Guidance note

Scottish Natural Heritage
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Guidance on Methods for Monitoring Bird Populations at Onshore Wind Farms

January 2009

Background

1. The need for monitoring of birds at onshore wind farm sites, after they have been constructed is outlined in the 'Monitoring the impact of onshore windfarms on birds' guidance note. The purpose of this additional guidance is to offer more detailed advice on the design and methodology of such monitoring, so that results can deliver what they are intended to deliver, and that outcomes can be compared across wind farm developments. Inevitably monitoring may need to focus on species of conservation concern, but may also address impacts on other species where this is appropriate. This guidance deals exclusively with monitoring at on-shore wind farms. For the purposes of this guidance an on-shore wind farm also includes all the roads, infra-structure and other, ancillary developments that form part of the on-shore wind farm.

2. Monitoring is qualitatively different to surveillance: monitoring normally has a specific purpose and its outputs and outcomes will usually allow a comparison with some baseline condition, either of the site before the development was undertaken, or with a pre-determined reference (control) site.

3. Ideally, monitoring should be based on the BACI principle (Before-After-Control-Impact[1]), which will require knowledge of the pre-construction state, to provide a reference point for the state (and change in state) after the development has been constructed. Reference (or control) sites will be discussed in more detail later. However, there are considerable advantages to using such sites, though they may not always be appropriate, especially where suitable reference sites do not exist. Wind farm developers may want to consider the use of shared reference sites, especially where there are several development sites in a restricted geographical area, and where all of the developments share the same bird features of interest and the reference site(s) are as closely matched as possible in terms of habitat, topography and other variables. Shared reference sites may be appropriate when there are limited suitable areas, in regions where there may be multiple wind farm development sites. However, it is important to note that the statistical power to detect impacts may be reduced if shared reference sites are used. There is then a trade-off between practical considerations in finding suitable reference sites, and loss of statistical power when using shared reference (control) sites.

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[1] See McDonald, T.L., Erickson, W.P. & McDonald, L.L. (2000) Analysis of Count Data From Before-After Control-Impact Studies. *Journal of Agricultural, Biological and Environmental Statistics*. **5:** 262-279, for a description of the BACI approach and the approach to data analysis.

4. Where it is not possible to have pre-construction baseline studies, then a simpler Impact-Reference design may be appropriate where a wind farm area is compared with a suitable reference site. Alternatively, where the magnitude of any effect occurs along a distance gradient away from a wind farm, then an Impact – Gradient design may be suitable. The latter design may be particularly suitable for species with relatively small home range/territory sizes such as some passerines and breeding waders.

5. Monitoring methods must deliver results that can be used appropriately, both to understand impacts of wind farms in general, as well as delivering information on specific issues relevant to the wind farm in question. The format of the monitoring for any particular wind farm will depend in part on its size, as well as the issues raised by the initial environmental statement.

6. Clearly, the monitoring method chosen for any particular wind farm will relate to the major effects that have been identified for onshore wind farms. These include;

    a. Displacement and disturbance of breeding and/or non-breeding birds;
    b. Collision mortality (with turbines, buildings and overhead power-lines);
    c. The barrier effect to dispersing and/or migrating birds; and
    d. Habitat loss (direct) from the wind farm infrastructure, which includes the turbines themselves, access roads, buildings, quarries and underground cabling & drainage ditches.

7. Long-term habitat change will be picked up through other monitoring programmes, but as such change may have an adverse impact on birds if key habitats for birds change so they become unsuitable for bird use, then such monitoring will need to be integrated with bird monitoring to fulfil this need. Indirect habitat loss (e.g. through disturbance and displacement) would be quantified through direct observation of spatial use of habitats on site by relevant bird species. Note that long term habitat change may *confound* the attribution of species' population change to impacts arising from the wind farm, unless this can be controlled for (this may be where control or reference sites are particularly useful).

8. The guidance set out here is generic: it cannot deal with every situation or all circumstances. Consequently, monitoring will need to be developed as a specific programme for each wind farm development, where it is required. However, as far as possible appropriate standard methods should be applied to permit comparison across sites with similar issues.

9. Monitoring should be proportional to likely impacts, at least to a degree. This will depend in part on the size of the proposed wind farm, in terms of its area, turbine number and turbine size (larger wind farms will have larger impacts, in general), although some small or medium sized developments may have disproportionately large impacts, especially if there are particularly sensitive species affected.

10. The design of any monitoring programme should have regard to the level of statistical power[2] needed to detect agreed levels of change for those species and populations of interest. Monitoring programmes should be designed to detect change at agreed and acceptable significance level. It should also be noted though that on some sites where numbers of sensitive species are low,

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[2] A statistical power of 80% is generally regarded as being appropriate in such comparative studies and significance level of 95% is often regarded as being suitable. Note that the sampling effort required is a combination of statistical power and significance level adopted.

then the ability to detect change that can be attributed to the wind farm will be very difficult, and monitoring study designs will need to explicitly recognise this. Meta-analyses of many studies or studies that look across a number of wind farm sites can overcome such problems.

11. Other factors may also be important. Developments that may have an impact on designated sites, such as International/European sites (Special Protection Areas and Ramsar sites) or Sites of Special Scientific Interest (SSSI) – a domestic designation under the Wildlife & Countryside Act (1981), may need a robust monitoring programme that deals with the qualifying interest features, that may be proportionately more intensive than for similar, undesignated sites and the species they host. This will become apparent through the regulatory process leading up to the project's approval, and will generally feature in the response that SNH make to the development proposal.

12. In some cases, monitoring may be a required condition of a planning consent, though it is important to note that for International/European sites, monitoring cannot be proposed as a way for SNH to remove an objection for qualifying features (e.g. a particular bird species population present) where there is uncertainty over likely impact. SNH guidance on Natura 2000 interests discusses this in more detail.

13. It should also be recognised that approaches to monitoring of wind farms are changing, as knowledge and techniques become available from other sites. Developers should be prepared to modify monitoring approaches, where this is appropriate, bearing in mind consistency with earlier monitoring outputs. Adaptive approaches are common in long-term monitoring programmes (see Thompson & Seber, 1996).[3]

14. In particular, technical developments, such as use of remote sensing technology (e.g. infra-red cameras, thermal imaging, X-band radar or motion sensitive cameras), may improve knowledge of birds' behavioural responses to wind turbines, and improve estimates of collision likelihood. The uses of such equipment are beyond the scope of this guidance document, but for a recent review see Kunz *et al.* 2007[4].

How often: frequency of survey?

15. Wind farm impacts are likely to operate over a long time. For example, collision risk is likely to be sporadic and chance may mean that there will be significant periods of time when no casualties will be found, and especially when collision rates are lower than 1 bird per annum for many species, it may be some years before a casualty is recorded. For example a collision probability of 0.5 birds per annum, which is potentially significant for many bird populations, could mean that it may take 3-4 years before a collision victim is actually detected.

16. Furthermore, habitat effects, and lag effects resulting from chronic disturbance may result in change happening over periods of years rather than within one to two years of a development being built and commissioned. A

[3] Thompson S. K. & Seber G. A. F. (1996) Adaptive Sampling. Wiley-Interscience
[4] Kunz, T. H., E. B. Arnett. B. M. Cooper, W. P. Erickson, R. P. Larkin, T. Mabee, M. L. Morrison, M. D. Strickland, and J. M. Szewczak. 2007. Assessing impacts of wind energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife Management, 71: 2449-2486

recent review of wind farm impacts (Stewart *et al.* 2004[5]) suggests that some effects do only show up over time, though the association is statistical and the causal process involved is not clear.

