BTO RESEARCH REPORT 513

Developing guidelines for ornithological cumulative impact assessment: draft discussion document

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Birds Science People

BTO Research Report No. 513

Developing Guidelines for Ornithological Cumulative Impact Assessment: Draft Discussion Document

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September 2008

Report of work carried out by The British Trust for Ornithology
under contract to COWRIE

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EXECUTIVE SUMMARY

- 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 this agreement, the Crown Estate launched its "Round 3" leasing programme for the delivery of up to 25 GW (gigawatts) of new offshore windfarm sites by 2020. This programme is expected to greatly increase the number of UK offshore windfarms projects.

- Cumulative Impact Assessments (CIAs) are an important component of the Environmental Statements (ESs) prepared by developers to assess the likely effect of these wind farms on the environment. However, there is considerable inconsistency in the manner in which such assessments have been conducted. The aim of this report is to provide a review of the current methodologies for birds used in CIA and draft guidelines based on best practice. To gain consensus for the guidelines and to ensure a high-level of quality assurance, the recommendations will be reviewed by an expert group comprising scientists and ornithologists, regulatory and statutory bodies, developers and consultants. Final guidance and recommendations will be presented in a modified version of this report following the workshop on 2nd October, informed by the draft of this report.

- Windfarms may impact birds in a number of different ways, including collision with wind turbines, displacement due to disturbance and habitat loss and barrier effects. Collision at windfarms with rotors, towers, nacelles and associated structures such as guy cables, power lines and meteorological masts can cause mortaility or sub-lethal injury. Birds may be displaced from windfarms and surrounding areas due to direct loss of habitat (though this is usually minimal) or visual intrusion and disturbance, which effectively amounts to habitat loss. Barrier effects occur because birds are often forced to fly around wind farms and thus expend more energy. The significance of these impacts is generally assessed using a matrix approach in which the magnitude of effects is cross-tabulated with the sensitivity of species to these impacts. Cumulative effects derive from the additional impact of an individual development to the impacts of other developments.

- Environmental Impact Assessments (EIAs) generally have five stages: (1) screening / scoping, (2) data gathering, (3) analysis, (4) test of significance and (5) reporting. It has been proposed that Cumulative Impact Assessment (CIA) be integrated with all of these processes. In general however, it is more usual to give CIA post-hoc treatment in the reporting phase, although in some instances some analyses are undertaken. We present six case studies, which illustrate the ways in which cumulative impact have been assessed to date. The approaches used differ considerably.

- We identify three aspects to CIA for which guidelines are needed:

  Firstly, what plans, projects and developments should be incorporated into the cumulative impact assessment process. This aspect is covered in more detail in the second position paper provided for this workshop.

  Secondly, over what time-scale should impacts be considered?

Thirdly, over what area should impacts be considered?
We also identify the need for specific guidelines for data gathering, analysis and data reporting. By considering and discussing the regulatory and ecological implications of various approaches and assumptions, we provide appropriate guidelines.

- With regards to data gathering, we suggest that most requirements for CIA are the same as for EIA, but that additional data should be collected if (a) a specific project, plan or development has inadequate data associated with it to inform the CIA process and is likely to significantly add to the overall cumulative effects, (b) disturbance or barrier-effects are likely to be significant or (c) cumulative effects on designated features of protected areas are likely to be significant and cannot be assessed due to lack of knowledge about use of a wider area.

- With regards to which effects should be considered, we recommend that all sources of potential impact from developments, not just those from other windfarms should be considered. However, broader factors associated with environmental change such as fishing pressure and climate change should not be considered.

- With regards to time-scale we recommend that all ongoing and proposed projects should be considered, the exception being the consideration of impacts on designated features of proposed protected areas prior to the assessment of the conservation value of that area. Mortality should be presented as a rate per unit time rather than an overall number over a defined time-period.

- With regards to the area over which cumulative impacts should be assessed, we propose that areas be defined on a site-by-site basis following the same principals as are used to designate SPAs. Where an assessment of the boundaries of the CIA area cannot be made, we propose that the Strategic Windfarm Areas be used.

- We recommend that for collision and displacement, the significance of cumulative impacts is assessed by summing the impacts from each component development. Disturbance and barrier-effects impacts accrue sigmoidally. We propose that cumulative impacts of disturbance and barrier-effects are first considered in a qualitative manner making best-use of available information. If the cumulative impacts of disturbance and barrier effects are thought to be significant, then a more detailed quantitative study should be carried-out. We recommend that the significance of cumulative impacts be made using the same matrix approach that is routinely used for EIA.

- In order to facilitate the calculation of cumulative impacts, there is a need to ensure that the outputs of EIA are compatible. There is an urgent need for guidelines that specify more precisely, the outputs of EIA. More rigorous guidelines for CIAs could then be formulated.

1. INTRODUCTION

1.1. Background information

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 this agreement, the UK government has committed to obtaining 10% of the UK's electricity from renewable sources by 2010 and 15% by 2020. In June 2008, the Crown Estate launched its "Round 3" leasing programme for the delivery of up to 25 GW (gigawatts) of new offshore windfarm sites by 2020. This programme is expected to greatly increase the number of UK 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 displace wildlife from favoured areas or directly cause mortality to wildlife through collisions. 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) requires that States accept responsibility for assessing the effects of major offshore development on the environment.

Cumulative Impact Assessments (CIAs) are an important component of the Environmental Statements (ESs) prepared by developers to assess the likely effect of any major plan or project on the environment. However there remains uncertainty as to the way these should be implemented. In May 2007, COWRIE held a workshop on the cumulative impacts of offshore windfarms on birds to gauge opinion and provide recommendations for improving the delivery of CIA. The results of this workshop were published in November 2007 (Norman *et al.* 2007). This document, reflecting the consensus of the workshop, provides a very useful platform for consideration of CIA guidelines. However, in general, the document highlights the further actions required before specific guidelines can be provided. A clear series of simple-to-use and specific recommendations and guidelines, which could be used when undertaking CIA or when preparing the ESs, are now required.

1.2. Aims of this report

Building on the platform provided by Norman *et al.* (2007), the aim of this report is to provide methodological guidelines in relation to CIA for offshore windfarms. This is to be achieved through (a) a review of existing methods, with commentary on the implications of different approaches and examples of good practice flagged-up, (b) detailed discussion of the assumptions and complexities associated with CIA in both a legislative and ecological context and (c) the provision of set of specific guidelines relating to how to carry out CIA, justified by discussion in previous sections of the report.

To gain widespread recognition for these guidelines and to ensure a high-level of quality assurance, the recommendations will be reviewed by an expert group comprising scientists and ornithologists, regulatory and statutory bodies, developers and consultants. Final guidance and recommendations will be provided in a modified version of this report following the one-day workshop on 2nd October 2008, informed by the draft of this report.

To distil the information presented in this report and thus expedite its interpretation, salient points from each section are presented in blue-coloured boxes at the end of relevant sections.

2. ASSESSING ORNITHOLOGICAL IMPACTS

2.1. Collision with wind turbines

As birds pass through an area during migration or during the course of their daily activities, direct mortality or lethal injury of birds can result from collisions with rotors (Drewitt and Langston 2006). Additionally, mortality or injury can result from collision with towers, nacelles and associated structures such as guy cables, power lines and meteorological masts. There is also evidence of birds being forced into the sea as a result of being drawn into the vortex created by moving rotors (Winkelman 1992b).

The majority of studies of collisions caused by offshore wind turbines have recorded relatively low levels of mortality (e.g. Winkelman 1992a, 1992b, Painter *et al.* 1999, Erickson *et al.* 2001). This is perhaps largely a reflection of the fact that many of the studied windfarms are located away from large concentrations of birds. It is also important to note that many (onshore) records are based only on finding corpses, with no correction for corpses that are overlooked or removed by scavengers (Langston and Pullan 2003). Nevertheless, most Environmental Impact Assessments (EIAs) assume that a very high proportion of birds passing through a windfarm site avoid mortality and injury.

In general quantifying collision risk involves incorporating a high degree of uncertainty. Collision risk depends on a range of factors related to bird species, numbers and behaviour, weather conditions and topography and the nature of the windfarm itself, including the use of lighting (Brown *et al.* 1992; Drewitt and Langston 2006). Many recent assessments have employed a collision risk model (e.g. Band *et al.* 2005) to predict the rate of bird collisions following the construction of a windfarm. Such models are potentially useful but, in order to be effective, require sufficient data on bird movements (numbers, intensity, flight height and angle of approach) under various environmental and temporal conditions to parameterise them. Unfortunately, very few studies of existing developments allow the calculation of reliable avoidance rates and, at present, these only exist for a limited range of species under a restricted range of circumstances. This has led to some EIAs utilizing available estimates of collision risk, even though they may have been derived for different species in different habitats, and without the necessary testing of their relevance (Drewitt and Langston 2006). Moreover, given that very high rates of avoidance are assumed under most circumstances, even a very small variation in the estimated rate of avoidance can lead to very large variations in estimates of mortality (Chamberlain *et al.* 2006).

The net result of the limitations inherent in collision-risk assessment is that there is a very high degree of uncertainty. Typically this uncertainty is incorporated by using a precautionary approach. Assessment of cumulative impacts, irrespective of the precise approach used, entails some form of assessment of impacts from various developments. Since the accuracy of such assessment will always be constrained by the accuracy of assessing the impacts of individual developments, cumulative assessment of collision-risk will inevitably be fraught with similarly high degrees of uncertainty, compounding precautionary assumptions made for each individual wind farm.

