2004). The size of the buffer zone around the windfarm area also differs between studies, generally extending from one km to as far as four km from the periphery of the windfarm area.

Barrier effects: in all instances, the magnitude of barrier effect impacts has been assessed qualitatively and has usually been assigned as low or negligible for most species. This is largely because means of quantitatively assessing barrier effects have not yet been devised. In some instances, the qualitative assessment draws on data collected as part of detailed radar studies to assess bird movements, but in other instances radar studies were not undertaken.

Collision risk: the magnitude of collision risk impacts has sometimes been assessed qualitatively (e.g. RWE Group 2005; Kentish Flat), but is more often assessed quantitatively using the Band *et al.* (2000) model (e.g. Banks *et al.* 2005; PMSS 2005; Royal Haskoning 2005; RPS 2005; Banks *et al.* 2006; Jensen 2006; RSK 2006; RES 2007). In some instances (e.g. RSK 2006), formal collision-risk modelling was limited to a few key species. The model runs as a two-stage process. Firstly the risk is calculated making the assumption that no avoidance action is taken. This is essentially a mechanistic calculation, with the collision risk calculated as the product of the probability of a bird flying through the rotor swept area and the probability of a bird colliding if it does so. The second stage then incorporates the probability that the birds, rather than flying into the turbines, will actually take a degree of avoiding action.

In applying the Band model, it is necessary to first determine the number of birds at risk. The way in which this is determined can affect the results greatly, leading to incorrect estimates of collision mortality that are several orders of magnitude too low. The methodology is not usually reported in sufficient detail to allow an accurate determination of which method has been used, but a repeat analyses of data by the authors of this report would suggest that at least in one instance, the method of determining the number of birds at risk was incorrectly calculated (Appendix 2). There are a few studies where sufficient details have been presented to allow assessment (Banks *et al.* 2005; RPS 2005; 2006; RES 2007). These reveal that two broadly similar approaches have been used. In all of these studies, it is assumed that birds move through the area continuously and that the number at risk of collision can thus be determined by multiplying the number of birds in flight within the windfarm area at any one time, by the number flying within the risk zone (see Band *et al.* 2005 and detailed guidelines in next section) and the number of turbines. The way in which the number of birds in flight has bas been quantified in different ways for different studies. In the assessments at the Greater Gabbard (Banks *et al.* 2005; PMSS 2005; Banks *et al.* 2006) and the London Array (RPS 2005), the number in flight was determined by assessing number within the windfarm area (either from boat or aerial surveys) and then quantifying the proportion of birds in flight from aerial survey data. In some assessments (e.g. RES 2007), the number of birds in flight is determined directly from snapshot counts. In all instances where such analyses were performed, mean densities were used, but the derivation of these means did not account for potential biases which may arise if surveys are concentrated at particular times of year.

Collision rates are highly sensitive to assumptions regarding avoidance. Collision mortality is linearly proportional to the collision rate (which is assumed to be 1-the avoidance rate). Since high avoidance rates (e.g. 99%) are generally assumed, a minor difference in the choice of avoidance rate can greatly influence estimates of collision mortality (Chamberlain *et al.* 2005). In most of the assessments in which quantitative collision risk modelling was undertaken, precautionary principals have been adhered to. As such, mortality rates are presented for a range of avoidance rates and the selection of lower-bound avoidance rates are typically lower than would realistically be expected. However, the range of lower bound avoidance rates varies between studies, being as low as 0% in the assessments for one site (Royal Haskoning 2005; Jensen 2006), but more typically around 95%.

Table 5.10.1 Summary of analytical methods used in each of the Environmental Statements reviewed in detail

	Gwynt y Môr	**Lincs**	**Kentish Flats**	**West of Duddon Sands**	**Greater Gabbard**	**London Array**	**Race Bank**	**Thanet**
Aerial survey duration	Two years	2.5 years	1 month	3.5 years	1.5 years	2.3 years	1.7 years	1.5 years
Aerial survey frequency	8 in total	17 in total	1 in total	19 in total	8 in total	11 in total	14 in total	8 surveys
Boat survey duration	2 years	2 years	6 months	1.5 years	2.2 years	2.5 years	2 years	1.5 years
Boat survey frequency	Monthly	33 surveys in total	9 surveys	15 surveys	22 surveys	29 in total	25 in total	18 in total
Other surveys	Radar	Radar	Desk-based review	Desk-based review and Radar	Diurnal migration survey	Desk-based review	Visual tracking of terns	Desk-based review
Abundance estimate	Corrected to account for undetected birds	Corrected to account for undetected birds	Insufficient detail for evaluation	Corrected to account for undetected birds	Corrected to account for undetected birds	Corrected to account for undetected birds	Corrected to account for undetected birds	Not corrected to account for undetected birds
General approach to EIA	Standard matrix-approach	Standard matrix-approach	Unavailable to authors of this report	Standard matrix-approach	Standard matrix-approach	Standard matrix-approach	Standard matrix-approach	Qualitatively assessed
Direct habitat loss	Qualitatively assessed	Not considered	Unavailable to authors of this report	Qualitatively assessed	Qualitatively assessed	Qualitatively assessed	Not considered	Qualitatively assessed
Indirect habitat loss	Qualitatively assessed	Quantitative and considered species sensitivities	Unavailable to authors of this report	Qualitatively assessed	Considered alongside disturbance	Quantitatively assessed	Quantitative and considered species sensitivities	Qualitatively assessed
Disturbance	Qualitatively assessed	Quantitative and considered species sensitivities	Unavailable to authors of this report	Qualitatively assessed	Quantitatively assessed for all species	Quantitatively assessed: interaction with proportional distribution	Quantitative and considered species sensitivities	Considered with disturbance

	Gwynt y Môr	**Lincs**	**Kentish Flats**	**West of Duddon Sands**	**Greater Gabbard**	**London Array**	**Race Bank**	**Thanet**
Barrier effects	Qualitatively assessed	Qualitatively assessed	Unavailable to authors of this report	Qualitatively assessed	Considered alongside disturbance	Qualitatively assessed	Qualitatively assessed	Qualitatively assessed
Collision risk	Qualitatively assessed	Quantitative for all species using Band et al model; birds at risk calculated by assuming constant density of birds in flight	Unavailable to authors of this report	Quantitative for two species; no details on how number of birds at risk was calculated	Quantitative for all species using Band et al model; birds at risk calculated by assuming constant density of birds in flight	Quantitatively assessed for key species using Band et al model; birds at risk calculated by assuming constant density of birds in flight	Quantitative for all species using Band et al model; birds at risk calculated by assuming constant density of birds in flight	Assessed quantitatively, but possibly erroneously

6. Recommended methods of data analysis and presentation

6.1. Baseline assessment

6.1.1. Boat and aerial survey frequencies

For almost all of the assessments reviewed, at least two years of data were collected. Boat surveys were generally conducted approximately monthly throughout the year and aerial surveys at least four times in winter. Aerial surveys were often carried out during key migration periods or in the summer months if key ornithological features associated with the windfarm area were thought to be most abundant outside the winter period.

