



**Collision Avoidance of Golden Eagles at Wind Farms under the
'Band' Collision Risk Model**

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SUMMARY

1. Collision risk models (CRMs) are potentially useful, albeit crude, tools in predicting the potential avian collision mortality rates which rotating turbine blades at operational wind farms may incur. The 'Band' CRM (Band et al. (2007) has probably received the most utility in practice and therefore, attention, concerning potential deficiencies.

2. The most obvious barrier to the Band CRM in realising its potential to produce realistic mortality predictions is that it assumes that birds do not avoid collision, whereas it is apparent that avoidance rates are very high at operational wind farms. Deriving estimates of avoidance rates has thus become an urgent research field.

3. The present study calculated estimates of avoidance rates for the golden eagle *Aquila chrysaetos* under the Band CRM using results from monitoring studies at four USA wind farms, attempting to account for the many biases which are inherent in avoidance rate calculations.

4. Avoidance rate estimates for golden eagles varied between 98.64 % and 99.89 % depending on site and uncertainty associated with observed mortality rates before and after adjustment for potential biases. An overall 'worst case' estimate weighted by the scale of study was 99.33 % and the mean unweighted 'worst case' (lowest) avoidance rate for the four wind farms was 99.19 %. A precautionary value of 99.0 % is therefore recommended for use in predictive assessments of wind farm proposals. Other recommendations include the need for further research which avoids the biases inherent in many existing studies of wind farm effects on birds.

5. The estimated avoidance rates, and the means of their derivation, documented by the present study, are contrasted with those calculated for golden eagle by Fernley (2008), which are higher. Several discrepancies are identified which would lead to elevated estimates of avoidance rates by Fernley (2008), such as not accounting for some eagle deaths or relatively high inactivity of turbines at some sites, or using inflated measures of eagle activity.

1. INTRODUCTION

As a means of generating 'renewable' energy, wind farms represent a potential contributor to resolving the widely acknowledged problem of the impacts of anthropogenic increases in 'greenhouse gases' through burning of fossil fuels on climate change. Wind farms are not 'environmentally-neutral', however, and in particular their potential impacts on birds through fatality from collision with rotating turbine blades has been frequently cited as an adverse impact (Percival 2000, Langston & Pullan 2003, Whitfield & Coupar 2008).

The scale and pace of potential climate change and its impacts has engendered a rapid advancement of the wind energy industry against which research on its effects on birds has struggled to keep pace (Whitfield & Coupar 2008). With regards to the potentially detrimental effects of collision fatality, the collision risk model (CRM) described by Band et al. (2007) offers a crude mechanism for predicting potential avian mortality rates which proposed wind farms may create (Chamberlain et al. 2006, Madders & Whitfield 2006). Modelling collision risk under the Band CRM is a two-stage process (Band et al. 2007). Stage 1 estimates the number of birds that fly ('transits') through the rotor swept disc. Stage 2 predicts the proportion of these birds that will be hit by a rotor blade. Combining both stages produces an estimate of collision fatality in the absence of any avoiding action. The primary problem with the Band CRM is that fundamentally it does not assume that birds will avoid collision with turbine blades (Chamberlain et al. 2006, Madders & Whitfield 2006, Band et al. 2007). In practice the avoidance rate appears to be very high but suffers from a shortage of empirical demonstration (Chamberlain et al. 2006, Madders & Whitfield 2006).

Consequently, attention on the Band CRM has focussed on deriving measures of avoidance rates, which can be calculated, for some species, from a few existing post-operational wind farm studies (Whitfield & Madders 2006a, Fernley et al. 2007). While this ignores other challenges to the model, such as its potentially flawed assumption that risk of collision is positively related to the activity of birds in the vicinity of activity turbines (Whitfield & Madders 2006a, Fernley et al. 2007, de Lucas et al. 2008) the question of avoidance rate estimation appears to require the most immediate answer. Originally, in the absence of any empirical data, Band et al. (2007) suggested an avoidance rate of 95

%, but increasingly this is being shown to be overly conservative (Whitfield & Madders 2006a, Fernley et al. 2007, Whitfield 2007).

With currently available data at operational wind farms, one method for estimating avoidance rate is the difference between predicted fatality and observed fatality (avoidance rate = $1 - (\text{observed deaths}/\text{predicted deaths assuming no avoidance})$) (Madders & Whitfield 2006, Whitfield et al. 2006a, Fernley et al. 2007). Care must be taken in deriving estimates of both observed and predicted deaths, because both are prone to bias (Gauthreaux 1995, Chamberlain et al. 2006, Madders & Whitfield 2006, Smallwood 2007) and these biases can consequently affect estimates of avoidance rates.

