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Turbine height as a management tool for collision risk to birds at offshore wind farms

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Abstract

An important element of the environmental impact assessments for offshore wind farms is the potential for interactions with seabirds, particularly through collision of birds in flight with rotating blades. In many cases, these birds are protected through Natura regulations, and Appropriate Assessments are required of the responsible authorities. Traditional models of collision (the “Band model”) make use of the numbers or density of birds flying at turbine height (i.e. within the swept area of the turbine blades). In the UK, the minimum clearance of the blades above the water is normally 22m above HAT. Recent compilations of flight height information indicate that, for some species, most birds at risk of collision are flying in the lower part of the swept area. For such species, increasing the clearance above the water surface can significantly reduce the number of flights exposed to collision risk. Modelled distributions of flight heights for a range of species have been used to estimate the reduction in collision risk achieved by increasing clearance of turbine blades above the water. While it is recognised that there will be additional engineering and cost considerations involved in adopting greater clearance heights, increasing the clearance in areas of importance to seabirds may reduce the constraints on wind farm development arising from concerns over potential collisions with birds in flight. The ability to manage collision risk in this way adds a new dimension to the expressions of risk available to marine planners, and could lead to new formulations of development strategies.

Keywords: Seabirds, wind farms, collision risk, Scotland

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Introduction

The Scottish Government has set a range of challenging targets for energy and climate change. These recognise the potential to take advantage of the extensive marine energy resources (wind, wave and tidal power) available in Scottish waters and include meeting at least 30% of total energy demand from renewable sources by 2020, incorporating:

- 100% of electricity demand from renewables (31% by 2011)
- 11% of heat demand from renewables
- 10% of transport fuel from renewables

In addition, the Climate Change (Scotland) Act 2009 sets statutory targets of at least 42% emissions cuts by 2020, and at least 80% by 2050.

To assist in meeting these targets, the Scottish Government has adopted an iterative approach to marine planning for the renewable energy sectors. For example, a Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters (Blue Seas - Green Energy) sets out the Government's vision for developing offshore wind energy up to 2020 and beyond and has identified short term development sites for offshore wind up to 2020, with a potential to deliver almost five Gigawatts (GW) of electricity generation capacity.

An important element of an environmental impact assessment for an offshore windfarm is an assessment of the likely impact on bird populations. The key impact mechanisms are collision with turbine blades, displacement from foraging areas and impediment to movement (barrier effects) resulting in increasing energy requirements for routine activities such as transit between coastal breeding sites and foraging areas offshore. The risk of mortality as a consequence of collision with the moving blades is a particular concern.

Where the birds are from populations protected through Natura legislation, for example where such populations are designated features of Special Protection Areas (SPA), formal assessment procedures (Habitats Regulations Assessment) are required under Article 6 of the Habitats Directive. If it is determined that a plan or project is likely to have a significant effect on the conservation objectives of an SPA, it is necessary for the competent authority, normally the regulator, to undertake an “Appropriate Assessment” and the plan or project should only be approved in line with Articles 6.3 and 6.4 of the Habitats Directive.

In some circumstances the potential collision mortality after mitigation may still be significant – that is, at such a level as could impact adversely on the conservation objectives of an SPA, typically the maintenance of a bird population within the SPA as a long-term viable feature. Such an assessment would normally lead to changes to the plan or project, or to the project site being set aside in preference for other sites with lower collision risks (though in special circumstances, derogation may allow the plan or project to proceed).

The application of Natura regulations in the context of collision risk to birds is dependent on modelling of the interaction process. Most collision risk assessments make use of a model first published in 2000 (the ‘Band model’) which follows three broad stages:

- (i) an estimate is made of the number of birds which would fly through the windfarm rotors, assuming no change in flight behaviour;
- (ii) this is multiplied by the collision risk for a single bird transit through the rotor, averaged over the cross-sectional area of the rotor disc;
- (iii) allowance is made for changes in flight behaviour by including an ‘avoidance rate’ which takes account of avoidance of the wind farm as a whole, navigation through the windfarm to avoid rotors, or emergency avoidance of blades.