In determining the duration of surveys, the primary consideration is the extent to which numbers might be expected to change between years. Factors such as inter-annual changes in food supply and breeding success can greatly influence the foraging locations of birds, and will thus have major impacts on numbers in some areas (Perrow *et al.* 2006). Thus, longer-term data collection would give a better indication of whether such changes in foraging patterns occur and would minimise the risk of failing to identify areas that are particularly important for birds, but only in some years. However, there are also major constraints in that for the consenting process to be commercially viable, the assessment process must be relatively rapid. We believe that the current protocol of surveying for a minimum of two years is valid.

In determining the frequency and timing of surveys, there are four factors to consider. Firstly, surveys need to capture seasonal peaks in abundance so that precautionary assessments of displacement and disturbance effects can be assessed. Secondly, surveys need to have been conducted sufficiently frequently to allow precise estimates of mean numbers (see Figure 6.1.1.1), as this is required for collision risk modelling. Thirdly, there is a need to elucidate seasonal patterns of use. Lastly, surveys should have spanned a sufficient period of the year to ensure that unbiased estimates of mean numbers can be calculated. In general there is a trade-off between the first consideration and the last: concentrating surveys at key times of year when birds are expected to be most abundant will make it more likely that temporary peaks are identified, but will also make it more difficult to calculate unbiased means. We recommend the following therefore:

(a) For the purposes of collision risk modelling, both boat and aerial surveys should be conducted throughout the year, irrespective of whether key features are most abundant at key times of year. This is necessary to ensure that mean densities can be correctly calculated and to determine whether any features thought not to be key, are indeed present.

(b) As a guide, we recommend that 12 boat surveys and eight aerial surveys should be conducted within the year. The extent to which allows a precise estimate of mean numbers should be tested using the approach explained in Figure 6.1.1.1 and the results used to determine whether further surveys are required.

(c) Although surveys should be conducted throughout the year, aerial surveys in particular should be conducted more frequently at times when peaks in abundance of key features are expected. Statistical methods are required to correct for this bias and are outlined in the section below.

6.1.2. Methods for determining densities and numbers

We recommend that all data collected by aerial surveys and boat-based surveys must be corrected to account for the area sampled relative to the study area. All aerial data and boat data collected during transect surveys must also be corrected to account for undetected birds using Distance software (Buckland *et al.* 2001; Thomas *et al.* 2006) or correction factors (Stone *et al.* 2005). Analyses should also capitalise on the new feature in more recent versions of Distance software (Thomas *et al.* 2006), which allow covariates (e.g. observer, sea state, bird behaviour, sun glare) to be incorporated into the estimation of detection functions. The AIC values (Akaike Information Criterion) given in Distance software outputs should be used to determine whether incorporation of these covariates is advantageous. If the species in question is not sufficiently abundant to permit Distance analysis (i.e. less than 30 records), then correction factors published in Stone *et al.* (1995) should be applied.

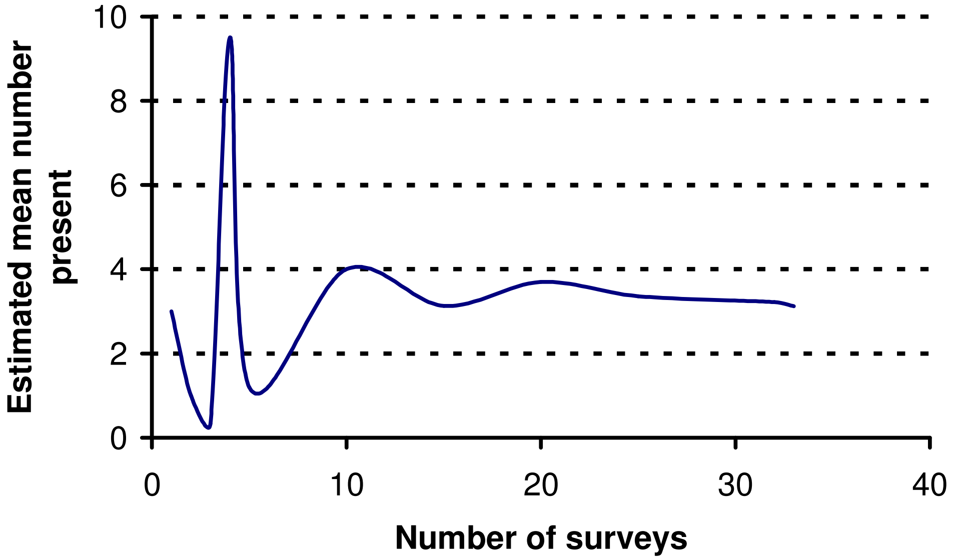

Figure 6.1.1.1 Estimated mean count as a function of the number of surveys. Data on divers within Lincs offshore from 33 boat-based surveys were used. We randomly removed one of the survey counts and recalculated the mean, thus simulating the effects of conducting fewer surveys. The figure shows that more precise estimates of the mean are obtained with more surveys. After 20 surveys there is little change in the estimated number present. Data source: RES (2007).

Snapshots are used to calculate the number of birds in flight, as line transects provide an unsuitable means of determining the density of moving birds (Buckland *et al.* 2001). However, it is still possible that the probability of detecting birds in flight may decline with distance from the observer. However, where tested (e.g. Banks *et al.* 2005; 2006), it appears that attempting to correct for undetected birds using snapshot count data using Distance software, leads to large over-estimates of the number likely to be present. This is most likely to be because most birds in flight are either those that have flushed due to the presence of the ship or those that are attracted to the ship. Irrespective of detection, there would therefore be a greater concentration of flying birds close to the ship. When applying Distance correction techniques, an implicit assumption of the method is that the density of objects does not change with distance from the observer (Buckland *et al.* 2001). Since this assumption is seriously violated, we recommend that Distance should not be used to estimate the density of birds in flight. Instead we recommend that raw counts be used. Frequency of snapshot counts should be adjusted according to changes in the ship's speed (see survey method recommendations).

