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AVOIDANCE RATES OF SWANS UNDER THE 'BAND' COLLISION RISK MODEL

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ABSTRACT

The Band collision risk model (CRM: Band et al. 2007) attempts to predict mortality rates of birds due to collision with rotating wind turbine blades at operational wind farms, and requires the appliance of a substantial ‘avoidance rate’ to correct raw model estimates, to account for the fact that birds are very adept at avoiding collision.

Most avoidance rates estimated to date suggest that precautionary values should usually be at least 98 %.

A 95 % avoidance rate for swans *Cygnus* spp. may be considered an appropriate (strongly) precautionary rate when using the Band CRM because they are vulnerable to collision with static overhead wires (e.g. power lines).

This argument requires that the factors which cause collision with wires are the same as those which cause collision with turbine blades.

Birds appear to collide with wires because they do not see them. As yet there is no evidence to suggest that the same causal mechanism applies to collision with turbine blades.

Species which are vulnerable to collision with wires do not necessarily appear vulnerable to collision with turbine blades, and vice versa.

Recent studies of swans at wind farms in The Netherlands tend to show that: a) susceptibility to collision with wires is not transferable to collision with turbine blades; b) swans are not especially vulnerable to collision with turbine blades; and c) swan avoidance rates are probably similar to goose avoidance rates.

As a 99 % avoidance rate is considered precautionary for geese, it is difficult to understand why swans should differ, and likely implausible that a 95 % rate is appropriate.

INTRODUCTION

The Band collision risk model (CRM: Band et al. 2007) attempts to predict mortality rates of birds due to collision with rotating wind turbine blades at operational wind farms. It requires the appliance of a substantial ‘avoidance rate’ to correct raw model estimates, to account for the fact that birds are very adept at avoiding collision (Chamberlain et al. 2006, Madders & Whitfield 2006, Band et al. 2007). Most avoidance rates estimated to date suggest that precautionary values should usually be at least 98 %.

Langston & Pullan (2004: P. 42) note that: “*Swans have a high hit-wire index (Rose & Baillie 1989), on account of their large body mass and slow manoeuvrability and are susceptible to collision with a variety of structures, including powerlines (Butler 1999) and wind turbines.*” As swans *Cygnus* spp. are considered vulnerable to collision with static overhead wires (power lines being one example), a 95 % avoidance rate may be considered to be an appropriate precautionary rate for this species, when using the Band CRM to predict potential collision rates at operational wind farms.

There is good evidence that swans are vulnerable to collision with static overhead wires. While most of this evidence refers to the mute swan *Cygnus olor* (e.g. Frost 2008, and references therein), understandably given its distribution, there is little basis for disputing its application to congenerics despite results being more anecdotal. The morphology of swans (Langston & Pullan 2004) also tends to fit with an analysis by Janss (2000), despite not being part of her analysis, in that they should be expected to be susceptible to collision with wires based on comparative morphology with species that she did study (Janss 2000).

SUSCEPTIBILITY TO WIRE COLLISION EQUALS SUSCEPTIBILITY TO TURBINE BLADE COLLISION?

The 'invisible turbine blades' hypothesis

For the assumption underlying a strongly precautionary Band CRM avoidance rate and Langston & Pullan's (2004) inference of 'collision risk similarity' to be correct, it is required that the factors which cause collision with wires are the same as those which cause collision with turbine blades.

Birds appear to collide with static wires (and die as a result) primarily because they do not see them. This is supported by several evidential strands, including the finding that thinner wires appear more dangerous (e.g. Janss & Ferrer 1998, Frost 2008) and notably by results of many experiments showing lower collision rates when lines are made more visible by line markers or 'diverters' (e.g. Bevanger 1994, Janss & Ferrer 1998, Alonso & Alonso 1999, Frost 2008). While these markers do not prevent all collisions they can substantially reduce them.