The estimate in stage (i) usually makes use of bird survey data acquired in sample boat surveys at the development site, in which the flight height of observed birds is categorised into two or more broad height bands. The proportion of birds within height bands covering the range 20-150 metres is then taken as the proportion of birds flying at rotor height and therefore at risk of collision.

Seabirds are a very important and characteristic feature of the natural heritage of Scotland. The purpose of the paper is to explore the potential for additional mitigation to reduce the predicted collision risk, specifically the changes in collision risk as a result of increasing the clearance between the sea surface and the tips of the rotating turbine blades. Exploration of the changes in collision risk requires more detailed information on the flight height distribution of vulnerable species.

Using the extended collision risk model to take account of flight height distribution

Two important improvements to the standard “Band model” assessment method have recently become available.

Firstly, in a review undertaken by Cook et al (2012) on behalf of the Strategic Ornithological Support Services (SOSS) group in the UK, flight height data from a large number of offshore wind farm surveys around the UK have been brought together, for a range of species, and this has enabled a generic flight height distribution to be generated for each species. The underlying data has many deficiencies – such as different observational height bands used when recording bird height at different sites – but combining the data has enabled generic flight height distributions to be generated, for most species, with well-defined error limits. Such generic distributions must be used with caution, as individual sites may have particular circumstances (eg adjacency to shore or to breeding sites) which may mean that the flight height distribution at an individual site may differ from the generic profile. However, where there are no such contra-indications, and where flight observations made on site appear compatible with the generic data, the generic data enables a full flight height distribution to be utilised in the collision modelling.

Secondly, the original Band collision model has been extended (Band 2012, on behalf of SOSS) to enable such flight height distribution data to be used in the collision calculation. Instead of simply estimating the number of birds flying through rotors, it uses the density of birds flying at each height (making use of the generic flight height distribution for that species). Instead of using the risk for a single transit averaged across all points of the rotor disc, it uses the risk appropriate to each point of transit through the rotor disc. The outcome is a much more refined estimate of collision risk in place of stages (i) and (ii) above. An avoidance rate must still however be estimated as in stage (iii).

The example in Figure 1 shows the generic flight height distribution for black-legged kittiwake, compared to the height range spanned by a typical offshore turbine rotor, demonstrating that a majority of flights lie below rotor risk height.

When compared to the results of the Band 2000 model, utilising the ‘extended collision risk model’ usually yields a significantly reduced prediction of collision risk for seabirds whose flight height distribution is skewed towards low altitudes. The reasons are:

(i) the actual risk height presented by the rotors is used in detail, rather than regarding all birds flying in the height range 20-150 metres as flying at risk height. Thus, if turbines are used with a clearance of 22m above sea level and a rotor diameter of 125m, collision risk will only be included for birds within this precise height range 22-147m in the flight height distribution.

(ii) the extended model allows for the fact that the proportion of flights at each height passing through the rotor reduces towards the lower edge of the rotor, as the length of a horizontal chord of the rotor decreases. This has a very significant effect on the collision risk where the flight height distribution is strongly weighted to low heights.

(iii) the extended model takes account of the decrease in collision risk of a single transit from the rotor centre to the rotor edge. Where the majority of risk relates to flights close to the rotor lower edge, the risk of collision is thus less than that used in the original model, which used an average collision risk over the full rotor disc.

(iv) finally, allowance may be made for the tide. Normally, turbines have a minimum height of 22m above Highest Astronomical Tide (HAT), to satisfy navigational clearance requirements. But bird flight height distributions are relative to the sea surface which varies with the tide and is on average some metres lower. The extended model includes a tidal offset, to allow for the difference between HAT and the average tidal level.

Figure 2 illustrates the effect of using the extended model on two species of seabird, northern gannet and black-legged kittiwake, whose flight distribution is strongly skewed to low altitude[1]. Use of the extended model with the generic flight height distributions leads to an assessment of collision risk only around 20% of that predicted using the original Band model; and reduces further if allowance is also made for the varying tide.