Because count data are usually over-dispersed and zero inflated - i.e. highly variable, with occasional high counts (see Figure 6.1.2.1) a simple correction based on dividing the count by the proportion surveyed is problematic if only a small proportion of the total survey area is sampled. When transects are spaced relatively close together, as is recommended by Camphuysen *et al.* (2003), the proportion of area surveyed is likely to be adequate to allow reasonable estimates of overall numbers within the study area. However, the Round 3 development zones are considerably larger than those of Rounds 1 and 2. As such, it may be problematic to ensure that a sufficiently large proportion of the areas are sampled to ensure that seabird hotspots are identified. Although the species present in Round 3 areas may be dispersed in such a way that count data are less over-dispersed and zero-inflated than those from Rounds 1 and 2, this is still a concern. At present there is uncertainty with regards to the extent to which transect spacing affects estimates of abundance. It is likely that the construction of habitat-association models (e.g. Skov and Prins 2001) or improved methods of spatial-kriging could provide improved estimates, but this requires testing. We strongly recommend that further research be undertaken to explore these issues.

When calculating mean abundances across the year from aerial and boat data, it is also necessary to account for biases in the timing of surveys, particularly where surveys were conducted predominantly during periods of low abundance. For example, if a disproportionate number of surveys were conducted in a three month period in winter, it is essential to calculate the mean density across the year by calculating mean densities in each season and then averaging across seasons rather than just dividing the cumulative totals by the number of surveys.

One issue that has never been adequately addressed by baseline assessments for offshore windfarms is the fact that diving birds spend a proportion of their time underwater and are therefore likely to be underestimated by aerial surveys. This is a major issue for species such as diver and scoter, which can flush a considerable distance ahead of boats, and for which abundance estimates are thus predominantly derived from aerial surveys. This emphasises the need to have observers onboard boats scanning ahead for birds that flush (see survey method recommendations). However it also highlights the need for further research to resolve what proportion of time, these species spend under water. Once this has been resolved, appropriate correction factors could be applied. This could be a subject for further study by COWRIE.

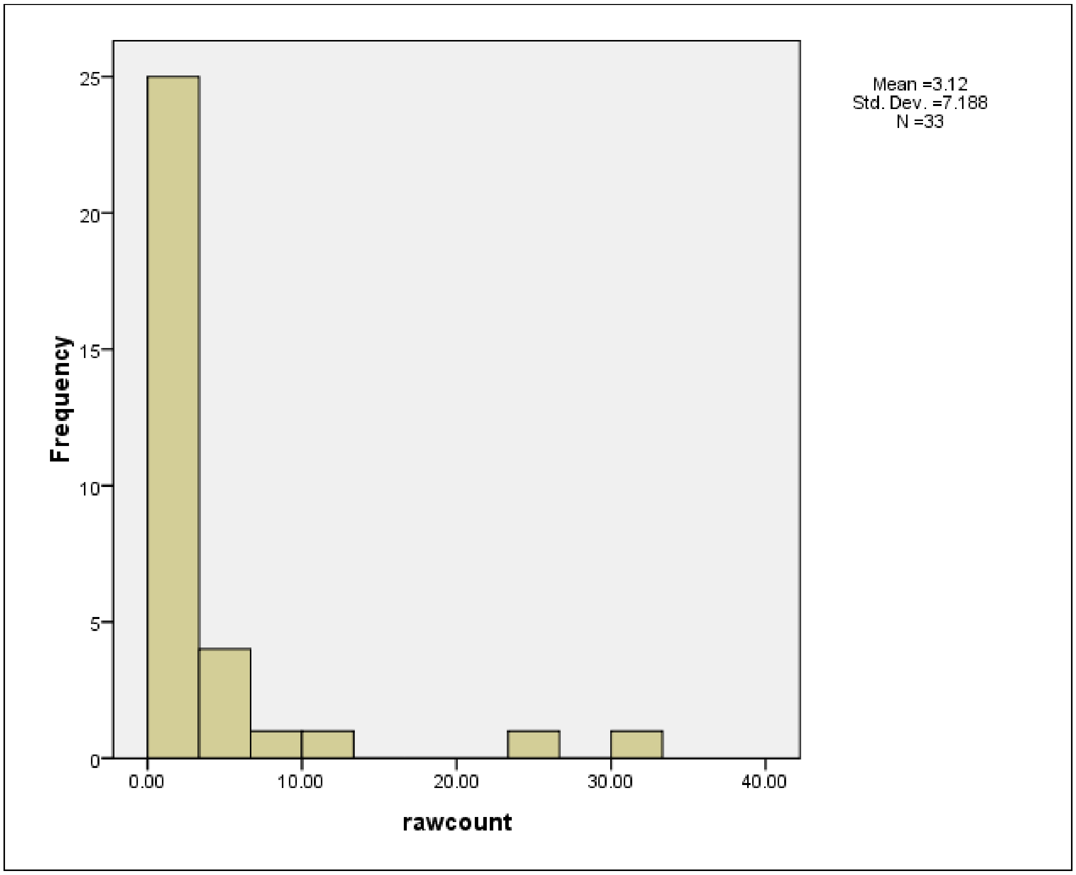

Figure 6.1.2.1. Frequency distribution of divers recorded within the Lincs offshore windfarm area by 33 boat-based surveys. During a large number of surveys, no divers were recorded within the area, whereas at other times, high numbers were recorded. Source: RES (2007).

When deriving totals for individual species, there is usually a problem in that many individuals recorded, particularly by aerial survey, are unidentified and assigned to more generic taxon instead. To circumvent this problem, we recommend that the relative abundance of each of the species comprising the taxon is calculated from positively identified individuals. Individuals of the generic taxon can then be randomly assigned a species identity using the ratio of relative abundances to determine the total number assigned to each species. If the relative abundances of the species comprising the unidentified taxon differ between seasons, than this process should be performed separately for each survey.

We also recommend that all raw data collected as part of boat-based and aerial surveys should be made available for meta analyses or inclusion in studies designed to improve methodology. This could be achieved by appending raw data to Environmental Statements or submitting it to a central database.

6.2. Impact assessment

6.2.1. General approach

Currently the approach used to assess the significance of impacts is based on the method developed and recommended by the BWEA and SNH (Percival *et al.* 1999). This approach is based on the Environmental Assessment Regulations 1999 and Institute of Environmental Assessment guidelines (IEA 1995). The method entails using a "matrix approach" whereby the sensitivity of species is cross-tabulated with the magnitude of impacts to determine the overall significance of an impact.