Being a more novel technology than transmission by overhead wires, there seems to have been an implicit underlying hypothesis in some early research connected with birds and wind farms (largely instigated by raptor mortality through collision at the Altamont wind farm in California) that collisions occurred because birds failed to detect spinning rotor blades through their speed relative to retinal image processing capacity, or 'motion smear' (e.g. Mc Isaac 2001, Hodos et al. 2001). It is important to note that this research was not based on the underlying hypothesis having an evidential basis, merely an assumption.

It also seems apparent that the concept of motion smear, if applicable to birds' perception of an operational turbine in the field (and there seems some doubt on its relevance: see later), does not mean that birds cannot see the rotor swept area, only that they do not see the motion of individual blades (Hodos 2003). Even if correct, therefore, and there are reasonable doubts about this (especially for modern turbine models), motion smear does not suggest that turbines blades are entirely invisible to birds, only that blade movement around the nacelle renders their appearance as a more-or-less solid circle. This is different to wires which under some circumstances are probably effectively entirely invisible to some birds.

Field trials to judge effectiveness of increasing blade conspicuousness have apparently not been conducted to date, although Young et al. (2003) indicate that using UV paint on blades to increase conspicuousness made no apparent difference to bird fatalities. Sinclair (2001) remarks that tests of painted blades at Altamont were being sought and large-scale application would not be recommended until there was evidence that fatalities were reduced by the method. It seems that at 42 turbines one blade was painted black but this was not done correctly (Smallwood & Karas 2009). (This pattern was the same as recommended by Hodos (2003).) However, the laboratory tests of Hodos (2003) have engendered comments such as "...*applicability of the results to typical facilities was very limited*...", "...*avian color vision is different from human color vision*...", "...*inconclusive results and the relevance to typical facilities is unknown*...", and "...*largely unproven effectiveness of this method*..." (US Department of the Interior & Cape Wind Associates 2008).

Arguably, the reason why there has not been any field testing of making blades more conspicuous, is that the underlying arguments are not considered sufficiently convincing to overcome the aesthetics and landscape effects of painting blades. First, as noted above, motion smear does not mean that birds are entirely unaware of the presence of turbine blades and most human observers would find it difficult to understand how birds cannot see modern turbine blades when they are so obvious to humans, and birds have greater visual acuity. Second, the concept of motion smear predicts that slower moving blades (as in modern turbines) should be easier to see than older turbines (such as the small lattice tower Kenetech models installed at Altamont and Tarifa, for example) (Hodos 2003). If motion smear was pertinent to collision probability, older turbines should be more lethal than modern turbines, but early research suggests that this does not appear to be the case (Barclay et al. 2007, Smallwood & Karas 2009), although more studies are needed. Third, at an operational wind farm, flights through rotor swept areas by red-throated divers *Gavia stellata* were most frequent at the outer limits of the areas (D. Jackson unpubl. obs.) and observations of collisions with turbine blades by griffon vultures *Gyps fulvus* occur most often at the outer limits of the rotor swept area (L. Barrios pers. comm.). While motion smear applies especially to moving blade tips (Hodos et al. 2001), these observations were made at modern turbines, and are probably more likely to suggest that birds are aware of blades but that when collisions occur they are due to birds' errors caused by fine-scale flight conditions or judgements on blade tip trajectories. Finally, the importance of motion smear may have implicitly fallen from favour as a mitigation measure and an important influence on bird mortality in wind farms because a wide range of other factors have subsequently been found to explain variation in turbine collision risk (e.g. Hoover & Morrison 2005) and many authors have commented that birds appear to be well-aware of wind turbine blades (e.g. de Lucas et al. 2004; and see later for swans).

Whatever the reason for the lack of field testing of the 'invisible blades' hypothesis, there is no experimental evidence to support the view that birds collide with wires and turbine blades through similar underlying factors. While this can be seen as inconclusive, due the lack of field testing of motion smear influences, there is another way of addressing the question, which reverts to the basic argument underlying the potential adoption of a low avoidance rate for swans. If this argument is reasonable we should expect that birds which are susceptible to collision with wires are also susceptible to collision with turbine blades.