17. Counter to this, habituation of birds to wind farms and wind farm infrastructure may mitigate initial impacts such that levels of displacement shown early on may be higher, but might decrease over time. Evidence from Blyth Harbour[6] [Percival 2001], suggests that levels of fatal collision of eider ducks with the coastal wind turbines have declined over the years, presumably as birds have either learnt to avoid the turbines, or have been displaced from areas nearby, use of which exposed them to risk of collision. Other possible reasons may also account for the observation, but the principle remains that bird responses to wind farms may operate over very long periods of time, and that monitoring needs to take this into account, as results from short term observational studies are unlikely to be representative. There is a need to distinguish between short- and long-term effects and monitoring needs to be designed accordingly in the light of the prevalent issues at a given site. Consideration of the species ecology is paramount in designing and interpreting the outcomes of monitoring

18. On this basis, it is recommended that monitoring takes place over at least 15 years, after the wind farm becomes operational, and that the periodicity of monitoring work should be structured according to the following outline timetable:

    a. It may be possible for studies that contribute to the environmental statement in support of the application to also act as a suitable 'Before' baseline. However, this may not always be appropriate, particularly if new impacts are identified, or if studies were undertaken a long time before consent is obtained, whereby changes may have occurred that could be erroneously attributed to the impact of the wind far. Where 'Before' studies are needed, then they could start once consent has been given, as there may be a time lag between issue of consent, and start of construction. Agreement with the developer for such an approach is needed as early as possible, e.g. in scoping so as not to delay construction of consented wind farms. This period *should* be used to enhance the data already available from the original environmental statement (ES). Longer periods of data from the pre-construction period will improve the power of the resulting statistical analyses. This also allows adaptation of the surveillance approach used for the ES to the monitoring approach require post consent.

    b. Ideally, monitoring should occur in years 1, 2, 3, 5, 10 and 15; <u>after</u> the wind farm becomes operational where major habitat change has not been part of the process, such as in upland wind farm construction. Where major habitat change has taken place, e.g. the clear felling of forest to accommodate wind farms, monitoring should take place at three-yearly intervals; i.e. years 3, 6, 9, 12 and 15 after commissioning. This will better address changes in bird communities as habitats change and evolve.

    c. Monitoring should also take place during construction, where these effects are likely to be more than temporary, for example where

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[5] Stewart, G. B., Pullin, A. S. & Coles, C. F. (2004). Effects of wind turbines on bird abundance. Systematic Review no. 4. Centre for Evidence-Based Conservation, Birmingham, U.K.

[6] http://www.berr.gov.uk/files/file20258.pdf

disturbance and habitat loss (before mitigation) may have longer term impacts. Temporary effects are different in nature to those during the operation of the wind farm, and as they are not strictly part of the monitoring protocol, they are best dealt with through compliance monitoring of planning conditions.

19. A decision will be necessary after 15 years as to whether monitoring needs to be continued or not. Long term studies at wind farms are, however, rare, and developers are encouraged to continue monitoring where this improves knowledge of long term impacts.

20. There is no fundamental reason why all the separate elements of monitoring should all take place in the same year, especially after 5 years from the start of operations, and some elements (such as carcass searches) are best continued at a more frequent rate, because of the likely intermittent nature of collisions.

21. The frequency and periodicity of habitat monitoring should be subject to separate guidance and discussion. Habitat change may occur over long periods of time, especially change relating to hydrological conditions, consequently, as with some of the other impacts, monitoring programmes should reflect the temporal scale over which such changes operate.

Monitoring of Breeding Birds

22. The principal purpose behind monitoring is to determine whether birds are disturbed or displaced from the wind farm development site, in addition to detecting collisions by searching for carcasses. Behavioural aspects are dealt with in the section dealing with vantage point watches: this section deals with breeding distribution and numbers.

23. SNH guidance already deals with survey methods for environmental statements, and it is not the intention here to repeat this, except in summary format, where this is appropriate. The SNH guidance 'Bird survey methods for use in assessing the impacts of onshore windfarms on bird communities' (2005) is published on the SNH web site, and to a great extent, survey methods appropriate to developing an environmental assessment can be used to undertake monitoring. There are, however, two caveats to this:

    a. Firstly, survey methods for species presence (surveillance) are necessarily low intensity, as large areas may need to be covered in a relatively short period of time. For example, it is usual to undertake Brown & Shepherd (B&S) surveys, for most moorland breeding birds, where the wind farm site occurs in the uplands. Such surveys require two to three visits per season, an early, middle and late season survey to ensure that most breeding birds are detected. However, it is now well-known (see Pearce-Higgins & Yalden 2005[7]) that Brown & Shepherd surveys underestimate moorland breeding bird numbers, and that increasing the number and frequency of survey visits leads to an increase in the number of breeding birds detected.

    b. Secondly, some species may be poorly surveyed by the standard methods used in pre-construction survey programmes. Species that are crepuscular (or nocturnal); species that are difficult to identify

[7] Pearce-Higgins, J. W. & Yalden, D. W. (2005) Difficulties of counting breeding Golden Plovers Pluvialis apricaria. *Bird Study* **52**: 339 - 342

(crossbills); or species that simply require periods of intense field work (such as raptors), may be under-recorded within environmental statements, unless there have been dedicated surveys to cover these species.

24. The consequence of this is that monitoring survey methods should, where it is appropriate, be designed to address the species-specific issues that may have arisen from the environmental statement. Because of their nature, monitoring of these issues may require a more labour intensive approach and a different methodological approach. However, it is strongly advisable that baseline conditions use the same methods as monitoring, and, as there is normally a lag period between consent being granted and construction beginning, in many cases, this should be possible. It should also be possible to select and survey relevant control sites for monitoring in this period, and developers are encouraged to undertake this at the earliest possible opportunity.

25. Monitoring approaches should follow the following standard methods:

    a. For **breeding divers** and other waterfowl, survey methods are given in (Gilbert *et al*[8]), and will require three visits to all suitable water-bodies in the search area (development site and control site, if present). Divers are known to move between breeding lochs between years (the turnover may be as high as 20% per annum, and any survey programme will need to look at *all* suitable breeding lochs and lochans.

    b. For moorland and upland breeding birds, **standardised area-based counts** should be undertaken (e.g. Brown & Shepherd surveys). These should be undertaken at least three times during the breeding season, to maximise the number of registrations.

    c. Similarly, other habitats should also be counted using **standardised area-based counts**, although in dense habitats such as scrub and woodland, point counts could be made, as opposed to area searches or line transects, which are more difficult in these habitats. **Point count** methodology is explored in more detail in (Sutherland 2006[9]). **Microphone point counts** are a possible refinement or enhancement to standard point counts, but are unlikely to be necessary, except under certain (likely to be rare) circumstances.

    d. Alternatives to area-based counts include **line transects** (using distance sampling analytical approaches (Buckland *et al.*[10]), or the two may be combined, sub-dividing the study area into a sampling grid within which transects are surveyed. The sampling grid will enable an assessment of distance effects away from the turbines e.g. Pearce Higgins *et al*. (2008)[11].