Dependence of collision risk on turbine clearance

This paper considers the further reduction in collision risk which could result from increasing turbine clearance above sea level. When flight height distributions for seabirds are taken into account, projected collision risk is strongly dependent on the height of the turbines above sea level. For example, the last two rows in Figure 2 show the reduction in risk simply from including an additional average 2.29m clearance due to the tidal range. The extended model thus enables collision risk to be examined as a function of turbine clearance.

Figure 3 shows relative collision risk as a function of turbine height above sea level for a number of seabird species which are designated features of some SPAs in Scotland, and for which collision risks could be a constraining factor on Scottish offshore wind development. The size and parameters of the rotor are kept constant as described above; only the hub height is changed (and hence the clearance between turbine and sea level). The minimum hub height is taken as 84.5m above HAT, so as to provide 22m minimum navigational clearance.

The change in estimated risk resulting from increasing turbine clearance by 10m or 20m is also shown in Table 1 for a range of species. All these species have been listed by MacArthur Green (2012) as being of potential concern in relation to offshore windfarm collision risk. It should be stressed that the risk reductions indicated in Figure 3 and Table 1 are in addition to those obtained through use of the extended collision risk model with a minimum turbine clearance, that is to say the reference risk for minimum turbine clearance corresponds to the method used in the bottom row in Figure 2.

Discussion

For many seabird species, the reduction in estimated collision risk from increasing the turbine clearance is quite pronounced. For kittiwake, adding 10m to the turbine clearance quarters the risk (the risk is 25% of that if minimum clearance were provided); while for terns the effect is even more marked: for Common tern a 10m increase in turbine clearance reduces the risk by a factor of 40(the risk is only 2.5% of that if minimum clearance were

[1] The collision risk calculations used in this example, and all other examples in this paper, are based on typical 5MW wind turbines with a rotor diameter of 125m, a maximum blade width of 4.8m, an average blade pitch of 15 degrees, and a mean rotor speed of 9.9 rpm. The standard hub height is 84.5m, giving a turbine clearance above sea level of 22m (the latter part of this paper examines the effect of increasing this). A latitude of 55 degrees is used to generate the number of daylight hours, and turbines are assumed to be operational for 100% of the time. Bird dimensions are taken from BTO Bird Facts, and bird flight speeds, where quoted, from Pennycuick (1987). Seabirds are taken to have a gliding flight style except for auks and divers, which are assumed to have a flapping flight style.

provided). The effect is however less pronounced for herring gull, for which the flight height distribution is not so concentrated towards the lower height limit of the rotors: a 10m increase in turbine clearance only reduces the risk to 71% of that at minimum clearance.

The risk reductions listed in Table 1 should be regarded as indicative, as there are substantial uncertainties inherent in the generic flight height data. In listing that data, Cook et al (2012) provide estimated 95% confidence limits.

Particular caution is needed for birds where the flight height distribution includes significant numbers of flights at mid-rotor height. For example, guillemot tend to fly close to the sea surface, such that a majority of birds fly below rotor height, even at minimum clearance, and collision risk with guillemot is unlikely to be a development issue at most sites. However their flight height distribution includes a small proportion of flights in the height range 100-130m. The effect of raising the hub height for this species is thus to include more of such flights within the risk zone of the rotor, and hence to increase the collision risk. For this reason, the entries in Table 1 for gannet, black-headed gull and guillemot all show an increase in risk with additional turbine clearance. These increases relate to a very small proportion of birds flying around mid-rotor height, for which detailed height information is limited and for which the uncertainties in the generic flight height data are particularly large. For these species, detailed on-site survey information on flight heights may be required before the effect of additional turbine clearance can be fully ascertained.

The range of improvements in the Band model outlined in this paper, linked with the more detailed consideration of flight height distribution, provide new insight into the operation of collision risk modelling. The availability of generic flight height distributions opens new mitigation options for wind farm projects which otherwise might have difficulty in meeting the requirements of Natura legislation. Furthermore, a key objective of strategic marine planning for offshore wind is to enable development to occur in a sustainable manner, minimising environmental impact while maximising the power output. Inclusion of this new dimension, namely the ability to manage collision risk through turbine height, may enable marine planning authorities to access wind resources in areas where classical turbine design might result in unacceptable degrees of risk to seabird populations.