The objective of the present study was to derive estimates of avoidance rates in golden eagles *Aquila chrysaetos* under the 'Band' CRM (Band et al. 2007) from available data presented by studies of operational wind farms in USA, and thereby to provide a recommendation for an appropriate avoidance rate to be used for golden eagles in the Band CRM, based on the best available evidence. A recent report by Fernley (2008) has also estimated avoidance rates for golden eagles, and so the results of the present study are also contrasted with those of Fernley (2008) in Annex 1.

2. METHODS

2.1 Collision modelling: approach and required parameters

Derivation of an avoidance rate estimate essentially followed the same method as described by Band et al. (2007) in deriving an estimate of predicted collision rate, with one exception. Instead of using an assumed avoidance rate to correct a predicted 'no avoidance' fatality estimate, as in Band et al. (2007), an observed fatality estimate after avoidance (i.e. as calculated from studies at operational wind farms) was used to derive the avoidance rate which was necessary as a correction of the 'no avoidance' fatality estimate resulting from Stages 1 and 2 of the calculations. In other words:

Avoidance rate = $(1 - a)$, where

$a = N \text{ observed collisions (with avoidance)} / N \text{ predicted collisions (no avoidance)}$

While there are alternative methods for deriving N predicted collisions (no avoidance) (Fernley et al. 2007), the present study followed the process described by Band et al. (2007) for clarity and ease for the reader to follow the steps in calculations (see also Whitfield & Madders 2006a). Under Stage 1 of this process, the rate of transits through the rotors is calculated, and under Stage 2 the proportion of these transits which result in collision is calculated. Combining the two stages gives N predicted collisions (no avoidance). The parameters required under Stage 1 are shown in Table 1. The following section describes how values for these parameters and for N observed collisions (with avoidance) were calculated for the wind farms in the study.

2.2 Study sites and source data

Estimation of avoidance rates initially considered data from five wind farms: Altamont Pass (e.g. Thelander et al. 2003, Smallwood & Thelander 2004), Tehachapi Pass (Anderson et al. 2004, Erickson et al. 2002), San Geronio (Anderson et al. 2005, Erickson et al. 2002), Foote Creek Rim (Johnson et al. 2000a, Erickson et al. 2002, Young et al. 2003a, b) and Buffalo Ridge (Johnson et al. 2000b). Buffalo Ridge data (Johnson et al. 2000b) have not been included in the present analyses because the level of golden eagle activity here was low and the number of turbines searched was relatively low, even though frequent searches were conducted over four years (and the majority of turbine vicinities were searched for an additional 19 months: Osborn et al. 2000). This may have predisposed analysis to produce an estimated 100 % avoidance rate and, indeed, no eagle carcasses were found during more than five and half years of searches (Johnson et al. 2000b, Osborn et al. 2000). This result has dubious utility, therefore, but it is worth bearing in mind.

Altamont Pass Wind Resource Area (WRA)

Altamont WRA is the largest terrestrial wind farm in the world and was one of the first to be constructed, involving a mixture of 5400 types of 'operational' turbines in 1998 (Smallwood & Thelander 2008) declining to 4489 by 2005 (Altamont Pass Avian Monitoring Team 2008), sited in the rolling grasslands of central California. Thanks

largely to its notoriety through the number of birds it kills it has been the subject of numerous research efforts, some of the most recent being presented by, for example, Thelander et al. (2003) and Smallwood & Thelander (2004, 2008). Smallwood & Thelander (2004: Table 1-1) document the numerous different turbine models in operation at the time of their work and taking these values, not weighted according to frequency, gives a 'typical' three-bladed turbine of 21.9 m rotor diameter, 25.5 m hub (nacelle) height and rotation period of 1 s.

To calculate the amount of time that eagles spent at risk of collision, the results from 30 min observation periods, provided by Smallwood & Thelander (2004) for 300 m radius observation areas, were employed as an initial step: 120.6 h of observation (Smallwood & Thelander 2004: section 8.3.1) which recorded 35 min of eagle flight (Smallwood & Thelander 2004: Table 8-3). In collision modelling it is necessary to estimate the proportion of flights at rotor swept height (RSH) (Table 1). Smallwood & Thelander (2004: Fig. 8-13) present data on golden eagle flight heights and note that 56 % of flights occurred at the RSHs of turbines at Altamont, but this value refers to the full range of turbine types. For the 'typical' turbine, the value is approximately 36 %.

Due to the turbines being 'old' models they were inoperative for a relatively large proportion of the time (Smallwood & Thelander 2004: Table 1-1). Inoperative turbine blades are highly unlikely to kill a golden eagle through collision, and so this needs to be factored in to collision modelling. Two estimates of the proportion of time that turbines were operative can be derived from Smallwood et al. (2003). The first, based on monthly rates of operation gave 0.49. The second, based on wind-related operation and average wind speed at the site (Smallwood & Thelander 2004), gave 0.58. It was assumed, therefore that turbines were operative for 0.55 of the time. It was also assumed that this also accounted for times when golden eagles may be inactive due to diurnal and weather-related effects.