[8] Gilbert G, Gibbons D.W. and Evans J. (1998) Bird Monitoring Methods. RSPB Sandy
[9] Sutherland, W. J. (2006) Ecological Census Techniques: A Handbook. Cambridge University Press
[10] Buckland S. T., Anderson D. R, Burnham K. P and Laake J. L. (1993) Distance Sampling: Estimating Abundance of Biological Populations Chapman and Hall. London
[11] Pearce-Higgins, J.W., L. Stephen, R.H.A. Langston & J.A. Bright (2008) Assessing the cumulative impacts of wind farms on peatland birds: a case study of golden plover *Pluvialis apricaria* in Scotland. Mires & Peat 2008 http://www.mires-and-peat.net/map04/map_04_01.pdf

e. For **colonial species** (e.g. herons, gulls, terns and skuas), whole colony counts will be necessary, normally during incubation, and before hatching, when numbers are normally at their peak. Count methods for most colonial waterbirds are given in the JNCC Seabird Monitoring Handbook[12] for gulls, terns and skuas. Other colonial species should use methods appropriate for the species, but the general principle that counts should be made of the whole colony remains.

f. For **breeding raptors**, survey methods need to be species specific, and relate to those species identified as being present during the survey work for the initial environmental assessment. Field survey work will need to focus on finding nests, and evaluating nesting outcomes. Breeding raptor surveys are time-intensive, require experienced surveyors and should follow standard survey protocols, (SNH/Raptor Study Group Raptor Monitoring Handbook[13]), keeping disturbance to a minimum and with the relevant Schedule 1 licences as appropriate.

g. For other species, specific survey methods will need to be adopted appropriate to the species concerned (e.g. woodland grouse, corncrake and crepuscular/nocturnal species such as owls, nightjar). Survey methods are given in (Gilbert *et. al.* 1998)[7].

26. It is recommended that control (reference) sites are established where these are appropriate, and monitored in parallel with the wind farm monitoring. These are sites of similar habitat close to the wind farm but not affected by it, and if these have not been selected during pre-construction, baseline surveys, they should be selected before construction starts. Control sites should:

a. Host a similar mix of bird species present on the wind farm development site.

b. Be similar in size to the wind farm area (this may be difficult for very large wind farms, where other approaches may be necessary).

c. Be located on ground with a similar mix of habitats and similar topography and aspect.

d. Be as closely matched as possible to the wind farm site, the main difference being the absence of wind turbines from the control.

e. Be situated as close as possible to the wind farm area without its bird populations being so close as to be affected by wind farm operations. For birds that range widely, control sites may need to be located >6km from the wind farm, but where species' ranges are much smaller, reference sites can be much closer.

27. It is recognised that these conditions may be difficult to meet in practice, and in some cases neighbouring land owners may not co-operate. None-the-less,

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[12] Walsh *et al*. 1995: *Seabird Monitoring Handbook for Britain and Ireland*. JNCC, unpublished

[13] Jon Hardey, Humphrey Crick, Chris Wernham, Helen Riley, Brian Etheridge, Des Thompson (2006) Raptors: A Field Guide to Surveying and Monitoring (2006). The Stationery Office

control sites provide powerful evidence, when combined with Before-After comparisons, for the detection of wind farm impacts on bird populations.

28. There may be merit in use of shared control or reference sites for several wind farms in a well-defined geographical area, in which case collaborative field data collection is recommended to minimise disturbance-induced disruption to the control site, undermining its suitability, though note that lower statistical power for meta-analyses may result from shared reference sites.

29. Similarly, in some areas of Scotland where wind farms are located close to particular designated sites, the designated site itself may be used as the reference site. In this case, the designated site could act as the reference site for several wind farm developments, situated outside but close enough, for valid comparisons to be made in breeding bird population trends.

Monitoring of Non-breeding Birds

30. The principal purpose behind monitoring is to determine whether birds are disturbed or displaced from the wind farm development site, and may also include collision risk analyses. Behavioural aspects are dealt with in the section dealing with vantage point watches: this section deals with non-breeding distribution and numbers.

31. There could be three separate elements to the monitoring of non-breeding birds:

    a. **Birds on passage**. Birds that pass over the wind farm site, but do not stop on the site. This is likely to be restricted to two main periods: August-October for the autumn passage, and March-May for the spring passage.

    b. **Stopover migrants**. Birds on migration that may aggregate in an area for short periods of time, before moving on. The timing of this is likely to be similar to (a).

    c. **Resident, wintering species**. Some individuals are likely to be present on the site throughout much of the winter (November through to March), though there may also be some turn-over, which may not be apparent from simple seasonal counts of birds.

32. The need for monitoring for any of (a)-(c) will be dependent on what has been identified during the field survey work for the environmental statement. Prior, baseline data will be necessary for (a) and (b), and for many wind farms, these data have not been gathered. In many cases, this will not matter, but for some wind farms in coastal locations, or on migration land-fall sites, the impact of wind farms on migratory birds is an issue that needs much further evaluation, particularly in relation to the possible effect of wind farms as a barrier to migrating birds.

33. SNH guidance already deals with survey methodology for environmental statements, and it is not the intention here to repeat this, except in summary format, where this is appropriate. The SNH Guidance 'Bird survey methods for use in assessing the impacts of onshore windfarms on bird communities' (2005) is published on the SNH web site, and to a great extent, survey methods appropriate to developing an environmental assessment can be used to undertake monitoring.

34. Monitoring of **passage birds** (where this is agreed as part of any monitoring programme) is likely to be labour intensive, especially for large wind farms,

and those where the wind farm footprint is set perpendicular to the principal migration axis (i.e. a long row of turbines). Migration is weather-dependent and there will be periods of unsuitable weather, between periods when heavy passage is the norm. This may require either observation periods 3-4 times per week during peak migration periods, or a programme of observations timed to coincide with suitable weather conditions. Direct observations of diurnal migrating birds are possible from suitable vantage points: however, many waders, some waterfowl and many passerines are nocturnal migrants, and will need other survey techniques (see later). Observations of passage birds may be made from suitable vantage points (see next section).

35. **Migration stopover counts** are used to estimate the presence, timing and abundance of birds using the development area as a stopover site while on migration, whether for resting/loafing or for foraging. Design of stopover counts will be dependent on the nature of the wind farm site and the habitats it contains. As for breeding bird surveys, **standardised area-based search methods** are appropriate. It is likely that for most species (except species concentrated in specific locations such as major water-bodies), the survey approach will require sampling, either through recording in subplots or areas, or through **line transects**. Counts should take place at least twice per week, as many birds will only remain at stopover sites for short-periods of time, and turnover is likely to be high, although even this level of survey may miss periods of intense migratory activity, and so for short periods of time, daily counts may be appropriate. Habitats should be sampled in the proportion that they exist within the survey site, though some stratification may be necessary as some habitats are used proportionately more than others. Species locations and abundances should be recorded onto maps. Control sites outwith the wind farm footprint will be necessary in most instances.

36. The main focus of monitoring at most wind farms will be on birds that are present throughout the winter period. Some species are likely to be resident all year round (e.g. some raptors such as peregrine and golden eagle), but many species of conservation concern are either present only in summer (red-throated diver, osprey) or disperse over relatively short distances (especially birds in moorland and upland habitats). Other species are found in Scotland in significant numbers only in winter (e.g. migratory Arctic breeding geese and swans, and many Arctic breeding waders, waterfowl and passerines). Some species undergo periodic eruptions, so numbers may show substantial inter-annual fluctuations.