2.2. Displacement due to disturbance and habitat loss

Birds may be displaced from windfarms and surrounding areas due to the direct loss of habitat (though this is usually minimal) or due to visual intrusion and disturbance, which can amount effectively to habitat loss. Displacement often occurs during both the construction and operational phases of windfarms. The scale and degree of disturbance will vary according to site- and species-specific factors and is usually assessed on a site-by-site basis (Drewitt and Langston 2006). Studies at Horns Rev found that divers, Gannets, Common Scoters and auks occurred in lower numbers than expected in the windfarm area up to 4 km from the windfarm itself (Petersen *et al.* 2004). However, there are several studies that have examined displacement from windfarm areas, and these studies show that the scale of disturbance caused by windfarms varies greatly. This variation is likely to depend on a wide range of factors including seasonal and diurnal patterns of use by birds, location with respect to important habitats, availability of alternative habitats and perhaps also turbine and windfarm specifications (Drewitt and Langston 2006).

Few studies of displacement due to disturbance are conclusive, primarily because ESs must be prepared prior to construction and thus direct assessment of displacement effects is not possible. Assessment of disturbance effects generally entails assuming that all birds are displaced within the immediate vicinity of turbines, that some of the birds (usually 50%) are displaced within a buffer zone surrounding this footprint areas, but that the influence of the windfarm does not extent beyond the boundaries of this buffer zone. The size of this buffer zone varies, but is intended to be indicative of the distance over which windfarms cause displacement. Typically buffer zones extend for 1 km from the perimeter of the footprint area. It is also worth noting that few impact assessments assume that birds become habituated to disturbance, thus taking a precuationary approach (Npower 2002, 2005; PMSS 2005; RPS 2005; RES 2007).

The construction of turbines and associated infrastructure also causes direct habitat loss. The scale of this direct habitat loss depends on the size of the windfarm project but, generally speaking, is likely to be small relative to the area from which birds are displaced. Typically, actual habitat loss amounts to less than 5% of the total development area (Drewitt and Langston 2006; Fox *et al.* 2006), though effects could be more widespread where developments interfere with geomorphological processes resulting in changes including increased erosion (Drewitt and Langston 2006). Although each turbine is likely to result in minimal direct habitat loss, the scale of offshore developments, especially in the context of relatively limited areas of shallow sandbanks supporting large aggregations of feeding seabirds, is such that their cumulative effects may be significant.

2.3. Barrier effects

Windfarms may also impose an effect on birds by altering their migration flyways or local flight paths to avoid them. This effect is of concern because of the possibility of increased energy expenditure when birds have to fly further and potential disruption of linkages between distant feeding, roosting, moulting and breeding areas otherwise unaffected by the windfarm (Drewitt and Langston 2006). As with other impacts, these barrier effects are dependent on a whole range of factors including the species, the type of bird movement, flight height, the layout of turbines and wind force and direction.

Studies of bird movements in response to offshore developments have recorded wildfowl taking avoiding action between 100 and 3000 m from turbines (Winkelman 1992c, Christensen *et al.* 2004, Kahlert *et al.* 2004b) and that such avoidance occurs even at night (Winkelman 1992a, Dirksen *et al.* 1998, 2000). However, depending on the distance between turbines some birds will fly between turbine rows, for example in the case of Common Eider at Nysted in Denmark, where the turbines are 480 m apart (Christensen *et al.* 2004, Kahlert *et al.* 2004a).

Bird movements around a windfarm are generally assessed using radar but, due to cost and limited range, the number of offshore sites where this technology has been deployed is limited. However, irrespective of costs, barrier effects can only assessed directly after a windfarm has been built and thus only quantitative measures using radar can feed into EIAs and ESs. Nevertheless, a review of the literature suggests that none of the barrier effects identified so far have significant impacts on populations (Drewitt and Langston 2006). However, several windfarms could act cumulatively to create an extensive barrier, which could lead to diversions of many tens of kilometres, thereby incurring increased energy costs.

2.4. Assessing the significance of impacts

Although approaches vary, typically assessment of the likely significance of the impact on each species is assessed using a cross-tabulation of two criteria: the magnitude of the expected effect and the sensitivity of the species in question (following Percival *et al.* 1999). The sensitivity of species has been assessed in different ways and in some instances is impact specific (e.g. different sensitivities are assumed for collision and displacement). One common way, in which the sensitivity of species is assessed, is to consider their conservation importance (e.g. Percival 2001; SNH 2005). For example, cited speces interest features of Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Sites of Special Scientific Interest (SSSIs) are considered very-highly sensitive, other species that contribute to the integrity of an SPA or SSSI or which occur in numbers in excess of 1% of the national population are considered highly sensitive. Those occurring in regionally important numbers or which are of conservation concern (e.g. listed on Annex 1 of the EU Birds, Schedule 1, UKBAP) are considered of medium sensitivity and all others are considered of low sensitivity i.e not sensitive to any effects. Other assessments of sensitivity also take into account the ecology of the species. For example, long-lived species with low productivity and slow maturation rates are considered more sensitive than shorter-lived species (Drewitt and Langston 2006). Other methods consider other species' attributes, such as flight characteristics and sensitivity towards disturbance, which have been combined into a single sensitivity index by Garthe and Hüppop 2004).

The magnitude of the expected effect is determined through the EIA. Total loss or expected declines in excess of 80% are typically considered very high. Major declines in the order of 20-80% are considered high, declines in the order of 5-10% medium, 1-5% low and less than 1% negligible. The cross-tabulation process varies across studies, but typically is as shown in Table 2.4.1..

Table 2.4.1 Matrix of magnitude of effect and sensitivity used to test the significance of effects. The significance category of each combination is shown in each cell (see Percival *et al.* 1999).

Magnitude of impact	**Sensitivity**			
	Very High	**High**	**Medium**	**Low**
Very High	Very High	Very High	High	Medium
High	Very High	Very High	Medium	Low
Medium	Very High	High	Low	Very low
Low	Medium	Low	Very low	Very low
Negligible	Low	Very low	Very low	Very low

However, particularly in the assessment of impacts on populations of European importance, the threshold for significance is less formulaic. Often, consideration of whether there is an impact on the "integrity" of the population that forms the interest feature of the European site that may be affected (IEEM 2006). In practice, determining what constitutes an impact on "integrity" is rather subjective and a default threshold of 1% change is often used in the first instance.

3. A REVIEW OF EXISTING METHODS FOR CUMULATIVE IMPACT ASSESSMENT

3.1. General methodology

EIAs generally have five stages: (1) screening / scoping, (2) data gathering, (3) analysis, (4) test of significance and (5) reporting. It has been proposed that CIA be integrated with all of these processes (Norman *et al.* 2007). In general however, it is more usual to give cumulative assessment post-hoc treatment in the reporting phase, although in some instances some analyses are undertaken. It is sometimes considered in the scoping phase, but only in the most general terms and the need for CIA only rarely results in additional data collection. In this section, the nature of the way in which cumulative impact assessment has been carried-out to date is described. We also describe the range of ways in which CIA has been undertaken by referring to specific examples, in which different approaches were used.

3.1.1. Screening and scoping

Typically, scoping tends to focus on project specific matters and although CIA is usually recognised as a requirement, it is usually dealt with in general terms (Norman *et al.* 2007). However, the process of scoping provides an opportunity to identify, at an early stage, the nature of potential cumulative impacts, leading to clearer identification of information requirements. This stage is discussed in more detail in the accompanying paper by Andrew Prior.

3.1.2. Data gathering

In most instances, little, if any additional data gathering occurs specifically for CIAs, although on the whole, data, particularly from aerial surveys, are collected over an area that extends well beyond the windfarm footprint and buffer areas for other reasons (e.g. Cranswick *et al.* 2007). The availability of data from entire regions make it possible to gain insight into effects on populations that forage over large areas (e.g. Common Scoter and divers) and to assess the likely impacts of other developments occurring within the same region. Likewise, the use of radio-tracking to assess the relative importance for foraging of areas occupied by windfarms (e.g. Perrow *et al.* 2006) could be used to determine the range over which specific features of SPAs forage and thus, the likelihood of them being affected by any offshore development identified as contributing cumulative effects.

3.1.3. Data analyses

A wide variety of approaches has been used to assess cumulative impacts. Some ESs do not give any quantitative details of cumulative effects, relying instead on qualitative interpretation, whereas others provide quantitative assessment. In some instances, all other relevant developments are considered (PMSS 2005; RPS 2005), but in other instances (RPS 2007), only the cumulative effects of other windfarms are considered. Issues of scale and the area over which cumulative assessments are carried out differ. Some consider cumulative effects of developments occurring within Round 2 strategic areas (PMSS 2005), whereas others examine cumulative impacts within functional ecological units such Liverpool Bay (Npower 2002). In some instances there are limitations that constrain the effectiveness of the

CIA process and the highly varied approaches mean that objective comparisons of cumulative impacts across developments are difficult to make.

3.1.4. Test of significance

There are a number of different ways in which cumulative impacts have been assessed to determine their significance. Most follow the basic approach adopted when conducting EIA, whereby likely significant impacts on different species are determined by considering both the magnitude of the impact and sensitivity of the species. Indeed, for the most part, the significance of cumulative impacts has been considered in a manner similar to the significance of environmental impacts generally.