According to Smallwood & Thelander (2008), golden eagle mortality across the Altamont WRA during their studies, accounting for several potential biases (but not all), was 67 per annum (80 % CL = 25 – 109). This analysis attempted to address criticisms of Smallwood & Thelander's (2004) estimates (e.g. Weisskopf 2005).

Tehachapi Pass WRA

Tehachapi Pass WRA in southern California consisted of about 3300 turbines in 1998, being similar to Altamont and San Geronio WRAs in comprising a mixture of several different turbine models of 'early' design. The 'typical' three-blade turbine had a rotor diameter of 19.2 m and a hub (nacelle) height of 24.7 m (weighted means from Anderson et al. 2004: Table 2). Studies at the site are described by Anderson et al. (2004) and Erickson et al. (2002).

Carcass searches and bird utilisation surveys were conducted at 201 plots sampling 637 turbines over 1.5 y 1996 – 1998 (Anderson et al. 2004) and an additional 1.5 y starting in 1995 (Erickson et al. 2002) i.e. 3 y in total. Bird use surveys were two consecutive 5 min 'circular point counts' (Reynolds et al. 1980) observation surveys recording birds to a radius of 200 m, for a total of 276.5 h. Golden eagle activity at Tehachapi Pass was relatively low (Anderson et al. 2004); typically slightly lower than Buffalo Ridge (Erickson et al. 2002: Table 11) with three seen. To derive an estimate of the amount of time that eagles were seen in flight it was assumed, with an average flight speed of 15 m/s (Provan & Whitfield 2007) and a 400 m diameter survey plot that each observation of an eagle lasted $400 \cdot (\pi/4) / 15 = 20.94$ s (Fernley et al. 2006). With three sightings, there was thus an estimated total of 1.05 min of eagle flights observed.

Anderson et al. (2004: Table 9) only present data on the flight heights for all raptors, with 40.4 % in the band 10 – 35 m (typical RSH = 15 – 34 m). Reference to Altamont data (Smallwood & Thelander 2004) where raptor flight heights were presented by species and, after attempting to account for the different raptor communities between sites, gave an estimate of approximately 33 % of flights at RSH for golden eagles at Tehachapi. As the turbines at Tehachapi are similar in type and age to those at Altamont, it was assumed that they were operative for 55 % of the time, as described in the previous section.

Carcass searches were three months apart. Anderson et al. (2004) do not note any finds of dead golden eagles during 1.5 y in their report (Appendix B) but amongst several unidentified remains a 'large raptor-sized sternum' was noted. Erickson et al. (2002), however, document (P. 25) that one golden eagle fatality was found in 3 y. The longer

study period (Erickson et al. 2002) should be preferred because collisions are typically rare events and a longer study period therefore gives a better estimation of rates (Smallwood & Thelander 2004). This gives 0.33 dead eagles per year before any adjustments for carcass detection biases.

Trials to assess the rate of carcass removal (e.g. by scavengers) and the efficiency of observers to detect carcasses used chickens to represent 'large birds' (such as eagles). These established that removal of carcasses by scavengers was relatively quick, with 96 % disappearing within 8 d and the mean time to removal being less than 3 d (Anderson et al. 2004). Observers detected 81 – 84 % of 'large' carcasses (Anderson et al. 2004). Smallwood (2007) has suggested, at least for sites dominated by grassland, that searchers may be less able to find surrogate species, such as chickens as used in the Tehachapi trials, than native species. Counteracting this bias, however, is that, as Smallwood (2007) also points out, when observers know that they are being tested for their efficiency (as at Tehachapi) then they are liable to find more birds than during searches for collision victims because their effort increases. Brush land (more difficult to search than grassland) also occurs at the botanically diverse and complex Tehachapi Pass WRA (Anderson et al. 2004). In view of these conflicting tendencies the observer search efficiencies were taken at face value, i.e. as recorded.

The disparity between inter-search interval and carcass persistence meant that methods for calculating the number of collision victims, correcting for search biases, were not employed (Anderson et al. 2004). Smallwood (2007) gives an equation (1) which allows estimation of 'adjusted' fatality rates by allowing for the inter-search interval, searcher efficiency and the mean time for carcass removal. Taking into account the Tehachapi results of the scavenging and searcher bias trials by using equation (1) of Smallwood (2007) gives an estimated 4.25 eagles killed per annum at the sampled turbines. The problem with this estimate is that Smallwood (2007) has shown that the carcasses used in the Tehachapi trials, chickens, are scavenged far more rapidly than the native species for which they are supposed to be surrogates. Using Smallwood's (2007) Appendix for predicted disappearance rate of large raptors with the search interval at Tehachapi (88 % after 90 d) and applying this to equation (2) which Smallwood (2007) also presents, gives an estimated 0.46 eagles killed per annum.