37. As for breeding bird surveys, **standardised area based searches** are the most appropriate methods. Surveys should ideally be conducted weekly, as numbers can show considerable short-term fluctuations in both abundance and habitat use. Sampling approaches (either plot/area based or line transects, based on distance sampling) are appropriate for large sites.

    a. Other monitoring methods for some species groups such as **wintering geese and swans** may be appropriate, such as use of dropping counts. While these are labour intensive and require a sampling approach, they have a number of significant advantages over direct observations of feeding, roosting and loafing birds.

    b. **Other waterfowl** may be adequately counted using **Wetland Bird Survey (WeBS)** methods, but counts should be undertaken more frequently as for area based searches, given short-term fluctuations in numbers. It is essential that tidal influence or diurnal/nocturnal cycles, depending on species, are taken into account in designing the sampling protocol, frequency of sampling etc. These factors are likely to be major determinants of movements and locations used.

c. Surveys for **raptors** should follow protocols set out in the Raptor Monitoring Handbook.[14] Note that some species (e.g. hen harrier) may aggregate into communal roosts in winter, with some birds being those resident during summer, but many wintering birds will be birds dispersing from areas further north.

d. For species in **woodland and scrub habitats** (woodland grouse, crossbills), standardised area based searches may not be appropriate and either point counts or transects should be adopted. Many bird species are much less vocal in winter, and visual contact may be preferred for sampling. Point counts are less appropriate as many species aggregate into single/mixed flocks such that the variability within point count estimates is likely to be much greater (there will be many low counts and a few very high counts). Line transects or area-based searches may be more appropriate, although crossbills are better surveyed using specialised techniques (tape luring and recording). Woodland grouse can be surveyed using dropping counts[15].

38. As for breeding surveys, it is strongly recommended that control or reference sites are established where these are appropriate, and if these have not been selected during pre-construction, baseline surveys, they should be selected before construction starts. These sites may be the same sites as used for breeding bird surveys, but this is not essential, and there may be valid reasons for having separate control sites for breeding and wintering monitoring approaches. Control sites should:

   a. Host a similar mix of bird species present on the wind farm development site.

   b. Be similar in size to the wind farm area (this may be difficult for very large wind farms, where other approaches may be necessary).

   c. Be located on ground with a similar mix of habitats and similar topography.

   d. Be situated as close as possible to the wind farm area without its bird populations being so close as to be affected by wind farm operations.

Vantage Point Watches & Collision Risk Studies

39. Vantage point (VP) watches are a means of quantifying, for bird species of conservation importance, flight activity that takes place within the wind farm envelope, with the principal aim of determining the likely collision risk. Activity patterns and time spent flying within the turbine envelope may also

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[14] Jon Hardey, Humphrey Crick, Chris Wernham, Helen Riley, Brian Etheridge, Des Thompson (2006) Raptors: A Field Guide to Surveying and Monitoring (2006). The Stationery Office

[15] Care needs to be taken in separating female capercaillie and black grouse as dropping size is similar.

permit an assessment of the consequences of *displacement* from feeding areas assuming that the turbines are built.

40. For monitoring purposes, **Vantage point watches** are used to determine whether birds are displaced by wind farms, on the basis that levels of activity within a wind farm after construction are likely to be much lower if displacement or disturbance is occurring at a level sufficient to alter ranging and flight behaviour. Behaviour may change in one of several ways: by altering the height at which birds fly; by altering the horizontal flight pattern (e.g. more changes in flight direction), or by altering the extent to which they use an area (i.e. by avoiding it altogether).

41. An abridged version of the **Vantage Point Methodology** recommended by SNH is given in **Appendix 1**. Full details are found in 'Bird survey methods for use in assessing the impacts of onshore windfarms on bird communities' (2005).

42. Vantage point watches should be adapted to the species of interest, information that will have been identified within the environmental statement. It is important to ensure that VP observations are undertaken at the appropriate times of the day (e.g. sufficient early morning and late evening watches for breeding red-throated divers), and that watches are undertaken in comparable weather conditions to baseline surveys (which may be the field survey work for the ES), as well as representing the range of weather conditions applying to the site (allowing for health and safety considerations).

43. Survey work should be spread over the whole season for which it is being collected (breeding, passage or wintering) and should adhere to the current recommended time of at least 36 hours[16] per season.

44. In contrast to field survey work for an environmental statement, the primary purpose of monitoring of flight activity is not to assess likely collision risk. The data should be used to undertake collision risk calculations to enable validation of the Collision Risk Model against data from corpse searches and to validate avoidance rate estimates. There is also a requirement to provide a direct comparison of activity levels (and flight heights) with baseline conditions and flight activity from control or reference sites[17] to determine behavioural changes that may be attributable to the presence of wind turbines.

45. VP watches are also necessary to assess behavioural response to other infrastructure, such as power lines, buildings and any habitat changes (including habitat mitigation, such as forestry felling, or vegetation management – burning, grazing etc.) pertaining to the wind farm.

46. VPs will not be appropriate for studies of passage birds at night, but can be used for observations of passage during the day, subject to caveats discussed earlier. The intermittent nature of passage may mean that the minimum 36 hour watch period is insufficient, and longer periods should be adopted or alternative methods (see later) as appropriate for the scale of migration.

47. VP observations should also be used to watch behavioural interactions with wind farm structures (turbines, power lines, buildings etc.). Behavioural

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[16] It is important to note that this figure may be revised at some point, based on experience.

[17] Some caution is needed here: birds that are displaced from a wind farm may end up using adjoining areas proportionately more, so that any control site should be surveyed both before and after turbine construction.

categories of avoidance have been described by Meredith *et al.* (2002): these are reproduced in **Appendix 2**. Behavioural observations are best recorded onto digital tape recorders and analysed/transcribed at a later stage. This allows uninterrupted observation, and minimum down-time from focal bird recording in the field. Analysis of these data is likely to prove challenging but it will help interpret field observations, particularly across species, given that it may be used to infer detection distances for birds flying near turbines; differences between stationary and moving turbines; and the interaction of flight behaviour with weather conditions and topography.

Carcass Searches for Collision Victims

48. Carcass searches are the most direct way of estimating the number of collisions and hence the likely impact on species of conservation importance. Measures of the number of collisions can also help to quantify avoidance rates (as used in collision risk modelling calculations), and, when collisions can be ascribed to a particular time, contribute to an understanding of environmental conditions and behaviours that increase collision risk.

49. There is widespread agreement that collisions are more likely in poor flying conditions (that may relate to weather) and at night, although the empirical evidence for this is weak. Among migrant passerines and waterbirds, nocturnal migrants do seem to collide more frequently than diurnal migrants (Kunz *et al.,* 2007)[3], but high levels of collision with static and moving objects have also been reported for some diurnal raptors, terns, game birds and waders. A combination of topography and low wind speed has also been associated with increased collision risk (Barrios & Rodriguez 2004, 2007).