Despite these generalities, the concept of "significance" has been interpreted in remarkably diverse ways. In some instances, such as with cumulative impacts reported in the Environmental Statement in relation to the London Array windfarm, cumulative impacts were considered to be insignificant because the additional effects of the *other* windfarms were low in comparison to that of the London Array (although subsequent assessments examined cumulative impacts by summing effects). In other instances, for example when considering cumulative impacts in relation to the Greater Gabbard, cumulative impacts were considered to be unimportant because the impact of the windfarm *itself* is low in comparison to that of other impacts. This somewhat paradoxical approach of considering the additional impact of the windfarm with a lesser effect, will inevitably lead to a biased interpretation in which cumulative impacts are considered of low importance. A third approach, which has been used and is not subject to such bias, has been to identify all developments contributing cumulative impacts and simply to sum their effect.

3.1.5. Reporting

The environmental statement is the main method of reporting on outcomes of impact assessments, including CIAs. In some instances, discussion papers on cumulative impacts over a broader area have also been produced (PMSS 2004). Most studies only consider cumulative impacts during the operational stage, or at least do not specifically differentiate between construction cumulative impacts and those occurring at other times. However, the limited plant available to build offshore windfarms, means that projects are likely to be built sequentially and not overlap temporally. Nonetheless, there is scope for concurrent construction in terms of piling to install turbine bases at a site with installation of topsides (nacelles and blades) at another. Moreover, there is a need to consider the construction and operational phases separately as the cumulative impacts of two windfarms during the operational phase may not be the same as for one windfarm during the construction phase combined with another during the operational phase.

3.2. Specific examples

3.2.1. London Array

The CIA approach used for the proposed London Array (RPS 2004) was to discuss with English Nature (now Natural England) and identify five key categories of existing or planned activity within the Thames estuary area that could potentially contribute significantly to impacts on birds in combination with the construction and / or operation of the London Array Windfarm. These categories were:

(1) Other windfarms
(2) Marine aggregates extraction

(3) Capital dredging
(4) Shipping
(5) Submarine cable installation.

The potential cumulative impacts were assessed for the one species (Red-throated Diver), which was expected to experience a greater than negligible adverse effect due to the presence of the London Array. In so doing, there is an inherent assumption that negligible effects cannot accumulate to become non-negligible. For most of the categories, the assessment was qualitative, being quantitative only when the cumulative impacts of other windfarms were considered. The quantitative method used was as the "interaction with proportional distribution method", in which the distribution (and/or relative abundance) of species is mapped and the proportion of the population encompassed by the windfarm footprint and buffer area is assessed.

Issues	Method adopted
Developments considered:	Proposed windfarm and other developments.
Area considered:	Thames estuary.
Key cumulative impacts investigated:	Red-throated Diver displacement.
Key techniques employed:	Quantitative: interaction with proportional distribution.
Assessment of significance	Other developments relative to London Array in ES; Summing in subsequent assessments).

3.2.2. Greater Gabbard

The CIA approach for the proposed Greater Gabbard windfarm mainly considered those cumulative impacts arising through the construction of additional windfarms rather than other categories of activity (PMSS 2005). However, the Environmental Statement does note other developments, i.e shipping (e.g. port expansions at Harwich Haven and London Gateway), marine aggregate extraction and capital dredging. Cumulative impacts were discussed both when the significance of the likely impacts from the proposed Greater Gabbard Offshore Windfarm alone was at least moderate and when there is was realistic possibility of cumulative impacts being capable of raising the assessed level of significance. No quantitative assessments of cumulative impacts were made, except in so far as noting that since effects of indirect loss of habitat through disturbance / disruption of flight-lines and collision risk were considered of Very Low to Low Significance and as such, the additional impacts of the Greater Gabbard were likely to be low in comparison to that of the London Array. This was largely because the information necessary for quantitative CIA was lacking.

Issues	Method adopted
Developments considered:	Proposed and existing windfarms.
Area considered:	Thames strategic area aerial survey blocks.
Key cumulative impacts investigated:	Displacement & collision of all species; emphasis on those occuring in nationally important numbers.
Key techniques employed:	Qualitative.
Assessment of significance	Greater Gabbard relative to other developments.

3.2.3. Anonymous site (Commercially Sensitive – ES in preparation)

The CIA approach for this site was to consider those cumulative impacts arising through the construction of additional windfarms rather than other categories of activity. In many respects, it is one of the most robust and rigorous assessment of cumulative impacts of the examples given here. All windfarms within the strategic area within the planning process as well as those that have been consented were considered in the assessment of cumulative impacts. Cumulative impacts were considered both during the construction and operational phases. In so doing, a realistic assumption was made that on the whole, simultaneous construction of windfarms is unlikely due to limited plant, but a worst case-scenario of increased boat traffic during construction of three sites simultaneously as sufficient plant exists to install turbine bases at one site while simultaneously installing nacelles and blades at others.

Using the matrix approach typical of Ornithological Impact Assessments (Percival 2001; SNH 2005), a matrix of impacts was constructed for all possible impacts and potentially sensitive species. Any species identified as sensitive in any of the Environmental Statements for each development was selected for inclusion and impacts were assessed in an additive manner where possible. Since cumulative impacts can occur only if a species occurs at more than one site, those species which occurred only at one site were excluded. Cumulative disturbance impacts were assessed by combining the sensitivity of the species with the magnitude of the effect (using Garthe and Hüppop 2004) to produce a significance of impacts for each site separately and a score assigned to each indicative of the impact. These scores were then added together to determine the final score. Cumulative displacement impacts during operation were assessed by determining the abundance of birds within each windfarm and buffer zone using aerial survey data and then comparing the maximum population of birds in the combined sites to the overall maximum population within each aerial survey zone (Cranswick *et al.* 2007).

In manner similar to the interaction with proportional distribution method, regional aerial survey data were used to map the relative abundance of species and an assessment of the extent to which the species showed preferential use of each windfarm area and all windfarm areas combined was made using Jacob's Selectivity Index (Jacobs 1974). Predicted cumulative collision mortality for each species at each site where this was available was combined by summing to give an overall annual mortality rate. The significance of both the additive mortality (proportion of birds colliding compared to the total population) and the percentage increase above background mortality was assessed using the same method as for the EIA.

Issues	Method adopted
Developments considered:	Proposed and existing windfarms.
Area considered:	Round 2 strategic area.
Key cumulative impacts investigated:	Displacement, collision & disturbance of any species considered as potentially sensitive at any site provided it occurred at more than one site.
Key techniques employed:	Quantitive: Disturbance - Garthe and Hüppop scores, Displacement - Jacobs Selectivity Index, Collision – sum of annual rates.
Assessment of significance	Greater Gabbard relative to other developments.

3.2.4. North Hoyle

The CIA approach for the proposed North Hoyle windfarm was to consider existing developments around the coast and waters of Liverpool Bay as part of the existing environment, even if they do not affect bird populations, and to suggest that they form the existing environment against which any predicted change should be measured. It was thus considered impossible to assess cumulative effects against the bird populations that might exist in the absence of all these activities and possible only to assign a level of risk to the Liverpool Bay seabird populations from one or any combination of the proposed projects.

One of the arguments for the above, was that for SPAs the "favourable status" that should be maintained relates to the habitats that support the population level for which a SPA is classified and not that which supports a hypothetical population that could exist in the absence of existing activities. This is indeed true if the developments have been ongoing since prior to SPA designation, or as is the case for Liverpool Bay, the area is a potential, rather than existing SPA. However, there are other regulations that specify the need for CIA. Although these other regulations do not specifically state that ongoing developments should be considered as contributing impacts, rather than being part of the baseline, there is an inherent assumption that they should be considered. For example, the guidelines for managing Natura 2000 make specific reference to the need to take account of progressive loss of site integrity. The use of the term "progressive" logically implies that the impacts of each proposed development should be considered in relation to previous developments as, in this context, it is clearly taken to refer to changes occurring through time. Moreover, the concerns associated with developments that underpin the regulatory needs for cumulative impact assessment is that the impacts of any given development in its own right may not be significant, but in combination with others, both existing and proposed, the overall impacts are significant.

In relation to seabird populations, cumulative effects were thus considered in relation to proposed windfarms for development in Liverpool Bay, although it was highlighted that little useful baseline information existed from which the cumulative effects of other offshore activities could be assessed. Thus, to assess the risk of those potential impacts on bird populations, a semi-quantitative assessment was undertaken. Cumulative effects were assessed by summing the known or estimated proportion of populations occurring in European or nationally important numbers within the area over which there was considered to be a risk of impact. Regarding both cumulative collision risk and cumulative habitat loss, it was argued that, since the observed bird movement through the North Hoyle site were so small and there was little habitat or feeding potential for important seabird populations in the site or in the area surrounding it, it could be concluded that the proposed North Hoyle Offshore Windfarm will not of itself contribute to the risk of cumulative impact. It should be noted, that using this line of argument, cumulative impacts would only be perceived as of risk, if the environmental impacts of a particular project were perceived as of risk. This approach does not guard against the possibility that cumulative effects, while not being significant in their own right, may act in combination to result in a significant effect.

To assess the cumulative impacts of disturbance, the proportion of seabird populations at risk due to North Hoyle and nearby Rhyl Flats, was summed and then assessed against sensitivity in the same way as for the EIA to determine the overall significance of the impact. The cumulative effects due to other windfarms were assessed in a qualitative way due to lack of data. Analyses focused on populations of European and national importance.