Unfortunately this estimate too may not be problem-free, for two reasons. First, the rate of disappearance of chicken carcasses in Tehachapi trials appeared to be particularly rapid which may suggest that results on the persistence of large raptor corpses elsewhere are too conservative relative to Tehachapi (e.g. scavenging rates *per se* at Tehachapi may be relatively high due to the community of scavengers). Secondly, the data used by Smallwood (2007) to derive predictions of persistence of large raptor corpses is necessarily constrained by sample size of sites. The predictive curve for large raptor corpse persistence (Smallwood 2007: Fig. 3) clearly has large (non-plotted) residuals implying a low degree of confidence: there is also uncertainty in whether the data used by Smallwood (2007) to derive this predictive curve are independent-by-site. Taking these two points into consideration may imply that, at Tehachapi, large raptor corpses would not remain for as long as suggested by Smallwood's (2007) laudable attempts to construct a way forward through all the possible biases connected with collision fatality estimation. Consequently, a further mortality estimate for Tehachapi assumed that 0.67 eagles died per annum i.e. twice that of the unadjusted estimate but considerably lower than the rate given by Smallwood's (2007) equation (1). This value represented a reasonable compromise to resolve the problems with other mortality estimates, although there is still a degree of uncertainty.

San Gorgonio WRA

San Gorgonio WRA in southern California is a large wind farm (c. 3000 operating turbines in 1998) constructed in the early 1980s containing a mixture of 'old' turbine models, similar to Tehachapi and Altamont WRAs. The vegetation is a mixture of brush land and semi-desert, resembling Tehachapi more than the rolling grassland of Altamont, although it does include areas of standing water which are not found at the other two large Californian WRAs (Anderson et al. 2005). The 'typical' three-blade turbine had a rotor diameter of 17.6 m and a hub (nacelle) height of 25.5 m (weighted means from Anderson et al. 2005: Table 2). Studies were conducted over 26 months in two periods between March 1997 and August 2000 (Anderson et al. 2005).

Carcass searches and bird utilisation surveys sampled 423 turbines using the same methods as employed at Tehachapi. A total of 27,675 min of observation recorded 14 golden eagles within 200 m radius observation points. As for Tehachapi, it was

necessary to derive an estimate of the amount of time that eagles were seen in flight. By the same method as used for Tehachapi, this gave an estimated 4.89 min of eagle flight observed. Anderson et al. (2005: Table 9) only present flight heights in height bands for all raptors, and so the same method as used for Tehachapi was employed to estimate that approximately 33 % of golden eagle flights were at 'typical' RSH. As the turbines San Gorgonio are similar in type and age to those at Altamont, it was assumed that they were operative for 55 % of the time, as described in the section for Altamont.

The study recorded one golden eagle killed by collision giving an unadjusted mortality rate of 0.46 per annum at 423 turbines. Detection of chicken carcasses by observers was 55 – 84 %, dependent on habitat, with a mean 71 % detectability (Anderson et al. 2005). For the reasons described under the Tehachapi section, this estimate was taken at face value. Chicken carcasses disappeared rapidly in the scavenger trials, with 90 % removed by day 8 and mean time to removal of 3.92 d.

As for Tehachapi, several 'adjusted' mortality estimates can be derived from the San Gorgonio data, using the same arguments. Using equations (1) and (2) of Smallwood (2007) gave 14.88 and 0.74 dead eagles per annum, respectively; assuming the study of Anderson et al. (2005) only found half the eagles which were killed (i.e. two were killed, not one) gave 0.92 casualties per annum.

Foote Creek Rim

Foote Creek Rim wind farm consists of 133 turbines built in phases between 1997 and 2000 on a grassland plateau in Carbon County, Wyoming. The avian studies were conducted over several years, as new phases became operational, but included 105 turbines, primarily three-bladed Mitsubishi 600 types which have a rotor diameter of 42 m and a hub height of 40 m (Johnson et al. 2000a, Erickson et al. 2002, Young et al. 2003a, b).

Bird utilisation observations at Foote Creek Rim were based on 800 m radius circular point counts at six locations conducted for 40 min twice per day every 1 – 2 weeks over more than 3.5 y, during which all raptors were recorded. Instant sampling was also conducted at the beginning of each observation session and at 10 min intervals

thereafter when all raptors visible were recorded (Johnson et al. 2000a). This allowed estimation of the proportion of time when golden eagles were seen (Johnson et al. 2000a: Appendix E; 0.053) which was corrected by the proportion of observations that involved flying birds (Johnson et al. 2000a: Appendix H; 0.927).