Is vulnerability to wire collision transferrable to turbine blade collision?

There are several examples which suggest that many birds which may be vulnerable to wire collision are not similarly vulnerable to turbine blade collision. In Spain, fatality rates due to collisions with wires by white storks *Ciconia ciconia* and cranes *Grus grus* have given cause for concern (Janss & Ferrer 1998, 2000, Janss 2000). These species are similar morphologically, and another species of crane has been highlighted as being susceptible to collision with wires in other parts of the world (Morkill & Anderson 1991, Brown & Drewien 1995).

However, despite huge numbers of white storks passing through and staging near Tarifa in southern Spain on migration, where there are large numbers of wind turbines, this species is only rarely a victim of turbine blade collision (e.g. Barrios & Rodríguez 2004, de Lucas et al. 2004). Similarly, despite a large non-breeding population of cranes near wind energy installations around Tarifa, this species does not appear as a victim of turbine blade collision in the region (pers. obs., L. Barrios pers. comm.). In Germany, cranes are not considered as a species vulnerable to collision with turbine blades (F. Bergen in litt.) and neither storks nor cranes appear as frequent victims in collations of records by Dürr (2009). There is little basis on current evidence, therefore, to support the notion that storks and cranes have a similar susceptibility to collision with overhead wires and with wind turbine blades.

Rose & Baillie (1989; as cited by Langston & Pullan 2004) reported that raptors were frequent victims of collision with overhead wires. This review was based on reports of dead ringed birds from, predominantly, the general public. This conclusion is diametrically opposed to those from dedicated research which pointedly highlights that raptors are not vulnerable to collision with wires (e.g. [Olendorff et al. 1981, Olendorff & Lehmann 1986; cited by Janss et al. 1999], Bevanger 1994, Janss et al. 1999). The most likely explanation of this stark difference in conclusion is that dead raptors are often found near power lines, but through electrocution, not collision

(Janss & Ferrer 1998, 2000, Janss et al. 1999, Janss 2000), and that observers submitting ringing returns used by Rose & Baillie (1989) would not necessarily be appreciative of the difference.

Raptors therefore, in general, do not appear to be especially susceptible to collision with overhead wires. This contrasts with the notion that this group of birds have been highlighted as being disproportionately vulnerable to collision with wind turbine blades (e.g. Madders & Whitfield 2006, Whitfield & Madders 2006, Whitfield & Coupar 2008). This does not support the argument that collision vulnerability to static wires, such as power lines, and to wind turbine blades can be considered as equivalent in causation or effect.

To take one example of a raptor where available evidence suggests, through several bases, relatively high vulnerability to collision with turbine blades, the common kestrel *Falco tinnunculus* (Barrios & Rodríguez 2004, de Lucas et al. 2004, Whitfield & Madders 2006), there is no indication, despite the species' relative ubiquity and abundance in Europe, that it is also vulnerable to collision with static overhead wires (Janss 2000, Janss & Ferrer 1998, 1999, Janss et al. 1999).

FATALITY RATES OF SWANS AT OPERATIONAL WIND FARMS

Larsen & Clausen (2002) documented how the flight behaviour of whooper swans *Cygnus cygnus* could potentially lead to collision risk at a proposed wind farm site in Denmark. This paper did not document wind farm collision effects but speculated on 'potential' and 'risk' issues, as it simply described possible consequences of flight behaviour recorded at a proposed (not operational) wind farm site. It does little, therefore, to contribute to understanding the actual effects of wind farms on swans.

The Wieringermeer Polder in The Netherlands is one of the major wintering areas for Bewick's swan *Cygnus columbianus bewickii* in Europe, and is also one of the main areas for wind farms in The Netherlands. Here the swans usually form feeding flocks with bean geese *Anser fabalis* and their exposure to wind turbines involves many scores of thousands of swan-days and several hundreds of thousands of flight movements each winter. Several studies have been carried out on operational effects of wind farms on Bewick's swan and bean goose in the region. The net conclusion of these studies is that this swan is not at serious risk of collision with turbines, and has no greater collision risk than the bean goose (Fijn et al. 2008 and references therein). Fijn et al. (2008) note that the number of swan and goose collisions was extremely low, substantially less than expected and orders of magnitude lower than other bird species (which it should be noted, have typically been estimated to have avoidance rates in excess of 95 % under the Band CRM).