Issues	Method adopted
Developments considered:	Proposed windfarms.
Area considered:	Liverpool Bay.
Key cumulative impacts investigated:	Displacement of populations occurring in European or nationally important numbers within areas considered at risk of impact.
Key techniques employed:	Semi-quantitative by summing populations where possible
Assessment of significance	Greater Gabbard relative to other developments

3.2.5. Gunfleet Sands II (GS2)

The CIA approach for the proposed Gunfleet Sands II windfarm was to consider cumulative impacts arising from other offshore wind developments in the Thames Estuary only. However, other developments were not included. Cumulative impacts associated with habitat loss were not quantified but were argued to be negligible on the basis that the area of seabed directly affected by windfarm construction and operation would be very small. Cumulative impacts arising due to displacement effects were assessed, giving consideration to the extent to which construction of different windfarms would occur concurrently. On the basis that cumulative effects had been assessed for the London Array and were found to be negligible and because of the relatively small magnitude of the predicted displacement effect arising from Gunfleet Sands, cumulative impacts arising from displacement effects were considered to have no effect on any species. It is worth noting that the CIA for London Array noted that there was no significant cumulative effect because the impact of Gunfleet Sands (and Kentish Flats) was low in relation to the London Array, but did not consider the impacts arising by summing impacts from each development and in particular, did not consider the contributing component of the London Array itself in the CIA process. For this reason, the CIA that is presented in the ES for Gunfleet Sands II (based only on the impact of Gunfleet Sands and the CIA for London Array) does not actually consider cumulative impacts arising due to the London Array. Moreover, it is difficult to see how a conclusion of “no effect” can be derived by considering component impacts, which all have an effect, albeit negligible or relatively low. It should be noted however, that a sunsequent asssessment of cumulative impacts within the Thames Estuary area was made.

Similarly, cumulative impacts arising as a result of collision and barrier effects were considered to have no impact because no significant impact from any of the component windfarms feeding into the CIA were significant. Again, it is difficult to see how a conclusion of “no effect” can be derived by considering component impacts, which all have an effect. Importantly also, the fact that no attempt was made to sum the effects in a quantitative manner and as such, a significant effect would only result if one of the component developments had a significant effect, rather undermines the reason for carrying-out a CIA in the first place.

Issues	Method adopted
Developments considered:	Windfarms only
Area considered:	Thames estuary
Key cumulative impacts investigated:	All cumulative impacts considered to be negligable
Key techniques employed:	qualtitative
Assessment of significance	Gunfleet Sands !! relative to London Array

3.2.6. Lincs offshore

The CIA approach for the proposed Lincs offshore windfarm was to consider cumulative impacts arising from other offshore wind developments only. Consented Round 1 sites as well as proposed Round 2 sites for which data existed were incorporated into the assessment. The broad approach was to assume that any identified impacts could potentially occur on a cumulative level and as such, the standard matrix analyses used for the EIA was performed for the CIA incorporating other windfarm developments in an additive manner wherever this was possible. Those sites for which no data existed were excluded from the assessment, thus making the assumption that they have no effect.

The analysis was not limited to species identified as sensitive at Lincs, but also included an analysis of how Lincs might impact cumulatively on species identified as sensitive at other sites. Where species were listed in ESs as groups, e.g. ‘geese’, and ‘divers’, these were assumed to be Pink-footed Geese and Red-throated Divers, which were the most sensitive species at Lincs, in order that the worst-case scenario could be assessed.

The general aim of the analyses was to produce a measure of the cumulative impacts of all four developments on the regional populations of potentially sensitive species in the context of the national and international importance of the regional populations of these species. The sensitivity of each species was thus classified in the same manner as in the analysis of impacts of the Lincs development alone. Where sensitivity was determined on the basis of the numbers present (as a result of 1 per cent of the national population) in the EIA process, this sensitivity was also applied during the CIA process as numbers at all sites would inevitably be in excess of the 1% threshold. However, when numbers did not exceed 1% thresholds at any given site, no quantitative assessment was made of whether 1% thresholds were exceeded when numbers from all sites were added, although this issue was partially addressed qualitatively.

Cumulative impacts during construction and decommissioning were assumed to be negligible, if negligible at all sites, thus assuming that negligible impacts do not accrue to become non-negligible. This is partially justified as being necessary due to data constraints. During the operational phase, numbers from the aerial surveys from each of the sites were added to assess impacts.

Issues	Method adopted
Developments considered:	Other windfarms
Area considered:	Round 2 strategic area.
Key cumulative impacts investigated:	All species identified as sensitive at Lincs or any of the other sites
Key techniques employed:	Aerial surveys data used to calculate peaks for the area
Assessment of significance	Summing

3.2.6. Other Assessments

In additional to CIAs carried out for ESs, there have been a number of broader and/or more detailed assessments that have been undertaken for key species, as additional information is often requested by statutory agencies or to inform the appropriate assessment. Several of these assessments are briefly described here.

Individual-based models

This technique was applied to assess Common Scoter mortality in Liverpool Bay. Liverpool Bay is by far the most important site in the UK for Common Scoter, regularly hosting in excess of 60,000 birds (Austin *et al.* 2008). To assess the cumulative impacts of displacement from potential feeding habitats through the avoidance of windfarms in Liverpool Bay, COWRIE commissioned a study that used field observations and surveys combined with an individuals-based modelling approach (Kaiser *et al.* 2002). Model simulations were run to predict the cumulative impacts of various existing and consenting wind farms.

The computer code developed for this model is generic and could be applied to a very wide range of consumer-resource systems including assessments of disturbance and barrier effects. The model is based on fundamental ecological principles such as fitness maximisation by individual animals that will apply under any change to environmental circumstances. However, in order to tailor the model to specific circumstances, it is necessary to collected detailed information so that accurate values can be ascribed to the model parameters. The model did not produce an absolutely perfect fit to the distribution of common scoter across the bay, suggesting that some of its predictions may be unreliable. However, overall, there was good quantitative agreement between model outputs and a variety of independent empirical data. It was found that the presence of a windfarm on Shell Flat which, in combination with the others, leads to significantly increased common scoter mortality.

Radio-tracking

This technique was applied to Little Terns of the East Norfolk Coast. Scorby Sands offshore windfarm encroaches to within 2 km of the most important breeding site for Little Terns in the UK: the Great Yarmouth North Denes Special Protection Area (SPA). In order to assess the relative importance of the area occupied by this windfarm ratio-telemetry was used (Perrow *et al.* 2006). The same principal could be applied to determine the relative importance of more than one area (although at present, there are technical limits to what distance terns can be tracked over. Many seabirds travel widely to exploit variably distributed prey resources, utilizing even profitable patches only briefly as prey become available. Assessing the relative importance of areas occupied by windfarms relies on sufficient survey effort to increase the probability of detection and later assessment to an acceptable level. Conventional techniques suffer from high sampling costs and infrequent sampling of patches within larger areas, but remote techniques, which continuously sample habitat, may offer a solution.

Although there were technical difficulties associated with tagging and subsequently following this small seabird, resulting in limited data collection, comparative data from 2 years (2003 and 2004), revealed striking differences in activity and foraging patterns, which changed the perception of the scope of the birds. Actively breeding birds occupied a much smaller range than failed breeders, suggesting that the impact of windfarms may differ substantially in years with good food availability than in years with poor food availability. The potential value of radio (and satellite) telemetry in illustrating habitat use within a wide area, is that it provides a more detailed means of risk mapping – i.e. identification of whether windfarm areas are located in important foraging areas. It could also be used set precautionary distance limits for wind farms from important breeding sites.

Mapping species abundances.

Mapping the abundance of species over a wider area is a highly informative way of assessing the proportion of the population with which developments are likely to interact and thus can be used to assess the significance of cumulative impacts. They could also be used to identify high-risk areas, thus informing various windfarm options. At its simples, this method entails plotting mean or peak numbers (as recorded by boat or aerial survey) within 2 km x 2km grid cells (e.g. PMSS 2005). Other more sophisticated techniques have been developed for doing this, which involve spatial kriging algorithms and/or the incorporation of habitat variables (e.g. RPS 2004; Newson & Noble 2003). In many instant the production of such maps forms part of the baseline assessment and it is thus a straightforward task to apply these maps in a CIA context. One method, which offers considerable scope would be to use dynamic oceanographic variables (i.e. ones which vary through time) to map species abundances. The use of such variables is essential if windfarm induced changes to bird populations are to be detected with high certainty (Maclean *et al.* 2006; 2007). However in the context of impact assessment it would be highly advantageous in identifying where concentrations of seabirds may occur at times other than the snap-shot period in which surveys are carried-out.

Population Viability Analyses

Population viability analysis (PVA) is a species-specific process used to identifying the process that determines the probability that a population will go extinct within a given number of years (Shaffer, 1983; 1987; Boyce 1992) and is thus used to identify the most important threats facing a particular species population. It differs from conventional population modelling in that it takes into account stochastic events, i.e. random changes in demographic rates such as survival or productivity. As such, it is the variability in demographic parameters that is as important as mean values and the greater the variability, the more prone a population is to extinction all other things being equal. PVAs are often used to reveal the sensitivity of populations to particular demographic parameters so that the most important impacts on extinction probabilities can be determined. Extrinsic forces, such as habitat loss, over-harvesting, and competition or predation by introduced species, often lead to population decline. Although the traditional methods of wildlife ecology can reveal such deterministic trends, random fluctuations that increase as populations become smaller can lead to extinction even of populations that have, on average, positive population growth when below carrying capacity and mechanisms that incorporate intrinsic factors are needed if extinction risks are to be determined (Lacy 1993).