Johnson et al. (2000a: Tables 11 & 12) divided their observations by three features of the wind farm and its environs: off rim, rim edge and rim. Golden eagle activity was less off rim, which was a basis for the study's recommendation that turbines should also be located off rim (Johnson et al. 2000a). It was therefore appropriate to estimate eagle activity at RSH in the area where there was a risk of collision i.e. where the turbines were placed, off rim. This was achieved using data presented by Johnson et al. (2000a: Tables 11 & 12) to derive correction factors for the proportions of observation plots, eagle activity and flights at RSH which were off rim. These corrections were 0.62, 0.49 and 0.32 respectively. To account for turbine shutdown and maintenance and that eagles do not fly in all conditions it was assumed that eagles were only at risk of collision for 10 of the 12 h of daylight available on average per day per annum.

Carcass search protocols involved at least one search per 28 d at 69 turbines over two years and at half these turbines for a further year (Young et al. 2003a). An additional 36 turbines were searched every 28 d for a year (Young et al. 2003b). One golden eagle was found dead (Young et al. 2003b) giving the estimate of one casualty per 200 turbines per year (Erickson et al. 2002). For the main 69 turbines studied this produced 0.345 deaths per year as an unadjusted estimate.

Adult female mallards *Anas platyrhynchos* were used in searcher efficiency trials to represent large bird casualties such as eagles, and 92 % were detected. Mallards were also used in scavenger trials and the mean duration of stay was 29 d, with 57 % remaining after 28 d (Young et al. 2003a, b). Application of Smallwood's (2007) equation (1) gives an adjusted mortality estimate of 0.567 deaths per annum at 69 turbines. Given the problem in using some surrogate species in scavenger trials, Smallwood's (2007) equation (2) and Appendix (large raptors, 28 d search interval) was also used to derive a second adjusted mortality estimate of 0.403 deaths per annum at 69 turbines.

2.3 Collision modelling: estimation of avoidance rates

The steps in estimating N predicted collisions without avoidance (Stage 1 of Band et al. 2007) and the parameter values for the four wind farms included in analysis are shown in Table 1. The values used in estimation of Stage 2 (the probability of collision for every transit through rotors) were derived according to Band et al. (2007) with turbine metrics taken from each wind farm's 'typical' turbine, from manufacturer's websites or from the assumption that rotation period $\approx 0.1 \times \text{radius}$ (Fernley et al. 2007). The recommendation of Provan & Whitfield (2007) on golden eagle biometrics was not followed because the present study involved the smaller *canadensis* subspecies (Watson 1997): body length and wingspan were taken as 0.77 m and 2.0 m respectively. A flight speed of 15 m/s was assumed (Provan & Whitfield 2007) and that flight was 'gliding'. Estimated collision probabilities for a transit through rotor blades are shown in Table 1.

Combining Stages 1 and 2 gave N predicted collisions (without avoidance). Values used for N observed collisions (with avoidance) were as described under the section 'Study sites and source data'.

3. RESULTS

An example of the calculations and output, for mean mortality rate at Altamont (Smallwood & Thelander 2008), is shown in Fig. 1. The estimated avoidance rates for both Tehachapi and San Geronio when using equation (1) of Smallwood (2007), and which also used scavenging rates from trials using chickens (Anderson et al. 2004, 2005), were very low, at 74.35 % and 83.25 % respectively (Table 2). Chicken carcasses appear to be scavenged far quicker than any other 'native' species and so their use will artificially inflate estimated collision mortality (Smallwood 2007) and, hence, lower estimated avoidance rates. As chicken carcasses are clearly not a representative surrogate for large raptors such as golden eagles (Smallwood 2007), and the search interval was long at Tehachapi and San Geronio, these estimates of avoidance rates should probably be ignored.

More realistic estimates for avoidance rates under the Band et al. (2007) collision risk model varied between 98.64 % and 99.89 %, depending on site and the value of N

observed collisions (with avoidance) (Table 2). Combining values across the four wind farms for estimates of N predicted collisions (without avoidance) (Table 1) and for all 'worst case' (i.e. lowest values) N observed collisions (after avoidance) gave 16,536 and 111, respectively. This produced an estimated 'lowest' avoidance rate, weighted according to the scale of study of the respective wind farms, of 99.33 %. The mean unweighted 'worst case' (lowest) avoidance rate for the four wind farms was 99.19 %.