The approach differs somewhat from that presented in the draft IEEM guidelines for EIA in the marine and coastal environment (IEEM in press). These guidelines point to the legislative and policy origins of the need to quantify the significance of impacts, stressing the need to compare impacts against a defined baseline, rather than a wider timeframe or spatial consideration. The guidelines define an ecologically significant impact as an impact that has a negative, or positive, effect on the integrity of a site or ecosystem and/or the conservation objectives for habitats or species populations within a given geographical area (for example the relevant SPA populations). A further stage involves considering the likelihood that a change/activity will occur and also the degree of confidence in the assessment of the impact. Often, this confidence level is ascertained through expert judgement rather than frequency data. The guidelines also refer to several other broad principals. Firstly, it is stressed that the process of the EcIA should be iterative and responsive to increasing knowledge as the project evolves. The guidelines also suggest that the EcIA process can be greatly improved by early consultation with the statutory nature organisations (SNCOs) and the voluntary sector (NGOs).

We do not view the two approaches as incompatible. The IEEM guidelines refer to broad principals for determining whether impacts are significant, but do not spell-out specifically how significance should be *quantified*, instead stating that "expert judgement" should be used to assess the *likelihood* of a significant impact occurring. The SNH / BWEA approach attempts to *quantify* the significance of the impact, but makes no specific reference to *likelihood.* We feel it is important to retain elements of both sets of guidelines. The IEEM guidelines should be adhered to with respect to consulting widely and ensuring the assessment is iterative and responsive. Moreover, we concur with the use of expert judgement to interpret the outputs of the matrix approach, assess their likelihood and place the outputs in context. However, the results of section 5 of this report suggest that, to-date, the quality and compatibility of EIAs for windfarms has been severely constrained by an absence of prescriptive guidelines for carrying-out the assessment process. This lack of compatibility has made it very difficult to objectively assess individual impacts and nearly impossible to accurately quantify cumulative impacts. Consequently, we recommend a refined matrix-approach, which is more compatible than with IEEM guidance insofar as means of using expert judgement to interpret the outputs of the matrix are flagged-up more explicitly.

Thus, we recommend that the magnitude of impacts are assessed in the same way as suggested by Percival *et al.* (1999). As before, this should be cross-tabulated with sensitivity to determine the significance of the impact. However, we propose three modifications. Firstly, the likelihood of a significant impact should also be assessed using expert judgement, as proposed in the IEEM guidelines (IEEM in press). In particular, the concept of risk should be considered. Secondly, the results of the matrix analyses should not be considered as the "be all and end all" of impact assessment, put should be interpreted using expert judgement and in an iterative and responsive manner. However, we still strongly condone that where, possible, impact assessment should remain quantitative to and follow prescriptive guidelines, as this will help ensure compatibility between assessments and help to flag-up the severity of impacts. The results of the matrix analysis should only be over-ridden by expert judgement when there is a clear and justifiable reason for doing so. Lastly, we propose that for each individual impact, the sensitivity should also be assessed taking into account how susceptible species are to the particular impact in question. For example, when considering displacement impacts, species sensitivities should take into account how flexible the species is in its habitat use or for disturbance impacts, species sensitivities should take account of how susceptible the species in question is to disturbance (see Garthe and Hüppop 2004 for details). The precise definitions associated with each impact specific category and the ways in which these sensitivities are combined with non-impact specific sensitivities (i.e. those assigned using guidelines provided by Percival *et al.* 1999) to produce overall sensitivities are indicated in the sections dealing with each individual impact.

6.2.2. Disturbance

We recommend that the best way to quantify the potential magnitude of disturbance would be to determine peak densities within the windfarm footprint and buffer area and then to assume that, as a worse-case scenario, all birds are displaced. The magnitude of the impact can then be determined by quantifying the proportion of the regional, national or international populations hosted by the windfarm footprint and buffer zone. It is thus also important to establish the size of the buffer zone. To date, different assessments have adopted different sizes of buffers, ranging from 800 m from the periphery of the windfarm area to as far as four km. The choice of larger buffer areas is largely a result of recent post-construction at Horns Rev in Denmark indicating that Common Scoters and Auks show increased avoidance of areas up to four km from the boundary of the windfarm (Petersen *et al.* 2004; Petersen 2005; Drewitt and Langston 2006). We therefore suggest that, in the absence of more detailed research on the impacts of disturbance on the species in question, a four km buffer is used.

Species react differently to the ship and helicopter traffic that occurs during the construction and maintenance of windfarms. Such behaviour might also give an indication of the behaviour of birds towards disturbances generally. To incorporate species-specific behavioural responses, we recommend that indications of sensitivity suggested by Garthe and Hüppop (2004), Petersen *et al.* (2004) and Petersen and Fox (2007) are applied to each species (Table 6.2.2.1), and then cross-tabulated with non impact-specific species sensitivity to derive an overall sensitivity score (Table 6.2.2.2).

Table 6.2.2.1 Sensitivities of individual species to disturbance (see Garthe and Hüppop 2004), Peterson *et al.* (2004) and Petersen and Fox (2007) for details.

Sensitivity to disturbance	Species
VERY HIGH	Scoters, Divers
HIGH	Cormorant, Long-tailed Duck
MEDIUM	Eider, Grebes, Razorbill, Guillemot
LOW	Terns, most Gulls, Puffin, Gannet
VERY LOW	Little Gull, Skuas, Fulmar

Table 6.2.2.2 Matrix to determine overall sensitivities of ornithological features to disturbance.

Non impact-specific species sensitivity	**Sensitivity to disturbance**				
	VERY HIGH	**HIGH**	**MEDIUM**	**LOW**	**VERY LOW**
VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	MEDIUM	LOW
HIGH	VERY HIGH	HIGH	HIGH	MEDIUM	LOW
MEDIUM	VERY HIGH	HIGH	MEDIUM	LOW	LOW
LOW	HIGH	MEDIUM	LOW	LOW	VERY LOW
VERY LOW	MEDIUM	LOW	LOW	VERY LOW	VERY LOW

6.2.3. Direct and indirect habitat loss

As with disturbance, we recommend that the best way to quantify the potential magnitude of disturbance would be to determine peak densities within the windfarm footprint and buffer area and then to assume that, as a worse-case scenario, all birds are displaced. Again, the magnitude of the impact can then be determined by quantifying the proportion of the regional, national or international populations hosted by the windfarm footprint and buffer zone. We therefore suggest that, in the absence of more detailed research on displacement of the species in question, a four km buffer is used.

Displacement will affect different species in different ways, and will be largely dependent upon the availability of suitable feeding habitat in the areas to which they are displaced. Thus species with very specific habitat requirements are likely to be more vulnerable to the effects of displacement than habitat generalists. Habitats at sea are often defined by hydrographic characteristics such as water masses and fronts. We recommend therefore, that the habitat flexibility score devised by Garthe and Hüppop (2004) and based on data in Garthe (1997) and Skov and Prins (2001) be used is applied to each species (Table 6.2.3.1), and then cross-tabulated with non impact-specific species sensitivity to derive an overall sensitivity score (Table 6.2.3.2).