50. Carcass searches are an important part of monitoring, especially for species for which collision is highlighted as a critical issue in the preliminary environmental statement. There are, however, a number of serious methodological constraints that make obtaining reliable estimates of collision victims very difficult. In particular:

    a. Birds may fall outside the search area. This is especially likely if a moving turbine blade injures the bird, so that while the victim may be crippled it may be able to fly (or move) away from the turbine, (possibly into cover) thus taking it out of the turbine search area. These two sources of error: search area bias and crippling bias are clearly linked, but can be very difficult to correct for.

    b. For those birds falling within the search area around turbines, the efficiency of finding will vary considerably because not all birds will be found by observers. Different species, in different habitats, will have different detectabilities. Search efficiency can be corrected for (see later), but for good reasons, search efficiency must be calculated for each wind farm site, as there is currently no reliable means of extrapolating data from other wind farms to any particular site. Furthermore, there is likely to be variation in observer efficiency which cannot be evaluated *a priori*, but must be tested in the field

    c. Finally, there is scavenger removal. Predators which also scavenge may be attracted to wind farms and will therefore remove a proportion of carcasses, away from the wind farm and hence, out of the search area. Search frequency needs to be determined on the basis of prior assessment of scavenger activity and such activity must be corrected for.

51. These biases will cause the estimate of collision mortality based simply on numbers of birds found to be too low, and must be corrected for. Methods for estimating these correction factors are discussed below. However, there are a number of factors that will tend to bias collision estimates high, in particular, confusing natural background mortality for collision related mortality, though assessing background levels of mortality is an important component of assessing the importance of collision mortality. This effect is likely to be small in most situations but may be a bigger problem in coastal environments where tides (or winds) may concentrate carcasses along strand lines. Where this is a possibility, there may need to be some post-mortem assessment of carcasses for unequivocal signs of collision.

52. **Search bias.** Search bias arises from an unknown proportion of birds either falling outside the search area or birds crippled by collision, managing to move out of the search area. Crippled birds will invariably die soon after collision, if their injuries prevent flying or feeding. The proportion of birds crippled as opposed to killed outright <u>cannot</u> be estimated with confidence, so the number of birds found dead will always be an underestimate, regardless of the validity of other correction factors. The proportion of carcasses falling outside the search area can be estimated, if positions of dead birds are recorded. By allocating these to distinct search radii round a turbine a distance-detection function can be plotted (over time) showing how distance from turbine varies with probability of finding a corpse. Akin to distance sampling, the detection-distance function can therefore compensate for the proportion of birds falling outside the search radius. Smallwood & Thelander (2008)[18] found that about 90% of all carcasses were found within 50m of turbines at Altamont Pass Wind Resource Area (APWRA).

53. **Observer detection bias.** No observer will find 100% of carcases around a wind farm, and the likelihood of detection will decrease with decreasing body size and increasing vegetation height (Smallwood, 2007)[19]. The estimation of observer bias is a relatively simple undertaking albeit one beset by a number of potential errors. It will rarely be possible to replicate the species of interest in observer detection trials (especially for raptors, and rare species). However, detection trials should use birds of similar size to the species most at risk of collisions and where possible, colour and should attempt to replicate the appearance of a collision victim, which may require dismemberment and some feather scattering. Detection trials should <u>not</u> use numbers greatly in excess of likely number of victims, as this can enhance detection rates and thus bias collision estimates too low. It is also preferable to undertake search detection trials unannounced, so that the normal observer is unaware that a trial is taking place, so as to prevent any possible increase in observer vigilance.

54. **Scavenger bias.** Predators that scavenge will remove a proportion of carcases and because of this carcass searches at predetermined intervals will inevitably miss some carcasses that have been removed by scavengers. Generally, carcass removal is more likely with smaller rather than larger carcases, so carcass removal experiments should be undertaken to determine how fast scavengers remove carcasses. Smallwood (2007)

[18] K. Shawn Smallwood and Carl Thelander (2008) Bird Mortality in the Altamont Pass Wind Resource Area, California Journal of Wildlife Management **72**(1): 215-223
[19] Smallwood, K. S. (2007) Estimating Wind Turbine–Caused Bird Mortality. Journal of Wildlife Management **71**(8): 2781-2791

estimated from studies at a number of US wind farms, that for small birds the majority may be removed after 30 days, whereas over 90% of large raptors are likely to be still present. Paradoxically, chickens and game hens were removed fastest, at a rate greater than rock doves. As for observer detection bias studies, carcasses used should be similar in size and colour to species of concern. However, it is likely that only geese, game birds and pigeons will be available in the numbers needed. Carcass removal experiments should avoid scavenger swamping (too many carcasses), though low numbers can also lead to larger standard errors. Carcass removal is unlikely to occur at a constant rate (which would give a negative exponential distribution) as some carcasses, not removed early, may become unsuitable. Longer trials to establish carcass removal rates will bias removal rates high so underestimating collision mortality (Smallwood, 2007). To an extent using low numbers of carcasses will tend to limit the problem of carcasses becoming unsuitable, as scavenger swamping is less likely. Further refinements may involve use of motion-activated cameras to detect carcass-scavenging events. These allow assessment of detection times, scavenger behaviour and scavenger identity.

55. **Left skewed data**. Field searches for carcasses around turbines will invariably record a high proportion of zero fatalities, except in areas where high rates of collision occur. Correcting zero estimates for scavenger removal and observer bias will therefore still lead to a zero figure for collision victims, even though some zero estimates arise due to loss of carcasses to scavengers or failure to detect them. It is therefore necessary to estimate the proportion of 'false negative' (i.e. zero) figures when in reality, victims may either have been missed, or have been removed by scavengers. Given low rates of collision reported so far at most UK wind farms, left skewed data is likely to be common, and so simple statistical models may be necessary to estimate the proportion (e.g. Poisson based probability models) of false negatives (which give rise to left skewed data).

56. Other approaches to the assessment of collision mortality are possible.

    a. Firstly, the use of trained dogs to detect collision victims will reduce observer bias and use of dog's ability to detect carcasses could significantly reduce search time and increase search efficiency. Use of dogs is likely to be particularly appropriate for large wind farms (>30 turbines), or for sites where detection of collisions is particularly important, and where conditions (e.g. vegetation cover) make conventional searches difficult. There are few documented cases of use of dogs, but carcass searches for white-tailed eagles at Smøla[20], Norway are being undertaken with the use of trained dogs. Other examples include tetraonid mortality under power lines - see Bevanger 1995[21], or bat mortality – see Arnett 2006[22]).

    b. Secondly, technological developments may allow automatic detection of collisions. Technological approaches to monitoring are discussed in more detail in the following section. While valuable for on-shore

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[20] Follestad, A., Flagstad, Ø., Nygård, T., Reitan, O. & Schulze, J. 2007. Vindkraft og fugl på Smøla 2003–2006. - NINA Rapport 248. 78 pp. **Vis detaljer**

[21] Bevanger, K. (1995) Tetraonid mortality caused by collisions with power lines in boreal forest habitats in central Norway. – Fauna Norv. Ser. , Cinclus **18**: 41-51

[22] Arnett, E. B. (2006) A Preliminary Evaluation on the Use of Dogs to Recover Bat Fatalities at Wind Energy Facilities Wildlife Society Bulletin **34**: 1440-1445

developments, they are likely to be essential for offshore wind farms, where carcass searches are impossible.

c. In a very few situations, colour marking of individuals for survival estimates may give rise to indirect estimates of collision mortality. There are likely to be few situations where this might be appropriate, but colonies of some colonial birds (e.g. seabirds) close to an operational wind farm could be one such situation. Knowledge of survival rates before and after wind farm construction could lead to valuable, if indirect, estimates of collision mortality.

d. Similarly, radio tracking or satellite tagging studies may allow much better quantification of behaviour and assessment of risk to species. Radio-tracking is likely to be particularly suitable for scarce species, such as many raptors and owls. For example, Hunt *et al.* (1998) found that 23 (~13%) out of 179 radio-tagged golden eagles (*Aquila chrysaetos*) were killed by wind turbine strikes in the Altamont Pass Wind Resource Area. The Norwegians have been satellite tagging white tailed eagles and several tagged birds have been among the collision fatalities found at Smøla.