4. DISCUSSION

The present study suggests that a 99.0% collision avoidance rate for the golden eagle is a precautionary estimate, under the CRM of Band et al. (2007). This rate is not transferable to other CRMs, as noted by Madders & Whitfield (2006), since other CRMs may involve different assumptions, but the calculations in Table 1 should allow appropriate rates to be estimated. This rate is similar to that of several other raptor species (Whitfield & Madders 2006a, b) but lower than estimates for geese (Fernley et al. 2007) and waders (shorebirds) (Whitfield 2007). This finding is consistent with the observation made by several authors that raptors appear to be more vulnerable to collision with rotating turbine blades than many other bird groups (e.g. Erickson et al. 2002, Young et al. 2003b). Although the small number of study sites should temper conclusions, what is perhaps more surprising is that the estimated avoidance rate for Altamont Pass WRA, a site notorious for the rate at which it kills golden eagles, was not the lowest.

Some precaution should probably be exercised when using the estimated avoidance rate in predictive studies or EIAs because of the form of data on raptor use collected at USA sites and their relevance to the type of data collected during an assessment of a proposed wind farm site (i.e. during the typical application of the CRM when avoidance rates are usually required in practice). During the assessment process information is gathered on the level of flight activity in a proposed wind farm site (Stage 1: Band et al. 2007) and after application of a collision probability (Stage 2) and an 'avoidance rate', a predicted mortality rate for the proposed scheme results (Band et al. 2007). While termed an 'avoidance rate', however, in this context it is probably more properly considered as a correction factor which should incorporate avoidance and any displacement, according to the definition of these terms by Band et al. (2007). Band et

al. (2007) note the distinction between 'displacement' and 'avoidance', the former being a reduction in flight activity within a wind farm as a result of bird(s) staying away from the environs of the turbines, and the latter being the evasion of the rotor swept area of the wind farm's constituent turbines. Although termed differently, the processes are similar, not entirely mutually exclusive, and differ mainly by spatial scale: displacement is avoidance at a higher spatial scale than 'true' avoidance, but both involve the alteration of flight path relative to wind turbines. The USA studies, by taking observations of flight activity at operational wind farms close to turbines, provide measures closer to true avoidance (since any displacement effect, however slight, has already occurred and so is not incorporated). Thus the 'avoidance' rates derived from such observations may be too high when applied to a situation (as in a wind farm assessment, when no turbines are present) when both displacement and avoidance may result. Although there was no evidence of displacement at Foote Creek Rim (Johnson et al. 2000a) it was not studied at the Californian WRAs.

There are other caveats which should be borne in mind when using the estimated avoidance rate in predictive studies or EIAs. Several involve the nature of the sites from which the estimate has originated. First, the turbines in the study sites are different from the majority of types used in contemporary construction. While there is little evidence from the limited existing research of turbine type *per se* affecting collision rates (Smallwood & Thelander 2004, de Lucas et al. 2008) this research did not include large modern types which differ by scale (hub height, rotor blade length, rotation speed) and in spacing. Blade tip speed is greater in large turbines, but birds still, at least theoretically, have more time to pass safely through the rotor swept volume, even at the outer limit of the rotor swept area. On the other hand, larger turbines probably generate greater turbulence and this may mean birds may be less able to fly away successfully from a blade. Larger turbines are further apart. This could mean that birds have more space and more capacity for surviving slight errors in flight direction, but it might increase risk because there is a reduced 'wind wall' effect and so birds try to fly between larger turbines more often, rather than just avoid a string of several turbines.

A second consideration is an effect of weather, in that the climate of California and Wyoming is different to, say, Scotland. Weather, notably wind speed, can influence collision risk and low wind speed may be more problematic than high wind speed

(Barrios & Rodríguez 2004, de Lucas et al. 2008) because birds are less able to use wind energy in evading blades. Topographic features which generate high wind energy may be especially attractive to raptors (McLeod et al. 2002), and so turbines placed on such features may be especially prone to kill birds (Hoover & Morrison 2005, de Lucas et al. unpubl. data). Strikes may not be influenced too much by poor visibility. Despite research on 'motion smear' and painting blades to make them more obvious, there is little empirical support that blade visibility is influential (e.g. Young et al. 2003b). Observations of collisions in southern Spain suggest birds are aware of rotor blades when they collide and are usually hit at the outer limits of the rotors (L. Barrios pers. comm.) and they do not appear to die more often during conditions of poor visibility (Barrios & Rodríguez 2004). There are several studies indicating that during fog birds take flight actions which compensate for the reduced visibility (e.g. don't fly or fly close to the ground: Moyle & Heppner 1998, Richardson 2000, Piersma et al. 2002), so in foggy conditions birds may actually be at less risk of collision.