Table 6.2.3.1 Sensitivities of individual species due to flexibility in habitat use (see Garthe and Hüppop 2004) for details.

Sensitivity due to habitat flexibility	**Species**
VERY HIGH	Red-necked Grebe
HIGH	Divers, Scoters, Cormorant, Great-crested Grebe
MEDIUM	Eider, Common Tern, Arctic Tern, Little Gull
LOW	Sandwich Tern, Great Black-backed Gull, Auks, Great Skua, Black-headed Gull, Kittiwake
NEGLIGIBLE	Gannet, Lesser Black-backed Gull, Herring Gull, Fulmar

Table 6.2.3.2 Matrix to determine overall sensitivities of ornithological features to habitat loss.

Non impact-specific species sensitivity	Sensitivity to flexibility in habitat use				
	VERY HIGH	HIGH	MEDIUM	LOW	VERY LOW
VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	MEDIUM	LOW
HIGH	VERY HIGH	HIGH	HIGH	MEDIUM	LOW
MEDIUM	VERY HIGH	HIGH	MEDIUM	LOW	LOW
LOW	HIGH	MEDIUM	LOW	LOW	VERY LOW
VERY LOW	MEDIUM	LOW	LOW	VERY LOW	VERY LOW

6.2.4. Barrier effects

Barrier effects are the most complex to quantify and to date, all impact assessments of barrier effects have been qualitative. Barrier effects occur because windfarms may disrupt the flight-lines of birds imposing an increase in the energetic costs of daily movements and migration (Tulp *et al.* 1999, Pettersson and Stalin 2003). There is an urgent need for more detailed research to assess the impacts such barrier-effects have on species survival and populations sizes. Until the results of such research become available, any assessment of barrier-effects will be rather subjective. However, as an approximate guide, we suggest that a peak snapshot of the number of birds flying through the site (i.e. below 150 m) at any one time be used as a guide. The number of birds at any given time flying though the site should be determined by assessing the peak total derived from either aerial or boat-based surveys, multiplied by the proportion in-flight below 150 m as determined by either aerial or boat survey. Where large migration movements through the site are expected, the results of radar studies and migration watches should also be added to this total. To translate cumulative totals collected as part of radar studies and migration watches, to “snapshot” densities at any given time, it will be necessary to account for both the area covered by these surveys relative to the total study area, the proportion of time survey and the time taken for birds to move through the area surveyed. If the latter cannot be estimated directly, we propose that flight speeds as published in Campbell and Lack (1985) are used. This conversion process is essentially the inverse of that which needs to be done to calculate the number of birds at risk for collision risk modelling (birds per unit time are translated to snapshot densities rather than the other way round). Further details of the types of approaches that could be used to do this are thus given in Percival *et al.* (1999) and described in more detail in the next section. The magnitude of the impact due to this component can then be assessed using Table 6.2.4.1.

Table 6.2.4.1 Criteria used to determine one of the components of the magnitude of impact due to barrier effects.

Magnitude of impact	**Definition**
VERY HIGH	(i) windfarm is located between breeding site and key foraging area of a species flying through the site in nationally or internationally important numbers and/or (ii) is located close to key stopover, breeding or wintering site of species flying through the site in internationally important numbers and/or (iii) is located along the migration route of a species flying through the site in internationally important numbers.
HIGH	(i) windfarm is located close to key stopover, breeding or wintering site of species flying through the site in nationally important numbers and/or (ii) is located along the migration route of a species flying at through the site in nationally important numbers.
MEDIUM	(i) windfarm is located between breeding site and key foraging area if a species flying through the site in regionally important numbers ii) is located close to key stopover, breeding or wintering site of a species flying through the site in regionally important numbers (ii) is located along the migration route of a species flying through the site in regionally important numbers.
LOW	(i) windfarm is located between breeding site and key foraging area of any other species and/or (ii) is located close to a key stopover, breeding or wintering site of any other species and/or (iii) likely to be located on a migration route of any other species
VERY LOW	None of above

The impact on survival of a given barrier and concomitant deviation in flight will differ between species. Large, bulky species with a small wing areas are likely (i.e. those which have high wing-loadings) will be more adversely affected than those that don't. Using body mass and wing-length ratios presented in Robinson *et al.* (2005) we have devised sensitivities for different species (Table 6.2.4.2), and then cross-tabulated with non impact-specific species sensitivity to derive an overall sensitivity score (Table 6.2.4.3). Although based on real data, the assignment of species to particular categories is rather subjective and we would welcome any refinements that could be made as a result of actual quantitative studies of bird energetics.

Table 6.2.4.3 Sensitivities of individual species to barrier-effects

Sensitivity to barrier effects	**Species**
VERY HIGH	Black-throated Diver
HIGH	Red-throated Diver, Cormorant, Geese, Auks
MEDIUM	Ducks
LOW	Fulmar, Skuas, Gulls
VERY LOW	Gannet, Terns, Passerines

Table 6.2.4.4 Matrix to determine overall sensitivities of ornithological features to barrier effects.

Non impact-specific species sensitivity	**Sensitivity to barrier effects due to wing-loading**				
	VERY HIGH	**HIGH**	**MEDIUM**	**LOW**	**VERY LOW**
VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	MEDIUM	LOW
HIGH	VERY HIGH	VERY HIGH	HIGH	MEDIUM	LOW
MEDIUM	VERY HIGH	HIGH	MEDIUM	LOW	LOW
LOW	HIGH	MEDIUM	LOW	LOW	VERY LOW
VERY LOW	MEDIUM	LOW	LOW	VERY LOW	VERY LOW

6.2.5. Collision risk

We recommend that the Band *et al.* (2000) model be used to assess the impacts of collision for all ornithological features. Throughout the collision risk assessment process, we concur with a precautionary approach whereby (a) the number, dimensions and layout of turbines that would be most damaging is assessed, (b) birds are assumed to be moving through the site continuously and (c) densities are maintained, irrespective of any collisions that might deplete the population. One of the difficulties in applying the Band *et al.* (2000) model in the offshore context is calculating the number of birds at risk. We recommend that this is calculated as follows:

$$B_R = \frac{\pi \times r^2}{w \times h} \times T_N \times B_F$$

Where B_R is the number of birds at risk, r is the radius of the area swept by the turbine (i.e. the turbine blade length), w is the width of the windfarm (perpendicular to the direction of flight), h is the height of the height band that corresponds most closely with the area swept by the turbine blades (maximum height – minimum height) and T_N is the number of wind turbines. B_F is a snapshot measure of the mean number of birds in flight in the windfarm and within the height zone that corresponds most closely with the area swept by the turbine blades.