PVAs can be used to address several questions, and often the nature of these changes during the course of a PVA analysis as the process is refined. Typically, initial questions are very general, such as "Is this species threatened, and if so, why?" PVAs often then concentrate on the identification of factors (including natural factors and human impacts) that are important in dynamics of the specific populations and meta-populations under study, as well as conservation and management options. The methods to be used for this depend on the specific case at hand, and might include statistical analysis of historical data, comparison of populations that are declining with those that are stable, and correlating recent changes in the environment (climatic or habitat changes, introduced species, changing harvest patterns, etc.) with changes in the species. In the context of cumulative impact assessment, the broad question is “do several offshore windfarms acting in combination have a deleterious effect on bird populations?” Specific questions are likely to be “what is the maximum level of windfarm-induced mortality that can be absorbed by bird populations of species X, so that the overall population does not decline by an amount greater than Y within Z years” or “given that windfarms cause X number of bird species Y to die, by how much will the population decline within Z number of years?”

However, there are some limitations with regards to what population viability analysis can achieve. Mortality resulting from windfarms may reduce competition for resources, thus reducing the rate of natural mortality. The extent of the latter cannot be determined solely through conventional population viability analysis, but also requires detailed understanding of the extent to which demographic parameters are density-dependent. Reasonable data on density-dependence are only available for three species: cormorant, shag and kittiwake (Maclean *et al.* 2007).

Tool	Use	Limitations
Individual-based modelling	To provide actual estimates of mortality resulting from displacement. Could also be used to obtain mortality estimates from disturbance and barrier-effects.	Difficult to parameterise models. Requires intensive data collection
Radio-tracking	To provide a detailed assessment of habitat-use in areas in which windfarms are located	Technological constraints on how big an area can be covered and on how much data can be collected. Labour intensive.
Distribution mapping	To assess proportion of population with which developments interact; identify high-risk areas (i.e. those with high bird densities)	Best method of mapping likely to be species- and location-dependent.
Population Viability Analysis	To assess effects of windfarm-induced mortality on population size and likelihood of persistence	Limited data availability and very costly to collect more data. Requires measures of density-dependent demographic parameters, which is currently only available for three species.

4. CUMULATIVE IMPACT ASSESSMENT

4.1. The need for Cumulative Impact Assessment

4.1.1. Regulatory needs

Windfarm projects are proposed for various consents through a variety of regimes. However, the lead consent is likely to be Section 36 of the Electricity Act, the EIA of which is carried out under the Electricity Works (Environmental Impact Assessment) (England and Wales) Regulation 2000. Schedule 3 to these Regulations requires that in addition to the individual potential environmental effects of a proposed development, the potential for cumulative effects should be considered and, where appropriate, assessed. In Scotland, Schedule 4 of the EIA(S) Regulations 1999 specifies matters to be included in an Environmental Statement, and includes under item 4 " a description of the likely significant effects of the development on the environment, which should cover the direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the development….". Additionally, the EC Habitats Directive 92/43/EEC, in Article 6(3), states "any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or *in combination* with other projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives". Similarly, the EU guidance document for managing Natura 2000 sites indicates that "..it is important that some account is still taken of such plans and projects in the assessment, if they have continuing effects on the site and point to a pattern of progressive loss of site integrity". For most purposes, cumulative, progressive and in combination effects are considered to be the same.

4.1.2. Definitions of Cumulative Impact Assessment

There are numerous definitions of cumulative effects and cumulative EIA and agreeing a definition of cumulative impact has proved contentious (Norman *et al.* 2007). In a COWRIE workshop designed to address issues associated with cumulative impact assessment, it was recognised that there are two classes of factor to be addressed – timescale and source of impact – and that both these need to be explicitly reported upon (Norman *et al.* 2007). With regard to timescale there are four components – past (historic) impacts, current impacts, impacts not yet manifest but that will occur due to factors already operating and future predicted impacts. With regard to source of impact there are four components - the proposed windfarm, other windfarms, other projects that have been given consent or are reasonably foreseeable and activities such as fishing and boat traffic that are not consented on a project basis. We propose three additional that should be considered: (1) which species should be included in CIA, (2) how to ensure a compatibility of outputs from each EIA, so that CIA can be undertaken and (3) what area should be used to delineate the boundaries of the reference population and that in which assessments should be considered. The lack of formal definitions, particularly with regard to the intended reason for and desired output of conducting a CIA, has constrained the delivery and effectiveness of CIAs.

4.1.3. Selecting species for inclusion in CIA

At present there are no clear guidelines as to what features should be included in CIA. As a consequence, a variety of approaches have been used. One of the most common to only select those species for which a significant effect is expected in one or more of the contributing developments. However, this approach does not account for the possibility that several non-significant impacts may accumulate to become significant. An alternative approach is to consider all species. This has its merits, but is likely to be highly time-consuming if done rigorously for all possible impacts and in many instances, even the cumulative impacts are likely to trivial. A reasonable compromise might be to introduce a screening procedure for identifying which species should be included in the cumulative impact assessment, including those that are non-significantly, but almost significantly impacted by individual developments, but excluding those for which the impacts of individual developments are truly trivial. Problems arise as it is difficult to provide guidance for this screening procedure, particularly as broad guidance may be inappropriate, and screening necessary on a windfarm by windfarm basis. This inevitably introduces a high-degree of subjectively into the process and is likely to lead to approaches of varying rigour being used.

Species for inclusion	Issues
Option A: consider only those species for which there is a significant impact is expected in one or more of the contributing developments	Does not guard against non-significant impacts accumulating to become significant.
Option B: Consider all species	Potentially costly and time-consuming if done rigorously for all impacts
Option C: Implement a screening procedure to select species for inclusion in CIA	Subjective interpretation of screening procedure could result in approaches of varying rigour being used.

4.1.4. Ensuring compatibility of EIA outputs so that CIA can be conducted

One of the major stumbling blocks to carrying-out quantitative CIAs is that at present, different EIAs use different approaches and the outputs of each are not necessarily compatible or useful the sense that can be summed for example. The best and easiest way to address this issue would be to provide very explicit guidelines with respect to what outputs should be produced from EIAs and to make these a requirement of the EIA process. All that would be needed to perform CIA would be to obtain this outputs and combine them using simple algebra, such as summing. We urge strongly that such guidelines should be set in place in time for the Round 3 assessments. The alternatives would be (1) to make all data publicly available so that compatible outputs can be calculated from first principals or (2) to continue the status quo of qualitative assessments where quantitative CIAs cannot be carried-out. In many instances, particularly those in which assessments have been performed by different consultants or where wind farms are operated by different companies within a windfarm strategic area, the necessary data is likely to be commercially sensitive. The present method of performing qualitative assessments in many instances, is highly subjective and has lead to assessments that differ substantially in quality and rigour.

Ensuring compatible outputs	Issues
Option A: ensure compatible outputs from individual EIAs by providing further EIA guidance	Production of such guidelines may not be ready in time for Round 3.
Option B: ensure greater data sharing so that compatible outputs can be calculated	Data may be commercially sensitive
Option C: maintain status quo and carry-out qualitative assessments where quantities assessments are not possible	Highly subjective and likely to lead to assessments that differ substantially in quality and rigour

4.1.5. Cumulative impacts and time-scale

None of the regulations that refer to the need for cumulative impact make specific reference to the time-scale over which cumulative impacts should be assessed, nor which of past, present and proposed developments should be included. Thus, the time-frame over which cumulative impacts have been assessed has varied from windfarm to windfarm. Some, such as North Hoyle, have considered only proposed developments, arguing that others form part of the baseline environment. Most others consider all ongoing developments. We argue that it is more relevant to include all ongoing developments. Regulatory needs for CIA stem from concerns that as more developments occur, the environment is degraded through time in a manner that would go unnoticed if each development were considered in isolation. To illustrate the logical inconsistency of considering ongoing developments as part of the baseline environment, we consider what would happen if developments were proposed sequentially such that each were assessed prior to further developments being announced. Under such circumstances, cumulative impacts over and above the impacts of each development in isolation would always be zero and any cumulative effects arising from the combined effects of all developments would go undocumented even if 100% of the natural environment were destroyed.

There is some argument to be made that this may not be relevant with regards to designated features of SPAs being maintained in "favourable status", since the features that should be maintained relate to population levels for which an SPA is classified and not the hypothetical population that could exist in the absence of existing activities. We propose that the most consistent and logical way in which this should be interpreted should be to consider all ongoing activities if the site is already designated. However, where a site is a proposed SPA, the cumulative impacts of developments should be considered on species assigned as highly sensitive because they are candidate SPA designated features, if that development is expected to have resulted in increased impacts since the baseline survey for site designation. Nevertheless, the cumulative impacts of all ongoing developments should also be assessed on these species, but by assigning them to whichever sensitivity category they would be assigned to if they were not designated features of the proposed SPA. The overall significance of the impact should be assessed using both methods, and which ever is highest taken as the actual significance of the impact. However, in the context of Round 3 developments, as few lie adjacent to SPAs, there would rarely be a need to do both.