Predicting the rates at which birds collide with rotating wind turbine blades is difficult because there is uncertainty in many of the parameter values which are required to produce robust calculations, and empirical measures of collision rates are rare both by study-number and by frequency within-study (Whitfield & Coupar 2008), making objective support for predictive models difficult. Avoidance of collision has been stressed as a major influence on uncertainty in the predictions of CRMs (Chamberlain et al. 2006, Madders & Whitfield 2006, Whitfield et al. 2006a, b, Band et al. 2007, Fernley et al. 2007). The absence of robust avoidance estimates for CRMs generates acute uncertainty in the value of CRMs which attempt to predict estimates of collision mortality, especially when other deficiencies may be pertinent to CRM assumptions (Madders & Whitfield 2006, Smallwood 2006, de Lucas et al. 2008). The absence of robust avoidance rate estimates has led to a call for the abandonment of CRMs until avoidance rates can be calculated (Chamberlain et al. 2006). Avoidance rates have now been estimated for several species and it is apparent that typically they are extremely high with evidence coming not only from quantitative attempts to estimate rates (Whitfield & Madders 2006a, b, Fernley et al. 2007, Whitfield 2007, present study) but from other observations (Desholm & Kahlert 2005, Everaert & Steinen 2007). These studies show that Band et al.'s (2007) original proposal of 95 % as a generic avoidance rate, made in the absence of any empirical measures, is too low.

The difficulty in deriving reliable mortality estimates for collision victims has been stressed as an obstacle to deriving reliable avoidance rates (Chamberlain et al. 2005, 2006). There are several potential biases in typical methods used to search for collision victims around turbines (Gauthreaux 1995) but one which has remained resistant to study to-date is crippling bias, in which mortality is underestimated because some birds which are fatally injured by turbine blades may die away from areas searched for casualties (Gauthreaux 1995, Smallwood 2007). In the past, studies monitoring avian collision casualties seldom attempted to correct for the other main biases in search protocols, searcher efficiency and removal of carcasses (e.g. by scavengers), but more recently attempts have been made (Whitfield & Coupar 2008). If these biases are not accounted for, then mortality can be underestimated (and avoidance rates inflated). Smallwood (2007) has highlighted complexity in the issue of carcass search biases, and noted that trials to estimate raptor carcass removal rates, through choice of surrogate species, may bias mortality estimates low or, high (despite the objectives of such trials). Tests of scavenger removal rates may also use so many carcasses (often many more than apparently resulting from collision) that scavengers are 'swamped' (Smallwood 2007) or attracted to the wind farm area (Madders & Whitfield 2006). There are also often several problems with searcher efficiency trials and perhaps the most severe of these is when trials are conducted with the searchers' knowledge that they are being tested. The present study tried to account for these difficulties in search protocols, but as Smallwood (2007) recommends, far more research is needed on search biases using carcasses of the species which are at risk of collision and with more attention on searcher efficiency trials simulating 'field conditions'.

Whitfield & Coupar (2008) note that that another difficulty in gathering 'reliable' collision mortality data is that they can require many birds to be killed over, potentially, many years – features that EIAs should be trying to prevent. Hence, results will often involve 'unreliable' data and/or more 'reliable' data but from a small number of sites where the assessment process has failed, raising the further difficulty of their representativeness. There is high spatial variation in collision mortality and high temporal variation because collisions are fundamentally rare events (e.g. Smallwood & Thelander 2004). This potentially generates wide margins of 'error' in mortality estimates and is an intrinsic feature of collision mortality. Even at the best-studied wind farm, Altamont, confidence

limits around the mean mortality estimates of raptors were wide (Smallwood & Thelander 2008), although for golden eagles the mean estimate derived from carcass searches was similar to that derived from radio tracking (Hunt 2002)

Attention on the problems facing research on wind farm effects on birds, and predicting such effects, has tended to surround deriving reliable mortality estimates, although observational influences on deriving reliable measures of bird use may be just as problematic (Madders & Whitfield 2006, Smallwood 2006). Potential biases may be introduced by observer skills or unrealistic assumptions that an observer can record at 360° during circular point counts, especially if distracted by the need to document any birds seen (Madders & Whitfield 2006), and decrease in detectability with distance from observer in several species (Madders & Whitfield 2006, Smallwood 2006) or increase in detectability in other species (Madders & Whitfield 2006). Resolving these difficulties should receive as much attention as those surrounding mortality estimates if predicting wind farm effects is to be improved.

Given the many sources of potential variation in the parameters used by the present study, its approach of (in most cases) employing mean estimates can be criticised statistically because it effectively ignores, while implicitly compounding, several sources of variation. An alternative approach, that is more valid statistically (and so potentially 'better'), would have been to perform Monte Carlo simulations incorporating variance in parameter estimates and hence giving confidence limits (CLs: e.g. 95 % CLs) to the avoidance rate estimate. Undoubtedly, this approach would have generated extremely wide 95 % CLs in the avoidance estimate, with the upper at 100 % avoidance and the lower substantially less than 99 % avoidance. It would also have given a false sense of 'confidence' in the results because, as noted above, many sources of error (as described in the preceding paragraph) cannot be accounted for by any method because the relevant data rarely exist.