Technological Methods

57. There are a range of approaches that rely on remote sensing or use of technology to study the impacts of wind farms on wildlife, especially nocturnal birds and bats. A full discussion of these is not appropriate within this guidance, but recent reviews (e.g. Kunz *et al.*, 2007) provide a more detailed technical background.

58. In many cases technology can support visual and other observations, but may be insufficient on their own due to limitations (described below) or conversely, remote techniques require visual or other methods alongside them for verification, at least initially or under certain conditions.

59. Many of the approaches developed in recent years have been applied to the study of nocturnal birds (and bats) where conventional methods for onshore wind farms are inappropriate or in offshore situations where methods described in this guidance, are unsuitable. Among the approaches which are increasingly being used are:

    a. **Ceilometry** – use of powerful lights to illuminate the night sky to detect passage birds (Gauthreaux, 1969).

    b. **Night-vision imaging** – a range of devices are available for use at night or in low visibility situations. As with ceilometry, such approaches mirror conventional diurnal methods, except for the use of different equipment to enhance bird detectability.

    c. **Thermal infrared imaging** – these detect heat emitted from birds (and bats) and can be used to detect movement in and around wind turbines (Desholm *et al.* 2005). As with other devices, species identification can be problematic unless there are acoustic or visual clues to aid identification. Some Thermal Infrared Imaging devices can be linked to automatic motion detectors, which means cameras are only triggered when targets are close to a turbine which also aids species or at least group (e.g. large gull) identification.

d. **Radar** is increasingly being used to monitor bird movements in and around wind farms. A significant problem with radar is that many devices are fixed or relatively immobile, (e.g. airport and weather radar systems), or are difficult to move to locations where wind farms operate. There are some mobile units (e.g. the CSL Bird Surveillance Radar, which incorporate both X and S band radar) in the UK, but they are expensive to operate and much in demand, especially at airports, where they are used to assess bird-strike risks. Potentially more suitable are simpler, more portable marine (X-band) radar systems that can be mounted on vehicles: these can be used to detect directional movements, and speed as well as altitude when aligned in a vertical position. In the horizontal position, radar will track movements, e.g. through the wind farm area. Radar systems are particularly useful in offshore environments (see Desholm & Kahlert, 2006[23]), where conditions mean that 'conventional' observations are difficult if not impossible. It is, however, important to note that radar systems, like all remote sensing devices, cannot be used to reliably distinguish between different species, and some systems may even struggle to differentiate birds, bats and insect swarms, and it is not always possible to obtain quantitative data in terms of numbers of birds. It is therefore essential to integrate these with other approaches (e.g. acoustic monitoring or visual detection with night vision systems) to validate and interpret radar signatures. A particular shortcoming of the most available radar systems is the problem of interference, e.g. from turbine towers which have higher reflectance than birds and so birds passing turbines are likely to be lost from the radar screen. Gauthreaux & Livingston (2006)[24] have developed a technique combining fixed vertically directed radar in tandem with a vertically aimed thermal imaging camera which allowed accurate estimates of birds passing and their altitudes to be obtained.

e. **Acoustic monitoring.** Useful for nocturnal passage migrants, but subject to so many caveats that the value may primarily lie in its use as a means of identifying species detected through other means (e.g. radar, thermal infrared imaging or night-vision goggles). The situation is complicated further by mixed species flocks, and the time needed to separate out and identify flight calls, especially from similar sounding species. Furthermore, not all species call during migration so will be overlooked.

f. **Collision detectors.** It is possible to mount sensitive collision detectors on wind turbines (e.g. sensitive microphones) that can detect collisions when they occur (Wiggelinkhuizen *et al.* 2006[25], Pandley *et al*. 2007[26]) though their efficacy has yet to be demonstrated. Data from such devices can be used to trigger carcass searches, thus increasing their efficiency.

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[23] Desholm, M. & Kahlert, J. (2005) Avian collision risk at an offshore wind farm *Biology Letters* **1:** 296-298

[24] Gauthreaux, S. A. & Livingston, J. W. (2006) Monitoring bird migration with a fixed-beam radar and thermal imaging camera *Journal of Field Ornithology* **77**: 319-328

[25] E.J. Wiggelinkhuizen (ECN), L.W.M.M. Rademakers (ECN) S.A.M. Barhorst (ECN) H.J. den Boon (E-Connection Project BV) (2006) Bird collision monitoring system for multi-megawatt wind turbines WT-Bird®. Summary of prototype development and testing

[26] A. Pandley, J. Hermence, R. Harness (2007) Development of a Cost-Effective System to Monitor Wind Turbines for Bird and Bat Collisions - Phase I: Sensor System Feasibility Study California Energy Commission Report Number CEC-500-2007-004

60. The use of technology to enhance monitoring of wind farms can be extremely valuable, and this will become increasingly widespread in future as wind farm growth continues in the onshore and offshore environments. However, it is important to undertake appropriate baseline studies, as much of the information derived from technological assessments of bird passage are likely to be meaningless without good quality pre-construction data. This may limit usefulness of technology at many existing onshore wind farms where much of the pre-construction data has been collected using conventional observations, although there may be opportunities during additional baseline data collection once planning consent has been given and before construction commences. Such opportunity enables parallel use of remote and visual techniques for validation purposes (although it should be noted that for example radar detection extends beyond the range of human vision, even with the addition of visual aids).

61. The principal value of technology will lie in the assessment of flight activity for nocturnal species, or where poor weather conditions (fog etc.) are common, but note that high air-moisture levels reduce functionality in most remote technologies. Technology is also likely to be much more appropriate in the marine environment at offshore wind farms, and to this end COWRIE is developing guidance for monitoring of bird displacement in the offshore environment (see report on the COWRIE web site).

Additional Species-specific Studies

62. There may be a need to undertake specific studies of some sensitive species if they are present in the wind farm area. Among the species where this might be the case are the following: nightjar, corncrake, chough, Scottish crossbill, and most nocturnal species[27] where technological methods are likely to be appropriate (see previous section).

63. Species specific studies may rely in part on survey methods designed for each species (see Gilbert *et al.*[7], and JNCC Bird Site Condition Monitoring guidance), but may require more intensive methods, e.g. survival and productivity assessment, individually marked birds, etc.

64. Detailed demographic work to improve our understanding of the productivity of some species should also be considered. Targeted monitoring such as radio tracking, assessment of breeding success and survival rates can help build an accurate population model such as a Population Viability Analysis (PVA) to assess the potential impacts of a wind farm site. Colour marking of individuals can be used as a means to assess collision risk but in addition, this kind of monitoring can also be used to look at return rates. Fine scale monitoring such as this can be used to separate out different mechanisms effecting a populations and improve our overall understanding and assessment of impacts of wind farms.