As the width of the windfarm perpendicular to the direction of flight will vary for different flight directions, we recommend that, as a precautionary measure, the longest distance from one side of the windfarm to the other is selected. The snapshot measure of the mean number of birds flying within the flight zone that corresponds most closely with the area swept by the turbine blades should be calculated by determining the mean density of all birds (sitting in the water and flying) using either aerial survey or boat-based survey data (whichever gives a higher value), multiplying this figure by the proportion of birds in flight (derived from aerial survey) and multiplying the resulting figure by the proportion of all flying birds within the height zone that corresponds most closely with the area swept by the turbine blades. Birds in flight should be determined from aerial survey data, as many of the birds recording during snapshot point counts will be flushed by or attracted to the boat. We also recommend that the length of longest diagonal across the windfarm be entered into the model to allow calculation of risk exposure time, as this is the most precautionary approach.

Should information on flight and wind direction be available, than the modelling process could be refined by incorporating this information to calculate more realistic mean exposure times and angles of approach to the turbine blades. An additional refinement would be to adjust the profile of the rotor blade embedded in the original model to one more typical of offshore windfarms.

One of the primary determinants of model's estimates of collision mortality is the choice of avoidance rate (Chamberlain *et al.* 2006). In reality very little information exists on actual avoidance rates. We thus flag-up the urgent need for research investigating actual collisions with existing windfarms. Previous assessments have used precautionary avoidance rates that vary from 95-99%. Moreover, it is known that avoidance rates can vary with season, age and status of the bird, as well as with weather (e.g. Everaert and Stienen 2006). It is also important to note that there are different ways in which birds take avoiding action. Some species will by-pass the windfarm altogether, whereas others will only take avoiding action very close to the turbine. Often, species such as divers, that would be most susceptible to suffering collision should they approach a turbine, are far more likely to avoid the wind farm altogether. The reverse is also true: species that do not avoid windfarms, such as terns, are most manoeuvrable and least likely to get caught by the blades. Published avoidance rates thus require a degree of judgemental interpretation, as they may refer to only one or other of the forms of avoidance (i.e. near-turbine avoidance of the blades, or avoidance of the wind farm area altogether) or may refer to both combined. Until more information becomes available, we propose that a combination of published estimates of avoidance rates (e.g. Winkelman 1992; Painter *et al.* 1999; Chamberlain *et al.* 2006; Everaert and Stienen 2006) is used for species for which sufficient published information exists, and precautionary avoidance rates dictated by flight manoeuvrability and the extent to which birds are likely to avoid the windfarm altogether (see Garthe and Huppop 2004; Petersen *et al.* 2004 and Petersen and Fox 2007) are used for other species (Table 6.2.5.1).

Table 6.2.5.1 Choice of lower avoidance rates for different species and taxon, based on published avoidance rates, flight manoeuvrability. Note that Round 3 areas are likely to be considerably further offshore, where different factors may influence the risk of collisions, and these need to be assessed further.

Avoidance rate	Species
99.0%	Terns, Divers, Cormorant, Ducks, Geese, Grebes, Puffin
99.5%	Auks, Gulls, Gannet
99.9%	Fulmar, Shearwaters

We recommend the mortality over one year be assessed against regional, national and international populations to determine the magnitude of the impact. As mortality due to collisions affects species with high annual survival rates more than species with low survival rates (Garthe and Hüppop 2004), incorporating information on adult survival rates into analysis will allow a more realistic assessment of the significance of impacts on baseline populations. We thus propose that species sensitivities to collision should be partially dictated by adult survival rates. We recommend that the scoring system presented in Garthe and Hüppop (2004) be applied (see Table 6.2.5.2).

Table 6.2.5.2 Definitions of terms relating to the sensitivities due to adult survival. Annual survival rates are given in Garthe and Hüppop (2004).

Sensitivity due population recovery time	Definition
VERY HIGH	Annual survival greater than 0.90
HIGH	Annual survival 0.85-0.90
MEDIUM	Annual survival 0.80-0.85
LOW	Annual survival 0.75-0.80
VERY LOW	Annual survival less than 0.75

Overall species sensitivities can then be determined by cross-tabulating values presented in Table 6.2.5.2. with those presented in Table 6.2.1.2 to determine overall sensitivities (Table 6.2.5.2). The significance of the impact can then be determined by cross-tabulating the magnitude with the sensitivity in the standard way.

Table 6.2.5.3. Matrix to determine overall sensitivities of ornithological features to collision.

Non impact-specific species sensitivity	**Sensitivity to collision**				
	VERY HIGH	**HIGH**	**MEDIUM**	**LOW**	**VERY LOW**
VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	HIGH	MEDIUM
HIGH	VERY HIGH	HIGH	HIGH	HIGH	MEDIUM
MEDIUM	VERY HIGH	HIGH	MEDIUM	LOW	VERY LOW
LOW	HIGH	MEDIUM	LOW	LOW	VERY LOW
VERY LOW	MEDIUM	LOW	VERY LOW	VERY LOW	VERY LOW

6.3. Summary guidelines

Survey duration and frequency: surveys should be conducted over a minimum of two years. Boat-based surveys should be carried out monthly throughout the year and aerial surveys at least eight times in the year. Mean numbers should be plotted as a function of the number of surveys conducted to check the precision of estimates.

Calculating bird numbers and densities: all data should be corrected to account for the area surveyed in relation to the study area. All data collected by aerial survey and transect data collected by boat-based surveys should be corrected to account for undetected birds. Snapshot counts should not be corrected to account for undetected individuals, but birds beyond 300 m (200 m for auks) should be ignored. Unidentified birds should be accounted for by assigning them as positively identified species, based on the relative abundances of the species they could be. Peak densities should be used to assess disturbance and habitat loss impacts and mean densities (corrected for biases in the timing of surveys) should be used for collision risk assessment.

General approach to assessing the significance of impacts: we propose the use of a slightly modified version of the standard "matrix-approach" recommended by SNH and the BWEA in which species sensitivities to particular impacts are also considered. We also recommend that this approach be used a guide, but that the results should be interpreted using expert judgement using the approach recommended by the IEEM (IEEM in press).

Impacts due to disturbance: we recommend that, in the absence of better information, the magnitude of impacts should be determined by assuming all birds are displaced from the windfarm and a four km buffer zone and assessing the size of this population against relevant regional, national and international populations. We propose that published information of species' sensitivity to boat and helicopter traffic should be incorporated into the measure of species sensitivity to disturbance.

Impacts due to habitat loss: we recommend that, in the absence of better information, the magnitude of impacts should be determined by assuming all birds are displaced from the windfarm and a four km buffer zone and assessing the size of this population against relevant regional, national and international populations. We propose that published information of the flexibility of species' habitat use be incorporated into the measure of species sensitivity to displacement.