There is also an issue of time-scale with respect to mortality from collision, as the overall estimate of mortality will increase if longer assessment periods are used. This issue is not specific to CIA, and should ideally be addressed by adhering to EIA guidelines. However, since no such guidelines have been produced we recommend that collision mortality be reported as a rate, and the significance of this mortality be assessed by taking into account life-history characteristics of the species in question, such that longer-lived and slow-reproducing species such as Fulmar are considered more sensitive to any given mortality rate than shorter lived, faster breeding species such as Wigeon. The biological justification for this approach is that mortality from any source (including collision) will be at least partially compensated for by recruitment into the population. Particularly so if there is competition for resources and lower mortality of other individuals associated with the local population occurs due to the reduced competition for resources that would result from such mortality (Perrins *et al.*1993). However, there is generally a time-delay and it is widely recognised that long-lived species, which reproduce slowly, are far less able to compensate for such mortality, and the overall impact on populations of these species would thus be higher (Maclean *et al.* 2007).

Time-scale	Issues
Option A: consider all ongoing developments	Not method most frequently adopted/ may not be legally required.
Option B: Consider only proposed and consented developments:	Does not guard against baseline degradation (i.e. gradual degradation of environment through time)
Option A: Report collision mortality as rate:	Easier to assess against life-history parameters (e.g. longevity of species)
Option B: Report collision mortality as absolute amount over defined time-period	Gives overall mortality figure to compare to population thresholds but selection of time period arbitrary?

4.1.6 Cumulative impacts and source of impact

None of the regulations that refer to the need for cumulative impact make specific reference to what type of developments cumulative impacts should be assessed for. To date, several types of development have been considered. Some, such as the assessment of North Hoyle considered only those accruing from other windfarm projects. Others, such as that for the London Array and Greater Gabbard considered other types of development such as shipping and aggregates extraction. None to our knowledge consider cumulative effects of windfarms with climate change and fishing pressure, two of the major causes of seabird declines, (Frederiksen *et al.* 2004; Harris *et al.* 2005, Wanless 2005), although generally this is not required and, if part of the baseline then arguably not necessary.

The Electricity Works (Environmental Impact Assessment) (England and Wales) Regulation 2000 states that regulatory needs for CIA refer only to any application under section 36 of the Electricity Act 1989 for consent to construct, extend or operate a generating station. While it is clear that CIA only needs to be carried-out only for such generating stations under these regulations, nowhere are "developments" (as referred to in the regulations in relation to CIA" clearly defined. However, with the exception the EU guidance document for managing Natura 2000 sites, all regulations refer either to "projects" or developments". The Natura 2000 guidance refers to both "plans" and projects".

We interpret the relevant regulations, statutory clauses and guidance documents as referring to all developments and projects, not just windfarm projects. However, we interpret that the term "project" or "development" does not refer to longer-term and wide-scale issues such as climate change and fishing pressure.

Source of impact	Issues
Option A: consider all projects / developments	Not method most frequently reported in Environmental Statements
Option B: Consider windfarms only	Existing regulations and guidelines seem to imply that this is required

4.1.7 Cumulative impacts and area / reference population

None of the regulations that refer to the need for cumulative impact make specific reference to the area in which cumulative impacts should be assessed, nor what constitutes the population against which impacts should be assessed. However, where the need for CIA stems from the EU Habitats Directive and Natura 2000 guidance, one can infer that the area is that which is used by designated features of these sites and the reference population is that hosted by the site. As a result of lack of clear guidance, windfarm assessments have been quite varied in their approach. The most common is to consider only those additional developments and populations occurring within Round 2 strategic windfarm areas. Others, such as the assessment for North Hoyle consider a "discrete biogeographical area" such as Liverpool Bay the most appropriate in which to consider cumulative impacts.

In general terms, the larger the area that is considered, the more developments that are likely to be encompassed and thus the greater the cumulative impact. However, if the standard matrix approach is used (Table 2.4.1), then the reference population against which the magnitude of the effect is assessed also increases with area. Thus, although the use of a larger area will result in a higher cumulative impact, the impact per unit area being equal, the significance of the impact will be the same (provided the same sensitivity criteria are used). Problems associated with using a larger area, stem not from the magnitude of the cumulative impact itself, but from the availability of data and difficulties of assessment within this wider area. If a larger area is used, it may be more costly to carry out the assessment, but benefits are likely to arise because a more strategic approach is taken.

Much of the regulatory need for CIA stems from legislation and guidelines associated with the EU Habitats and Birds Directives and from Natura 2000 guidance and it may not be relevant to consider too large an area, because the protected features may utilise only part of it. However, in the context of Round 3, most of the proposed sites are far offshore and not adjacent to currently designated SPAs and determining use by SPA features may be problematic in any case.

Thus in summary, there is an absence of clear guidance as to what area should be used for CIA, and while the adoption of a large area may be strategically beneficial there would be practical constraints in so doing. For these reasons, we propose that the Round 2 Strategic Windfarm Areas (Thames, Greater Wash and North-west) or the strategic areas identified in Round 3, be used. However, where such areas demonstrably do not constitute a discrete functional unit, because regulatory needs for CIA stem in part from the EU Habitats and Birds Directives and due to ongoing efforts to designate marine SPAs, we propose that in some instances, the same principals as are used to designate SPAs in which functional units are defined, be used to identify appropriate areas for CIA. A detailed discussion of these principals is provided in Stroud *et al.* (2001), but in essence the process entails identifying an area that is distinct in habitat and/or ornithological importance from surrounding areas. In the context of marine environments this may be hard to assess, but bathymetry may offer a useful clue as it is of high importance in determining both habitat and species. Furthermore the mapping of species distributions as part of baseline assessments would allow discrete populations to be identified.

However, although terrestrial and coastal sites generally have obvious hydrological or physical boundaries, such boundaries are less obvious at sea. One method which offers considerable scope in the identification of such areas is to use Marine Classification Criterion based on relative species densities (Skov *et al.* 2006). Using real data collected from the North Sea and Baltic, they were able to demonstrate that the application criterion could be used to identify and delineate concentrations of seabirds. This method offers some scope for delineating the boundaries of concentrations of seabirds, but is likely to be costly to implement. We thus suggest that strategic wind farm areas are used as a default, but if demonstrably unsuitable, then identification of cumulative impact areas / reference populations should assessed on a case-by-case basis following SPA principals.

Area / reference population	Issues
Option A: define discrete functional unit using SPA principals	Ecologically sensible, but rather subjective
Option B: use Round 2/3 Strategic Areas	Easy to define, but may not be most appropriate ecologically

4.2. Cumulative impacts due to collision

Cumulative impacts due to collision arise primarily because of the development of more than one windfarm within an area. However, they could also arise if other types of development involve the erection of structures into which birds could fly, although in practise such developments are rare and estimates of collision difficult. The mathematically correct way in which to calculate cumulative impacts due to collision is as follows:

$$C_T = C_1 + C_2\left(\frac{P - C_1}{P}\right) + C_3\left(\frac{P - (C_1 + C_2)}{P}\right) ..... + C_n\left(\frac{P - \sum_{n-1}^{0} C_{n-1}}{P}\right)$$

where C_T is the total cumulative mortality due to collision, P is the population size of the bird in question, C_1, C_2 etc are the cumulative mortalities due to developments 1, 2 etc and n is the total number of developments. Technically, the cumulative effects arising from each development cannot simply be summed, as once removed from a population due to collision with one development, the bird cannot collide again. It should also be noted that the presence of one development could elicit a behavioural response from a bird that makes it more or less likely to collide with others. For example, a bird displaced or having deflected its flight from one windfarm, could be more likely to collide with other structures. Conversely, a near-miss from a turbine could make a bird more wary, thus making it less likely to collide with other structures. However, in practical terms, unless major behavioural responses occur or a high proportion of the population is removed through collisions, summing the effect from each development individually is likely to lead to an insignificantly small error in relation to other sources of error such unknown collision rates.

An alternative approach might be to develop generalised collision rates for key species likely to be susceptible to cumulative impact, based for example, on the number of turbines present within an area and on average birds thought to be flying through an area. This approach has advantages in that it would lead to rapid assessment, but would take no account of differing numbers of birds flying through different areas. A compromise, yet entirely reasonable approach might be to assume constant avoidance rates and flight heights throughout the area, although in practise the method of calculation in so doing differs very little from just summing the effects.

Cumulative collision impacts	Issues
Option A: account for behavioural changes that may arise through multiple developments	Ecologically valid, but highly complex and time-consuming and likely to result in only minimal improvements in accuracy
Option B: sum collision effects	Fairly rapid and straightforward to assess, provided collision rates are reported for each development
Option C: develop generic approach based on e.g. number of turbines	Very rapid and straightforward to assess, but does not take account of likely scenario of very different numbers of birds flying through different developments

4.3. Cumulative impacts due to displacement / habitat loss

The extent to which effects associated with habitat loss and/or displacement accumulate is complex. It depends largely on the extent to which the area around a windfarm development is at carrying capacity, i.e. to what extent numbers are limited by the availability of resources. If birds are displaced from a windfarm area then it is likely that they would settle at the highest quality area in the vicinity, quality being determined by the availability of resources and level of competition (Fretwell and Lucas 1970). If numbers are indeed limited by the availability of resources, then this displacement would result in increased competition and hence higher mortality in the remaining habitat (Burton *et al.* 2006). The cumulative impacts habitat loss / displacement would be calculated by summing the effects from each of the contributing developments. If numbers were not constrained by resource availability, then cumulative displacement effects would be negligible.