Data Sensitivity

65. Some of the data gathered will be sensitive (in terms of Environmental Information Regulations). Issues relating to environmental sensitivity of data

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[27] Kunz *et al.* (2007) Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document *J. Wildlife Management* **71**: 2449-2486.

are dealt with separately in the SNH Guidance: *Environmental Statements, Confidential Annexes and Sensitive Bird Information.* (*to be published).*

Concluding Remarks

66. The guidance here addresses monitoring of onshore wind farms, but it is important to highlight the need to provide adequate baseline information from pre-construction studies to underpin data gathered after construction and commissioning of the wind farm.
67. Pre-construction assessments may derive from baseline environmental assessments, but may also need to be supplemented by additional pre-construction monitoring before construction starts. This may be particularly relevant if a control site is selected which has not been surveyed as part of any environmental statement (which is normally the case).
68. The design of monitoring will be appropriate to the wind farm in question: the guidance outlined here identifies the elements that may be needed, but the extent to which all the approaches outlined here are needed, will depend on the individual wind farm circumstances.
69. A clear understanding of the purpose of monitoring at any particular site is necessary before designing a programme, and there may be essential elements, that are not covered here (e.g. work designed to monitor progress of any mitigation and/or enhancement work).
70. There is still a considerable knowledge gap on the effect of wind farms on birds, and though understanding is improving, there are still questions as to how serious collision mortality is in most situations; whether the barrier effect exists and if so, how serious it is likely to be; and whether displacement effects predominate over collision for many or most species. It is worth noting the different age classes of a given species may respond differently to wind farm impacts, and behavioural responses may also vary between breeding and non-breeding periods.
71. It is inevitable that technology will play a bigger role in monitoring as methods are improved and techniques are refined to answer the key questions posed by monitoring work. Currently, the expense and drawbacks of many of the technological approaches limit their use and applicability but for some species and situations, technological approaches offer the best long-term hope for good quantitative information on wind farms impacts.
72. Rigorous assessments of data gathered under monitoring, and a willingness to publicise and publish the data in peer reviewed publications, will improve the quality of understanding and allow better assessments of future wind energy developments. There may be merit in publishing interim results, where this will contribute to the further understanding of wind farm impacts on bird populations.

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Appendix 1

Methods statement for Vantage Point (VP) watches

Background

Vantage point (VP) watches are a means of quantifying flight activity of bird species of conservation importance that take place within the wind farm envelope, with the principal aim of determining the likely collision risk. Activity patterns and time spent flying within the turbine envelope may also allow an assessment of the consequences of *displacement* assuming that the turbines are built.

Further background is given in Section 6.1 of Bird survey methods for use in assessing the impacts of onshore windfarms on bird communities (SNH 2005).

Purpose

The purposes of vantage point watches are to:

1. Collect data on *target species* that will enable estimates to be made of:
   a. The time spent flying over the defined survey area;
   b. The relative use of different parts of the defined survey area; and
   c. The proportion of flying time spent within the upper and lower height limits as determined by the rotor diameter and rotor hub height.
2. Calculate an index of flight activity for other species - *secondary species* using the defined survey area.

Methods

Information is collected during timed watches from strategic vantage points (VPs) covering the defined survey, which encompasses the turbine envelope extending anything from 200m to 500m beyond the outermost proposed turbines. In the majority of cases, a 200m extension is believed to be sufficient to deal with inaccuracies of pre-consent turbine positions for flight line observations. However, breeding bird displacement may occur beyond this, and there are invariably good reasons for extending the survey boundary beyond the 200m buffer.

1. The survey area should not be too restrictive otherwise there is a danger that chance effects will have a large influence on the recorded flight activity. The envelope, including the 200m-500m extension reduces the risk of failing to record birds that use the wind farm area only occasionally. Also this distance is a useful distance over which at least short range avoidance of wind farm may be observed by birds flying around, rather than through, the wind farm.

2. When selecting VPs, the aim should be to cover all of the survey area such that no point is greater than 2km from a VP. It is very important that VPs are chosen parsimoniously in order to achieve maximum visibility with the minimum number of points. However, separation may be reduced where it is necessary to ensure reliable observations e.g. for smaller species. Ideally, it will be possible to scan an arc of up to 180^o from each VP. Larger arcs are difficult to scan efficiently. In exceptional circumstances it may be possible to observe the entire survey area from a single VP. In most cases, however, two or more VPs will be required. For example an upland site in Scotland measuring around 10km^2 typically requires three or four VPs. It is

important to minimise the observer's effect on bird behaviour. For this reason VPs are best located outside the survey area where possible. As acuity of observations will decrease with distance, VPs should be located as close to the survey boundary as possible. VPs should not be located near to the nest site of target species and observers should try to position themselves inconspicuously so as to minimise their effects on bird movements. This often precludes the use of hill summits for VP observations. VPs should be located outside the proposed wind farm site where ever possible, but if there is *no alternative* but to locate VPs within the wind farm site, then this should only be undertaken when the proposed site is sufficiently large that a part of the wind farm site at least 500m from the VP can be watched (observations at closer distances are potentially biased). Analytically, such potential bias can only be checked for if the area surrounding a VP within a wind farm site is also observed from another VP away from the wind farm site when there is no observer present at the within site VP (i.e. compare the observed bird use during potentially biased conditions against the observed bird use during unbiased conditions). If the observed bird use in the area surrounding the VP within the wind farm is not different with or without an observer present, then this would suggest that the observer has not biased the observation conducted within site. However, considerable effort may be required to generate sufficient records to make such a comparison. When several observers are involved it is advisable to mark the exact location of each VP on the ground, as in some situations, even 8-figure GR may be insufficient to ensure consistency in observer position. Because it is critical that the spatial coordinates of VPs are measured to the highest level possible, using a Global Positioning System (GPS) is strongly recommended.

3. Watches are undertaken between dawn and dusk (though note requirements for nocturnal and crepuscular species) by a single observer under conditions of good ground visibility (>3km). For exceptions see relevant sub-sections within Section 6 (e.g. 6.8.2 for nocturnal owls) in SNH guidance 2005. Use of more than one observer simultaneously may be required when the number of individual birds is large: responsibilities for taking records of different species and/or individuals should be clear to ensure no errors. When flight lines need to be tracked across large distances (e.g. simultaneously recording records of diver flights from a VP overlooking a nest lochan and from a VP at a distant proposed wind farm site) means of rapid communication between observers will be necessary. The cloud base should be higher than the most elevated ground being observed. In some instances and for some species, observations may be necessary in conditions of low cloud base: clearly in these conditions visibility will be impaired but auditory records may be possible to indicate if the target species continue to be active under such conditions. Ideally such observations should be made in a range of wind conditions. This is particularly important in the case of soaring birds when wind direction and strength is likely to have a large effect on ranging behaviour. Regular measurement of wind speed and direction using a hand held anemometer is advised in order to investigate the magnitude of this effect.

4. Each watch should last a maximum of three hours but can be suspended and then resumed to take account of changes in visibility (e.g. fluctuations in the cloud base). Experience derived from field trials suggest that the acuity of most observers declines after three hours, and some may prefer to conduct shorter watches. A gap of at least one hour between watches is advisable. A shorter gap might be used if the watch is shorter than three hours.

5. More detailed guidance for different species groups can be found in the main body of the Bird survey methods for use in assessing the impacts of onshore windfarms on bird communities guidance.