Conclusion

These results indicate that if seabird collision risk is presenting a constraint on windfarm development, increase in the design clearance of turbines above sea level could be used to reduce collision risks and could help avoid these constraints. While it is recognised that there will be additional engineering and cost considerations associated with achieving greater clearance heights, increasing the clearance in areas of importance to seabirds can help in reducing collision risks while accessing the more powerful wind resource present at greater heights above sea level.

There are substantial differences between species in the sensitivity of their collision risk assessments to turbine height, and it will always be important to calculate the collision risks for the species which are the subject of concern and using turbine parameters appropriate to the windfarm in question.

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Table 1: Dependence of collision risk on clearance height

Note that these figures relate specifically to the turbine parameters entered in the collision model (see Footnote 1) and would need recalculated for different turbines.

	Turbine clearance above sea level		
	minimum	**+10m**	**+20m**
clearance above HAT(m)	22	32	42
hub height above HAT(m)	84.5	94.5	104.5
Species	**Collision risk relative to risk at minimum clearance**		
Northern gannet	100%	130%	183%
Great black-backed gull		55%	31%
Lesser black-backed gull		75%	69%
Herring gull		71%	57%
Common gull		81%	72%
Black-headed gull		109%	112%
Black-legged kittiwake		25%	7%
Northern fulmar		53%	26%
Arctic skua		32%	24%
Great skua		79%	61%
Sandwich tern		49%	17%
Common tern		2.5%	0%
Arctic tern		31%	2%
Black-throated diver		69%	46%
Red-throated diver		66%	46%
Razorbill		107%	80%
Common guillemot		142%	136%
Shag		9%	3%