Impacts due to barrier effects: we recommend that the magnitude of impacts should be determined using by considering a combination of the number of birds likely to be flying through the windfarm and the extent to which the windfarm is likely to act as a barrier. We propose criteria to assign scores using these criteria. We propose that information on wing loadings should be incorporated into the measure of species sensitivity to barrier effects. We propose criteria sensitivity scores for different taxon.

Impacts due to collision: we propose a standard method for calculating the number of birds at risk in an offshore context. We also suggest some refinements that could be made to the standard collision risk model. We propose that the choice of avoidance rate be determined by published information on flight manoeuvrability and propose avoidance rates varying from 99-99.9% for different taxon. We recommend that annual collision rates are assessed against regional, national and international populations to determine the magnitude of collision impacts. We also recommend that published information on adult survival rates be incorporated into the measure of species sensitivity to collision.

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Appendix 1 – Checklist of standard information that could be reported for surveys

Note that this list comprises a standard checklist that could usefully be reported in an appendix to environmental statements (or accompanying technical reports) in order that the survey and analytical methodology can be checked by anyone reading the report. It does not cover all variables that should be recorded during surveys, for which surveyors should refer to Camphuysen *et al*. (2004).

BOAT SURVEYS – copy from Thanet

(1) Date and time – note for each transect

(a) date; (b) time at start and end of each transect.

(2) Observers – note for each transect

(a) ID code; (b) summary of experience; (c) roles for each transect – e.g. migration watcher / standard watcher; scanning ahead for divers and scoter.

(3) Ship

(a) type; (b) length; (c) height of observation platforms; (c) location of observation platforms.

(4) Viewing conditions – note for each transect

(a) wind speed and direction; (b) sea state; (c) temperature; (d) precipitation (e.g. light, heavy); (d) sun glare; (e) visibility (estimate distance) f) swell height

(5) BIRD INFORMATION – NOTE FOR EACH OBSERVATION

(a) time; (b) species; (c) number; (d) age/sex/plumage; (e) in flight (naturally)/in flight (flushed)/on sea; (f) direction of flight; (g) Distance from transect line when first detected (Bands A,B,C,D or E); (h) height; (i) behaviour;

AERIAL SURVEYS – copy from JNCC tender

(1) Date and time – note for each transect

(a) date; (b) time at start and end of each transect.

(2) Observers – note for each survey

(a) ID code; (b) summary of experience; (c) seat.

(3) Plane – note for each survey

(a) type.

(4) Viewing conditions – note for each transect

(a) approximate wind speed and direction; (b) sea state; (c) precipitation (e.g. light, heavy); (d) sun glare (each observer note separately); (e) visibility (estimate distance); (f) height.

(5) BIRD INFORMATION – NOTE FOR EACH OBSERVATION

(a) time; (b) species; (c) number; (d) in flight (naturally)/in flight (flushed)/on sea; (e) Distance from transect when first detected (Bands A,B,C,D or E).

Appendix 2 – Recalculation of collision risk for Thanet offshore windfarm

Raw count of number of red-throated divers present:

Mean = (1 + 3 + 24 +23 + 0 + 5 + 3 + 15) / 8 = 6.375

Likely actual count (corrected to account for undetected birds and proportion of area surveyed):

6.375 x 1.3[*] x 5[§] = 41.44

Number of birds at risk: 0.31[1]

assumes 80 turbines with 3 chords, 150 m rotor diameter, 6 km across wind farm [§§], c. 9% flying and 4.5% within "at risk" height (e.g. RPS 2005), bird dimensions published by Robinson *et al.* (2005) and flight speeds published in Campbell and Lack (1985). The method for calculating the number of birds at risk follows guidelines presented in section 6.2.5.

Annual mortality assuming 0% avoidance rate: c. 1,200 per year

Annual mortality assuming 95% avoidance rate: c. 60 birds per year

Annual mortality assuming 99% avoidance rare: c. 12 birds per year

Jensen (2006) calculate mortality of 1 bird per year assuming 0% avoidance, indicating a considerable discrepancy in the method used to calculate the number of birds at risk

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[*] Correction factor to account for undetected birds derived from Stone *et al.* (2005)

[§] Data only included if within Bands A – C (0 –200m from ship). Since transects were spaced 1km apart, suggesting 1/5 of area surveyed.

[§§] Turbine statistics from Thanet Offshore wind farm website (http://www.warwickenergy.com/thanet.htm)

Annex 1 - High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols

Executive Summary

The aim of this report was to review trials of high definition imagery technology in the monitoring and assessment of bird numbers at offshore sites, and produce recommendations and protocols on its use alongside existing survey methodology, notably in light of its possible use in surveying round 3 wind farm development zones. The specific objectives are therefore as follows:

1. To summarise the existing high definition imagery studies that have taken place, assessing what parameters were used in each.
2. To undertake a workshop bringing together key users, developers and regulators of the industry, with a view to setting protocols and standards on the use of high definition imagery technology for seabird and mammal surveys.

Information on the trials of high definition imagery technology for survey were obtained from the following institutions and organisations: HiDef Aerial Surveying Ltd (hereafter also HiDef), the Danish National Environment Research Institute (NERI), APEM Ltd, the University of St. Andrews, and the RSK Group plc. Information was collated in the form of reports and summaries on particular surveys, and was split into technical categories of digital video and digital still photography for further summarising.

At the workshop, consensus was agreed that protocols depended on the aim of the particular survey. In particular, species may vary in their detectability and thus parameters required. Furthermore, the level at which the survey is conducted will influence subsequent parameters. Levels of survey that are likely to be required are

1. <u>Characterisation</u> to investigate what species assemblages are present, allowing population estimation and distribution, e.g. of a Round 3 development zone prior to collection of project-specific environmental baselines:
2. <u>Baseline Environmental Impact Assessment (EIA)</u> to assess, understand, and take account of a wind farm's likely environmental impacts, before a development is given consent to proceed.
3. <u>Before and After / Control and Impact Analysis (BACI)</u> for a more detailed assessment and monitoring before and after a development requiring specific technical and survey design parameters.
4. <u>Purposes of meeting Appropriate Assessment (AA)</u> as part of the EIA process, to obtain detailed distribution data and accurate species identification to determine loss of habitat in marine Special Protection Areas (SPAs), or likely effect on onshore SPAs.
5. <u>Common Standards Monitoring,</u> a more detailed monitoring and a simple assessment for protected sites requiring accurate identification of species.