These Dutch studies did not estimate avoidance rates for Bewick's swan. But what they do tell us is that:

- Collision risk appears in stark contrast to those reported by studies of swans and power lines (Frost 2008);
- Similarly, Frost (2008) observed, on many occasions, that swans approaching power lines only appeared to see them when very close "*resulting in the birds taking rapid avoiding action*" and "*drastic evasive action causing swans to almost stall in mid-air*". Fijn et al. (2008) note that: "*Both birds flying in the day to and from foraging sites as well as birds flying at night to their roosting sites show no deflections of flight paths or panic shock reactions in the air*". While Frost's (2008) records are consistent with collision with power lines happening because swans do not see them, the observations of Fijn et al. (2008) from a wind farm are not;
- It is not unreasonable to expect that many thousands of flight lines took swans on a theoretical collision course with turbine blades (e.g. Larsen & Clausen 2002) in the Dutch studies. Fijn et al. (2008) clearly had an expectation that collision victims would be much higher than observed and remark that birds navigated "*effortlessly around and through the lines of turbines*";

- Avoidance rates of geese have been estimated (Fernley et al. 2007) and there is no indication in Fijn et al. (2008 and references cited therein) that collision risk differed between Bewick's swan and bean goose;
- If a precautionary avoidance rate of 99 % is appropriate for geese under the Band CRM (Fernley et al. (2007) argue for a higher rate), there seems little basis for considering that an avoidance rate for swans should be different. Application of a radically different 95 % avoidance rate for swans seems inappropriate as it is not based on sound evidence.

CONCLUSIONS

The Band CRM attempts to predict avian collision rates with wind turbine blades, but requires a substantial correction factor, termed the avoidance rate, in order to bring unadjusted predictions towards reality and be consistent with observed fatality rates.

It is becoming apparent that under the Band CRM, even precautionary avoidance rates (as a 'correction' factor to the unadjusted model) need to be at least 98 %.

A 95 % avoidance rate under the Band CRM may be considered as appropriate for swans on the basis that these species are especially vulnerable to collision with static wires, such as power lines. Most evidence on the susceptibility of swans to collision with wires is based on studies of mute swans, but there is no reason to dispute that this finding should not apply to other species in the genus.

However, this argument requires that the factors which cause collision with wires are the same as those which cause collision with turbine blades. Two lines of evidence indicate that the argument may have little basis and so undermine the fundamental premise for considering swans as having exceptionally low avoidance rates.

The first is that while it is obvious (supported by strong empirical data) that birds collide with wires because they do not see them, there is little to confirm that collisions with wind turbines blades have the same causal mechanism (even, arguably, theoretically). Birds appear to be well-aware of wind turbine blades, even if the oft-cited but untested principle of ‘motion smear’ is invoked. The second line of evidence is that species which are vulnerable to collision with wires do not necessarily appear vulnerable to collision with turbine blades, and vice versa.

Other lines of independent evidence which contradict the reasoning for swans having exceptionally low rates of turbine blade avoidance come from recent studies of swans at wind farms in The Netherlands, which tend to show that: a) susceptibility to collision with wires is not transferable to collision with turbine blades; b) swans are not especially vulnerable to collision with turbine blades; and c) swan avoidance rates are probably similar to goose avoidance rates.

Overall, therefore, the large weight of evidence does not support the fundamental premise of swans being exceptionally vulnerable to collision with turbine blades, disputing application of a radically different 95 % avoidance rate. Considering results from The Netherlands, if a precautionary avoidance rate of 99 % is appropriate for geese under the Band CRM (Fernley et al. (2007) argue for a higher rate), there seems little basis for considering that an avoidance rate for swans should be different.

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