The extent to which areas around windfarms are at carrying capacity is likely to vary from location to location as well as through time. An assessment of the extent to which areas are at carrying-capacity is time-consuming and difficult, requiring survival estimates to be calculated before and after displacement (e.g. Burton *et al.* 2006) or the development of individual-based models (e.g. Kaiser *et al.* 2002). Nevertheless, there is ample evidence, from many locations and over long time-periods, that seabird numbers are hugely affected by food availability (Wooller *et al.* 1992; Frederiksen *et al.* 2004; Harris *et al.* 2005, Wanless 2005). This would suggest that many, if not most areas are at or close to carrying capacity and as such, cumulative impacts associated with habitat loss or displacement from developments can be calculated by summing the impacts of each of the contributing developments.

Cumulative displacement impacts	Issues
Option A: assume all areas are at carrying-capacity and calculate cumulative effects by summing components	Would lead to inflated estimates of mortality (thus precautionary, perhaps overly so), but simple and straightforward to calculate
Option B: assess extent to which areas are at carrying-capacity and estimate mortality accordingly	Highly complex and time consuming, but results in realistic survival estimates

4.3. Cumulative impacts due to disturbance

The extent to which disturbance effects accumulate are likely to be non-linear for two reasons. Firstly because a single disturbance event can influence the behaviour of the bird subsequently and secondly because the relationship between energy expenditure and foregone energy intake and mortality risk is likely to be sigmoidal. After a bird has been disturbed it can becoming more panicky increasing the response to subsequent disturbances (Beale and Monaghan 2004). However, after repeated disturbances, birds can become accustom to the nature of the disturbance and thus become less likely to respond (Nisbet 2000).The relationship between energy expenditure (and forgone energy intake) and mortality-risk is sigmoidal as small amounts of energy-expenditure are likely to have a minimal impact (Figure 4.3.1). However, with increasing expenditure of energy or loss of time for feeding, a critical threshold may be crossed where a bird cannot meet its energy-requirements and mortality is likely to occur (Stevens and Krebs 1986). This threshold level will vary, being dependent on the condition of the bird, temperature food-availability and other factors.

An informative assessment of the cumulative impacts of disturbance may require detailed study of energy-budgets of birds within the area (which would in any case be required for an informative assessment of disturbance effect in isolation). If the cumulative impacts of disturbance are likely to be significant, then we recommend that such an assessment should be made. However, if resources are unavailable for such an assessment, or disturbance impacts are minimal, we recommend subjective treatment of the issue. We do not provide strict instructions for how cumulative effects of disturbance should be calculated. However, we recommend that those undertaking assessments of disturbance impacts should be alert to the fact that cumulative effects are likely to be greater than the sum of individual effects.

Cumulative disturbance impacts	Issues
Option A: carry-out detailed energy-budget study	Time-consuming, but only way in which disturbance impacts can be calculated
Option B: assess disturbance subjectively / desk-based scoping	Realistic within prescribed time-frame, but cannot provide quantitative measure of impact
Option C: sum disturbance impacts	Not precautionary and unlikely to lead result in a realistic assessment, but doable within prescribed time-frame

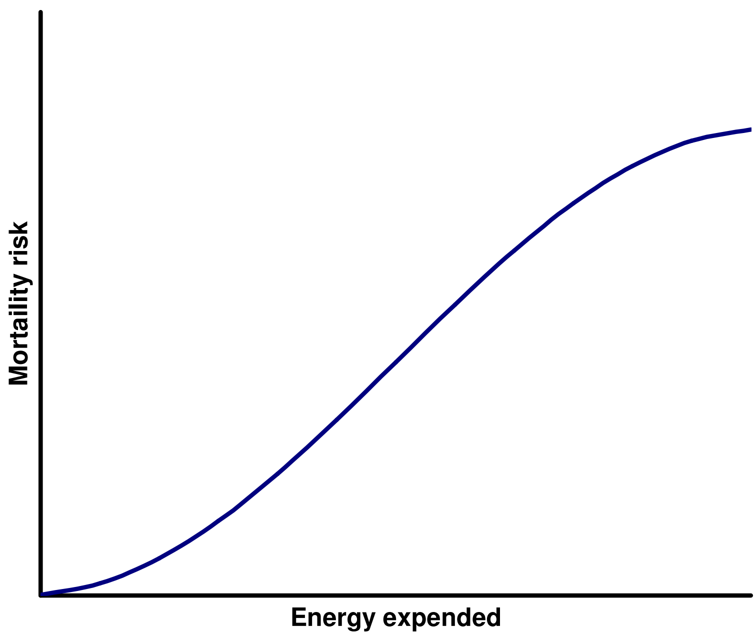

Figure 4.3.1 Theoretical relationship between energy-expenditure / foregone energy intake and mortality risk. Adapted from: Stevens and Krebs (1986).

4.5. Cumulative impacts due to barrier effects

The manner in which the impacts of barrier effects accumulate, will be dependent on the geometry of developments within an area and the way in which birds fly through / around the site. To illustrate this, consider two developments located adjacent to one another, with one due north of the other. If birds approach the northern development from the east or west, it is likely they would skirt around the northern edge of the development and the additional cumulative impact of the other development would be negligible. If birds approach the northern development from the north, then they would be forced to circumvent both developments. Since the relationship between energy expenditure / foregone energy-intake and mortality risk is non-linear (see discussion in previous section), the cumulative impact of both developments will greater than the sum of each.

If cumulative barrier effects are likely to be significant, we recommend that a detailed assessment of flight-directions, energetics and the source and destination of birds be assessed, informed for example, through the use of radar. However, if the cumulative barrier-effects are likely to be negligible, then we recommend that summing the individual impacts is a reasonable alternative. In some instances, the cumulative impacts will be less than summing the individual impacts, but in others it will be more than this. On average, summing impacts may thus not give an inaccurate result.

Cumulative barrier effects impacts	Issues
Option A: carry-out detailed energy-budget study	Time-consuming, but only way in which disturbance impacts can be calculated
Option B: assess disturbance subjectively / desk-based scoping	Realistic within prescribed time-frame, but cannot provide quantitative measure of impact
Option C: sum disturbance impacts	Not precautionary and unlikely to lead result in a realistic assessment, but doable within prescribed time-frame

5. GUIDELINES AND RECOMMENDATIONS

5.1. Summary guidelines

Clarify regulations	Issues
Clarify regulations for CIA, so that options presented hereafter have legal grounding	Developers are likely to conform to legal requirements irrespective of guidelines. However implementing legal clarifications is likely to be incur significant time delays.
Data gathering requirements	**Issues**
Use data already gathered for EIA. Collect additional data where existing data are inadequate for CIA	Additional data collection likely to be costly and time-consuming. Need for additional data likely to be subjectively interpreted.
Species for inclusion	**Issues**
Option C: Implement a screening procedure to select species for inclusion in CIA	Subjective interpretation of screening procedure could result in approaches of varying rigour being used.
Ensuring compatible outputs	**Issues**
Option A: ensure compatible outputs from individual EIAs by providing further EIA guidance	Production of such guidelines may not be ready in time for Round 3.
Time-scale	**Issues**
Option A: consider all ongoing developments	Not method most frequently adopted and may not be legally required, but guards against baseline degradation.
Option A: Report collision mortality as rate:	Easier to assess against life-history parameters (e.g. longevity of species), but does not give absolute mortality value for assessment against population thresholds
Source of impact	**Issues**
Option A: consider all projects / developments	Not method most frequently reported in Environmental Statements, but appears to be legal requirement
Area / reference population	**Issues**
Option B: use Round 2/3 Strategic Areas unless demonstrably not a discrete functional unit	Easy to define, but may not be most appropriate ecologically
Option B: define discrete functional unit using SPA principals where unit does not coincide with Strategic Areas	Ecologically sensible, but rather subjective
Cumulative collision impacts	**Issues**
Option B: sum collision effects	Fairly rapid and straightforward to assess, provided collision rates are reported for each development
Cumulative displacement impacts	**Issues**
Option A: assume all areas are at	Would lead to inflated estimates of mortality

carrying-capacity and calculate cumulative effects by summing components	(thus precautionary, perhaps overly so), but simple and straightforward to calculate
Cumulative disturbance impacts	**Issues**
Option A: carry-out detailed energy-budget study if cumulative impact of disturbance unlikely to be significant	Time-consuming, but only way in which disturbance impacts can be calculated. Requires method for determining whether impacts are likely to be significant
Option B: assess disturbance subjectively / desk-based scoping study if cumulative impact of disturbance unlikely to be significant	Realistic within prescribed time-frame, but cannot provide quantitative measure of impact. Requires method for determining whether impacts are likely to be significant
Cumulative barrier effects impacts	**Issues**
Option A: carry-out detailed energy-budget study if cumulative impact of barriers unlikely to be significant	Time-consuming, but only way in which barrier impacts can be calculated. Requires method for determining whether impacts are likely to be significant
Option C: sum disturbance impacts	Realistic within prescribed time-frame and likely to lead to fairly accurate results
Testing the significance out outputs	**Issues**
Sum impacts from individual components	Component information for summing may not be compatible. For some effects, impacts may not accrue linearly.