Parameters for which protocols could be developed include technical parameters, parameters on survey design and parameters on data analysis. The following is a summary of baseline protocols:

Technical

a. A current minimum flight height should be set as 450 m to avoid disturbance to birds, but this value could be lowered where increased resolution and species identification is required, and no disturbance is noted to species being surveyed.
b. The level of identification and observer error must be comparable between visual aerial surveys and high definition imagery to enable reliable comparisons, and standardised JNCC taxa groupings should be adhered to, including JNCC taxa groupings where species cannot be reliably determined.
c. A minimum resolution of 5 cm is suggested for all survey levels, with further increases encouraged so long as other minimum parameters are not jeopardised. However, if the level of species identification required by surveys (see above) can be shown to be made accurately at a resolution coarser than 5 cm, then such resolutions should also be permitted. A lower limit of transect width is recommended as 200 m, and should allow the identification of the same species or species groupings used as standard by JNCC.
d. Colour images should be used in all surveys.
e. For video methods a minimum of 5 images (suggested range 5-10) of a bird spanning 0.5 s is necessary for reliable identification.
f. Exposure should be optimised for specific species if conducting species-specific surveys, such as darker birds or gulls, with an acceptable exposure chosen for general characterisation surveys that maximises the number of species groupings obtained.
g. Use of automation should be encouraged but with consideration of costs incurred. However, manual inspection can still give reliable identification at adequate costs and speed, and should remain the default protocol with full quality control, until there is appropriate evidence that a species can be detected more reliably and at increased speed and efficiency under automation.
h. A slower speed of travel of aircraft can result in clearer images and should be given consideration, for instance where species-specific surveys are concerned, but typical speeds of *ca*. 220 – 350 km.hr^{-1} (*ca.* 120-190 knots) are suitable for a baseline parameter range. Speed, however, will be a trade off between reducing travel time and image resolution appropriate for species identification.
i. Advances in technology should be trialled, explored and incorporated where they do not compromise the above criteria and provide improvements in species recognition, and increasing diurnal survey time.
j. Avoid surveying in low cloud or adverse weather conditions of Beaufort force 4 or above in order that birds are not missed and that they are correctly identified. However, undertaking surveys in higher wind speeds should be permissible but only if it can be demonstrated that birds are not missed and that species identification is not adversely affected in these conditions with the technology being used. Clearly with all survey techniques there will be a maximum limit on the wind speed where these technologies can be used, however this is yet to be determined.
k. Additional information on the sex and age of birds should be recorded where possible.

Survey Design and Analysis

Protocols on survey design depend on the objectives of the survey. In most cases, surveys are primarily undertaken in order to produce population estimates; a further aim may be to detect change, and this may be achieved either through a comparison of the population estimates (and their confidence limits) or by a statistical comparison of raw count data. Unless stated otherwise, the following recommendations assume that the surveys' main aim is to produce population estimates and that it is these estimates will be used for detecting change.

It should also be noted that the recommendations are strongly interlinked and should not considered in isolation. Thus the 'Synthesis on Guidelines for Survey Design' provided in section 4.3.2 should be read in conjunction with these recommendations.

a. The same survey methodology should be maintained between consecutive surveys if the survey has the same purpose as the previous one, or a before-after assessment is required. Different survey methodologies should only be used if statistical comparison can be made and there is no bias in survey estimates from either survey.

b. Pseudoreplication can be avoided through using the transect strip as the level of analysis.

c. Where raw data are used for comparison of numbers before and after wind farm construction, covariates should be used in analysis to increase the power of detecting change.

d. For BACI analyses (and the EIA surveys that often form their baseline) which use population estimates and confidence limits to detect change, there should be a general recommendation for being able to detect a certain level of change with a certain degree of accuracy. The power to detect change is not necessarily based on the percentage of the region covered and for larger survey regions, it is generally preferable to increase the number of samples (i.e. transect strips) rather than coverage *per se*. Detecting a halving or doubling of the population is suggested as a minimum benchmark for all surveys.

e. The number of transect strips used and their spacing are interconnected parameters that should reflect the level of precision required to meet the objectives of the study, whilst giving flexibility to contractors to design the survey around maximising efficiency and reducing costs. Following the recommendations for conventional surveys, a spacing of 2000 m and minimum of 20 transect lines is recommended as a starting point for designing digital surveys, provided this can be achieved in one survey flight.

However, the number of transect lines is of greater importance than spacing and, clearly, in certain circumstances it will not be possible to maintain a spacing of 2000 m and still survey the entire area in one flight or to maintain an acceptable number of transects. If the desired level of precision for the area surveyed can be achieved through strips separated by more than 2000 m, then such procedures should be taken. Likewise, for smaller regions, 20 transect lines may not be achievable unless spacing is reduced. However, provided that there is no risk of double counting or disturbing birds, this spacing could be lowered for high definition imagery surveys to meet the desired level of precision. We therefore suggest the spacing and number of transect strip parameters to be retained as flexible around the recommended minimum protocols, determined by survey practicalities, precision and survey objectives.

Decisions will ultimately also depend on costs. If image processing is costly relative to aircraft time then fly more flight lines and create a sub-sample within transect strips; if aircraft time is more costly, then sample wider spaced transect strips, whilst adhering to the desired level of precision.

Transect strips should be perpendicular to the coast or an environmental gradient to reduce heterogeneity of counts within strips.

f. Whenever possible, *the whole study area should to be covered in one single day*. Population estimates from different sub-areas surveyed on different occasions should not be summed together, even if the gaps between surveys are anything up to weeks apart, due to local bird movements and/or seasonal migration. If one day of effort does not give the recommended level of precision then conduct repeat surveys of the entire survey region over different days to allow the appropriate precision to be obtained, and better estimation of actual numbers, distributions, and peak and mean population estimates.

If covering the whole area in one day does not give adequate precision, and repeat surveys cannot be undertaken due to the availability of resources, then a less preferred option is to survey sections on *consecutive* days to meet the desired level of precision, assuming distributions are more likely to be similar. However, this option is primarily not recommended.

g. Two or more observers should assess images independently, but validation must also be carried out by an independent consultant or expert providing a minimum of 90% quality control. We also recommend producing a dissimilarity matrix of identification across species, to help assess the level of error surrounding identification of particular species and confusion between similar species pairs.

Further Provisos

a. Additional consideration should be given to the species being targeted and, where possible, an a priori knowledge of populations and distributions from previous surveys should be used. If the species has clumped distribution, then consider prioritising increasing the number of transect strips, or sub-sampling within each transect strip to meet the desired precision of the survey.
b. Adequate training should also be allowed for new observers processing images to achieve the required level of precision as specified in “Survey Design and Analysis d”.
c. Correction of time spent at the sea surface within video images is needed for surveying marine mammals, and caution should be placed in fully using high definition imagery for mammals and diving seabirds until more work is undertaken.