6. During each watch, two hierarchical recording methods are used to record data: focal animal sampling for *target species*; and activity summaries for *secondary species*. These are as follows:

   a. Focal animal sampling. The area/view is scanned until an individual of a *target species* is detected at which point it is followed until it ceases flying or is lost from view. The time the target bird was detected and the flight duration are recorded. The route followed is plotted in the field onto 1:25 000 scale maps. The bird's flight height is estimated at the point of detection and then at 15 second intervals thereafter, using, for example, a count-down timer with an audible alarm. Note that this does not apply to display flights of hen harrier and short-eared owl. A 15 second interval is recommended as a practical compromise that aims to minimise dependency within data while maximising the sample of observations. If necessary, the data can be re-sampled after *post hoc* analysis (e.g. using a one-sample runs test). For monitoring of bird flight heights, flight recording bands should be classified according to turbine specifications. . If conditions allow a finer resolution of height bands (e.g. presence of features of known height) then more detailed observations of flight height should be made. Training and checking of observer accuracy in relation to height estimation should be made and accounted for where this is possible. Use of a clinometer and range finder provides one means of determining flight heights accurately. Observations of target species take priority over completion of activity summaries (b).

   b. Activity summaries. Each watch should be sub-divided into 5 minute periods, at the end of which the number and activity of all *secondary species* observed should be recorded. If a *target species* is being tracked at the end of a 5 minute period, then the activity summary for that period should be abandoned and a new one started once observations of the target species have ended. Observation of target species takes priority over recording of secondary species. Note that the number of birds recorded should be the minimum number of individuals that could account for the activity observed. Static and flying birds should be recorded separately. Observers should record perched birds and birds on water bodies once only on arrival at the VP, and the area or site used marked on a map. Thereafter only flying birds and newly noticed perching/swimming birds should be included in the activity summaries. This allows greater time for focal animal sampling, rather than repeated observations of the same static birds. It is simpler to record unusual movements (e.g. flights of gulls) as a separate event rather than incorporate them into 5-minute activity summaries. Wind speed and direction should be recorded as frequently as possible, preferably as part of the 5-minute activity summaries.

   At the end of each watch, the locations and activity indicative of breeding by divers, raptors and all other *target species* should be recorded on the map.

7. For some analyses it is necessary to calculate the amount of time birds spend per unit area of ground surveyed. The use of several VPs can therefore complicate the analyses of collision risk as described by Band *et al.*

(in press) because overlap in visibility means that some parts of the survey area will be observed for longer than others. However, a more statistically robust method is to calculate activity per unit area on the basis of watches from each VP (i.e. the activity is calculated per VP and the un-weighted mean of these measures is used as the metric for input into collision risk models), and then this source of error should not arise. However, if the areas for each VP are widely variant, then there may be a need to use an area-weighted mean, assuming the survey time for each VP is broadly consistent. Visibility from each VP can be mapped in the field, from photos taken from each VP, or using terrain data within a Geographic Information System (GIS). Software used to predict the Zone of Visible Influence (ZVI) of wind farm developments, such as Windfarm 2000™, can be useful in this respect.

8. Mapping in the field or from photographs tends to overestimate visibility because observers are unaware that some areas are hidden from view. This is particularly true when convex slopes or undulating terrain are being viewed. In general, therefore, use of GIS is to be preferred. However, in habitats with much woodland or other tall vegetation it will be necessary to make allowances for the effects on visibility of the vegetation relief. Note that in areas of complex terrain or vegetation relief, visibility can alter with small changes in observer position. It is therefore critical that the spatial coordinates of VP positions be are measured to the highest level of accuracy possible, using a GPS. Also as noted earlier, observers should take care to re-use the exact VP location in successive watches.
9. Birds are often visible when the ground they are flying over is not. Thus birds can sometimes be seen flying or soaring over hidden valleys and watersheds. Since a key purpose (see above) is to estimate the risk of collision with turbines, it is the visibility of the airspace with the turbine rotors (the collision risk volume) that is of prime importance. Therefore it is recommended that visibility be calculated using the least visible part of this airspace i.e. an imaginary layer suspended at the lowermost height passed through by the rotor blade tips (typically about 20m above ground level). Predicting this visibility at this level is a simple task using GIS.

Notes

i. Although all points within the survey area are required to be within the 2km of a VP, observations from each VP are not constrained to a 2km radius (i.e. birds are recorded regardless of their distance from the VP).

ii. There will be a bias in favour of records for larger target species (geese, swans and large raptors) at further distances compared to smaller species such as merlin and waders.

iii. The location of displaying hen harriers and short-eared owls should be recorded as accurately as possible on the maps (including start and finish point, plus extent of display area). Record the duration of display, number of oscillations – counted as number of dives – and the estimated minimum and maximum flying height.

Recording

Data should be recorded on two forms [called FORM 1 & FORM 2] and 1:25 000 map(s). Form 1 [activity summaries] must be completed for each VP watch, regardless of whether target species were recorded or not. Use different forms for different watches (i.e. do not combine data from different watches onto one form or map). Forms used should encapsulate the observations listed below and, of course, record start and finish times, observer name, weather records and VP location (cross referenced to the map).

FORM 1 Activity Summaries

- Use BTO species and activity codes.
- Record *target species* on both forms, but those not in flight will appear on Form 1 only.

FORM 2 Focal Sampling

- For each watch number each flying bout consecutively. Cross reference this number to the flight path recorded on the relevant map.
- Record the time the bird is first detected to the nearest minute e.g. 15:45.
- Record duration of flying bout to the nearest second.
- For each flying bout: starting at 0 (zero – point of first detection), number each 15 second interval consecutively, and tick appropriate flying height for each 15 second interval.
- Rule off under each flying bout to highlight end of recording.

Map(s):

- Mark the location of the VP used and if a GPS is used then cross refer GPS location to position on map.
- Mark flight paths of *target species* and indicate direction of flight. Use different colours and symbols for each species. Provide key on back of form.
- Number each flying bout and cross reference with Form 2.
- Use additional map(s) if data records are cluttering initial map.
- Include information on displaying owls and hen harriers on a separate sheet, but ensure that it is included with all other data sheets and enough information is recorded enabling cross reference with other forms and maps.

SNH, January 2009

Appendix 2

Behavioural Categories for the Observation of Bird Interactions (after Meredith, 2002) with Operational Wind Farms

Flight Behaviour	Description
WEAVE	Weaving flight line up to maximum height of turbine. For winds within a wind farm, a weaving flight path up to height of the turbine tip.
DIRECT	A direct flight line, within the turbine envelope but clearly in a line up to maximum turbine blade height, avoiding turbines.
HORIZ	A bird flying towards a wind farm site, which takes avoiding action by a horizontal movement (i.e. no change in height) so as to take it around the perimeter of the wind farm.
VERT	As for HORIZ but this time, the bird gains altitude to take it over the top of the wind farm site.
BULLET	Flight behaviour within or outside a wind farm site, which appears to take no avoiding action with regard to turbines (or other infrastructure).
HIT	A recorded collision event. Likely to be rare, but has been observed
AVOID	Avoidance behaviour near a turbine, generally taken at short notice, and is likely to appear as a sudden change in direction or height (or both).
OTHER	Any behaviour not easily classifiable into any of the above categories.

Note: It may also be appropriate to add other qualifiers, such as whether the bird appeared to be foraging, displaying, provisioning nest/chicks etc or simply passing through (passage).

Reference

Meredith, C., Venosta, M., & Ressom, R. (2002) Cordington Wind Farm Avian Avoidance Behaviour Report, 2002. Biosis Research Report.