Figure 1: Kittiwake flight density as a function of height

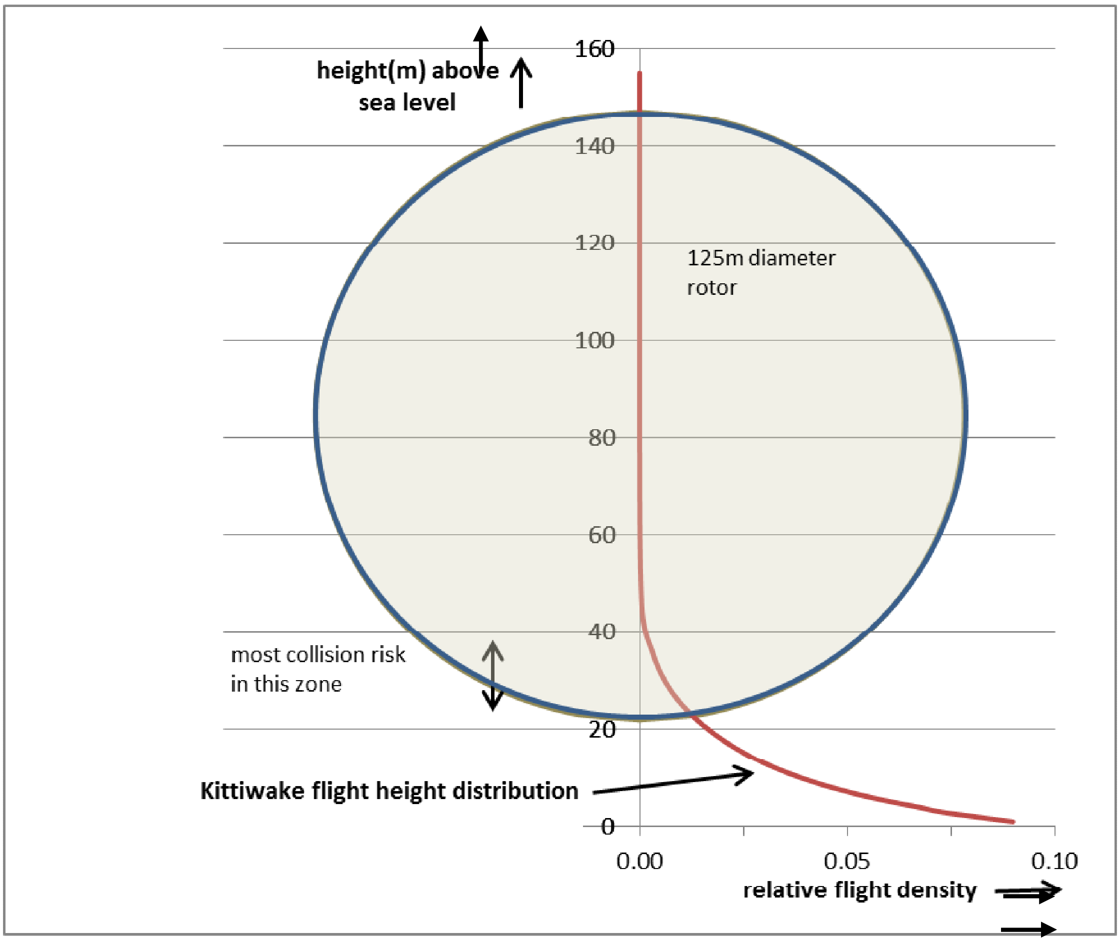

Figure 2: Example of effect of using seabird flight height distributions in calculating collision risk

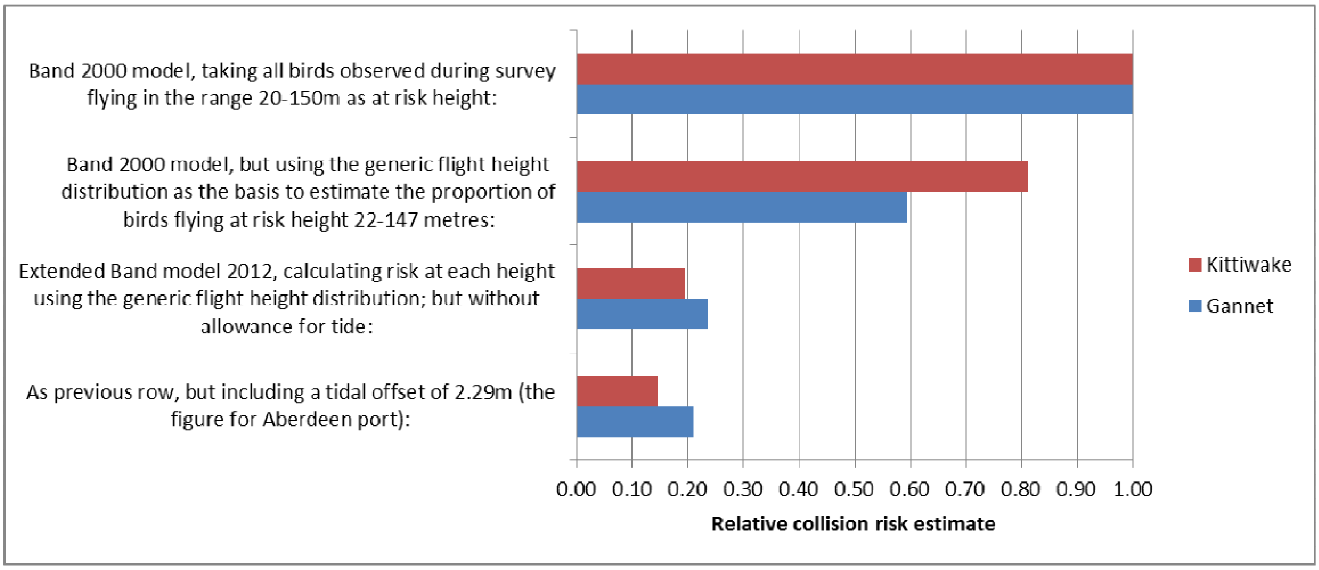

Figure 3: Relative collision risk as a function of turbine clearance