5.2. Clarification of regularity requirements

Hitherto, there have been no clear guidelines for carrying-out CIAs at offshore windfarms and it is the aim of this report to provide such guidelines. Nevertheless, it should be noted that the primary reason for the lack of guidelines to date, and one of the major hurdles in presenting the guidelines here, is that regulatory obligations pertaining to CIA are vague. Consequently both here and previously (see for example Norman *et al.* 2007), they have needed to be interpreted subjectively.

This subjectivity has lead to the wide variety of approaches used and the variable rigour with which CIA has been conducted. It is important that the obligatory requirements of cumulative impact assessment are more clearly specified.

5.3. Recommendations based on existing EIA

5.3.1. Data gathering

We recommend that in general, there is little need to gather additional data for CIA, so the data gathering requirements for CIA are the same as for EIA, although highlight that the data requirements for EIAs are not always clearly defined. The exception to this is as follows:

(1) If a project, plan or development to be considered in the CIA has inadequate data associated with it to inform the cumulative assessment process, yet it is likely to significantly add to the overall cumulative effects. We recommend that additional data gathering requirements should be assessed in the scoping / screening process and additional data collection implemented if necessary.

(2) If disturbance effects are likely to be significant. Since the impacts of disturbance cannot be assessed by summing the contributions from individual project, plans and developments, a more detailed assessment may need to be made. This would require a more detailed study focusing on disturbance and energetics or by parameterising of individual behaviour-based-models (Kaiser *et al.* 2002, 2006; Stillman *et al.* 2007).

(3) If barrier-effects are likely to be significant. Since barrier effects cannot be assessed by summing the contributions from individual project, plans and developments, a more detailed assessment may need to be made. This would require a more detailed study focusing on flight directions through the sites and the energetic costs of having to fly around sites and the need to do so.

(4) If cumulative effects on the designated features of protected areas are likely to be significant and cannot be assessed due to lack of knowledge about use of a wider area. In the assessment of cumulative impacts within a wider area, it may not be clear to what extent individual developments are affecting designated features, because it may be impossible to establish the origin of individual birds. In some instances, only a proportion may originate from the SPA, whereas others may come from elsewhere. To inform this assessment and to avoid specifying unduly high impacts on designated features, it may be necessary to quantify the proportion of birds within different parts of the cumulative impact area that actually originate from the SPA. This could be informed through radio-tracking (see Perrow *et al.* 2006) or colour-marking and resighting individual birds.

5.3.3. Data analysis

Many CIAs are hampered by the different approaches used to carry-out EIAs. Thus it is worth flagging in this report, that there is a need to standardise the methods for carrying out EIAs so that components that feed into the CIA are compatible. Additionally, we recommend the following:

Selection of species for inclusion: introduce a screening procedure for identifying which species should be included in the cumulative impact assessment, including those that are non-significantly, but almost significantly impacted by individual developments, but excluding those for which the impacts of individual developments are truly trivial.

Source of impact: all sources of impact, not just those from other windfarms should be considered.

Ensuring compatible outputs: provide very explicit guidelines with respect to what outputs should be produced from EIAs and to make these a requirement of the EIA process.

Time-scale: we suggest that all ongoing and proposed projects should be considered, the exception being the consideration of impacts on designated features of proposed protected areas prior to the assessment of the conservation value of that area. Mortality should be presented as a rate rather than an overall number over a defined time-period.

Area /reference population: we suggest that the reference population and area in which CIAs should be considered follow the boundaries of the Round 2 Strategic Windfarm Areas (Thames, Greater Wash and North-west) or any such areas identified in Round 3. Where these area demonstrably do not constitute a discrete functional unit, then the identification of the relevent area / reference population should follow the same principles as are used to designate SPAs. The process entails identifying an area that is distinct in habitat and/or ornithological importance from surrounding areas. In the context of marine environments the basline mapping of species distribution may help to identify discrete areas. This proces scould be further enhanced by undertaking habitat-association modelling incorporating environmental or physical factors such as bythemtry.

5.3.4. Test of significance and reporting

We recommend that for most impacts, the significance of cumulative impacts is assessed by summing the impacts from each component development. The exception to summing, should be in assessing cumulative impacts of disturbance and barrier-effects, where the impacts accrue in a non-linear manner. We propose that cumulative impacts of disturbance and barrier-effects are first considered in a qualitative manner making best-use of available information. If the cumulative impacts of disturbance and barrier effects are thought to be significant, then a more detailed quantitative study should be carried-out.

We recommend that the significance of mortality be assessed using mortality-rates rather than actual mortality over a finite period. The assignment of species to a sensitivity category should take account of life-history parameters, with long-lived species with low reproductive rates considered more sensitive. Population viability analyses could inform this assessment.

We also recommend that the significance of cumulative impacts be made using the same matrix approach that is routinely used for EIA. Assessment should not be based on only those species for which there is a significant impact at any one of the component developments, but should encompass all species. It is entirely plausible that the accumulation of negligible impacts could result in a non-negligible impact.

6. CONCLUDING REMARKS

It is our intention to provide specific guidelines so that CIAs can be standardised and the quality and rigour improved. However, one of the major constraints in presenting such guidelines is that guidelines for EIAs do not specify precisely what outputs should be provided for ornithological impact assessment with regards to offshore developments. As such, there is often a lack of a common currency that allows cumulative impacts to be assessed. There is an urgent need for these guidelines to be in place and for legal obligations to be clarified. More rigorous guidelines for CIAs could then be formulated.

7. WORKSHOP QUESTIONS

(1) How could regulations for CIA be clarified so as to provide a legal basis for proposed guidelines?

Although this document provides guidelines for conducting CIA, the interpretation of relevant regulations has been subjective. This has been necessary as in some instances the regulations lack detail. Developers are likely to conform to legal requirements irrespective of guidelines. However implementing legal clarifications is likely to be incur significant time delays.

(2) How can we ensure greater compatibility of data that feeds into CIA?

In many instances we propose the effects from individual developments to carry-out CIA. This is not possible if the component information for summing is not compatible. One means of ensuring greater compatibility would be to provide firmer EIA guidance. However, the production of such guidelines may not be ready in time for Round 3.

(3) How should data gathering requirements for CIA be assessed?

In many instances data for carrying-out CIA are collected as part of the baseline and environmental impact assessments. However, in some instances it may be necessary to collect additional data. Additional data collection likely to be costly and time-consuming. The need for additional data likely to be subjectively interpreted.

(4) What species should be included in CIA?

A common method to date has been to include only those species that are significantly impacted by one of the individual developments that contribute to CIA. This approach does not guard against non-significant impacts that could accrue to become significant. An alternative approach would be to include all species, but this is likely to be time-consuming if all potential impacts are to be considered in a rigorous manner. A possible compromise would be to implement some screening procedure for identifying the species that should be included. However the methods or guidance for such screening have yet to be developed

(5) Should all ongoing developments be considered, or only proposed developments?

Direct interpretation of legislation does not clarify this issue, but the matter may have been considered in a legal context elsewhere. Most CIA to date has only considered proposed developments rather than ongoing and proposed developments. There is some argument to say that ongoing developments form part of a baseline. However, not considering ongoing developments that there is no means of guarding against a degrading baseline. Theoretically 100% of the natural environment could be destroyed incrementally if developments occurred sequentially.

(6) Should cumulative collision mortality be reported as a rate or a fixed amount over a defined time-period?

Reporting collision mortaility as a rate makes it easier to assess against life-history parameters, but does not give absolute mortality value for assessment against population thresholds. Arguably it makes more to assess sensitivity as a rate, as loss of 10% in one year of a population of a long-lived, slow-reproducing species is much worse than the equivelent loss of a short-lived, rapidly reproducing species.

(7) Should all projects / developments be considered, or only windfarms?

Regulations seem to imply that cumulative assessment of all developments are needed, but norm to date has been to consider windfarms only.

(8) Should the Round 2/3 Strategic Areas be used as the areas in which to consider cumulative impacts and to define reference populations?

This is clear-cut and easy to implement. However in some instances, such areas may not form discrete functional units (a subjective term in any case!).

(9) Should collision effects be summed or should flight responses to developments be accounted for?

Summing effects is straightforward provided suitable data are available. However it does consider that a bird deflecting from one development, may be more/less likely to collide with others.

(10) Should we assume that all areas are at carrying-capacity and thus calculate cumulative displacement effects by summing component effects.

In relaity areas are likely to be close to carrying-capacity, but this may vary spatially and temporally. Summing effects is precuationary, perhaps overly so? Alternative methods of assessment, such as individual-based modelling, is complex, and fairly costly and time-consuming.

(11) Should detailed energy-budget studies be carried-out to asess the cumulative impacts of disturbance?

This is likely to be costly and time-consuming, but the only way in which cumulative disturbance impacts can be quanitifed. One option would be to only do so, if significant cumulative disturbance impacts are expected. A further question then arises: how can we determine whether cumulative disturbance impacts are likely to be significant?

(12) Should detailed energy-budget studies be carried-out to asess the cumulative impacts of barrier-effects?

This is likely to be costly and time-consuming, but the only way in which cumulative barrier impacts impacts can be quanitifed precisely. However, unlike with disturbance, summing barrier-effects may not lead to hugely erronious results. In a similar manner to disturbance, one option would be to only do so, if significant cumulative barrier-effects impacts are expected. A further question then arises: how can we determine whether cumulative disturbance impacts are likely to be significant?

6. ACKNOWLEDGEMENTS

The authors thank Sue King (Amec), Niall Burton (BTO) and Tim Norman (The Crown Estate) for comments on an earlier draft of this report.

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