Altman & Royston (2000) have pointed out that the objective of modelling is to produce a model that works satisfactorily in a situation (e.g. at another site) not involving the data from which it was derived, and that a model may be statistically valid but not valuable because it may not be 'clinically' valid. How valuable or 'clinically' valid would a model derived by the more statistically valid approach be in the present case? Even if we took

such a model for a site where it was derived, the CLs would produce results that would be patently wrong (not 'true'). Under a 100 % avoidance rate (the likely upper CL) no birds should die, but we know that birds did die, and avoidance rates of, for example, 95 % or 96 % would predict numbers of deaths substantially (likely, inconceivably) higher than those observed (even with the apparent uncertainty in some parameter estimates). So the 'true' value would probably not have a 95 % chance of lying between the values the statistical model was indicating. Application to other sites would encompass the estimates of observed deaths, because the CLs would be so wide, but this could not be described as satisfactory, so this modelling method, or at least the derivation of CLs, is arguably not valuable.

The modelling approach adopted by the present study has probably produced a more satisfactory output, in that an avoidance rate estimate derived at one site, when applied to other sites encompassed by the study, would predict mortality estimates that would not be radically different to observed. An approximation of the likely compounded error can be gleaned by simply examining the effect of varying the avoidance estimate on the mortality estimate (which is free of 'compound' errors). Nevertheless, we should expect that avoidance rates will differ between sites (since they demonstrably vary within sites).

Finally, it should be borne in mind that CRMs are crude and should not be 'over-interpreted' (Madders & Whitfield 2006, Band et al. 2007). This is not only because of the difficulties surrounding avoidance rates and the metrics necessary for their derivation, but also because the fundamental assumption of CRMs, that collision mortality increases with flight activity, is not necessarily borne out by empirical data (Whitfield & Madders 2006a, Fernley et al. 2007, de Lucas et al. 2008). At a crude level the logic of this assumption is difficult to fault in that, all else being equal, a wind farm with very high bird activity seems bound to lead to more collisions than a wind farm with very low bird activity. This logic seems not to hold, however, at the levels of bird activity documented by most post-construction studies. This may be because at least to date, whether by design or accident, construction of wind farms in areas of high bird activity is exceptional (or research and/or publication of monitoring studies at these sites are exceptional) (Whitfield & Coupar 2008) and restricted to 'problem sites' such as Altamont Pass and Smøla in Norway (BirdLife International 2006). Of course, construction of wind farms in areas where bird mortality could be severe should be avoided, and CRMs can

assist in this process. But focussing on CRMs and their predictions tends to ignore research showing that influences on mortality other than activity levels *per se* may be equally important (Smallwood & Thelander 2004, Hoover & Morrison 2005, Whitfield & Madders 2006a, de Lucas et al. 2008) and this may lead to errors in predicting effects of wind farms and, hence, planning their locations.

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Table 1. Steps, parameters, and parameter values used in the calculation of Stage 1 output (number of transits through rotor blades) and Stage 2 (collision probability) in the Band collision risk model (Band et al. 2007) to derive estimates of collision avoidance rates for golden eagle. Plot area is the study area under observation at any one time (not the total area of the study site). All estimates of values for each stage are not shown to improve readability, but estimates at key stages are illustrated as are the calculations (under ‘Units & calculations’) used to reach derivative steps. A = Altamont Pass WRA, T = Tehachapi Pass WRA, SG = San Gorgonio WRA, FCR = Foote Creek Rim; see text for details of sites and methods to extract parameter values for each wind farm.

Step	Parameter	Units & calculations	Wind farm			
			A	T	SG	FCR
[1]	Plot area	ha	28.3	12.6	12.6	124.7
[2]	Observation time	min	7236	16590	27675	
[3]	Time bird spent in flight	min	35	1.05	4.89	
[4]	Proportion of flights at rotor height		0.36	0.33	0.33	0.32
[5]	Proportion of observation time bird flights were at rotor height	$([3]/[2])*[4]$				0.016 ^a
[6]	Probability of rotor height flights per ha	$[5]/[1]$				
[7]	Flight risk area ^b	ha	4241	500.3	332.2	54.2
[8]	Proportion of time birds flew at rotor height within flight risk area	$[7]/[6]$				
[9]	Potential bird occupancy in days per annum	d	365	365	365	365
[10]	Potential flight hours per day ^c	hr	6.6	6.6	6.6	10
[11]	Potential total occupancy	$\text{hr/y} = [9]*[10]$				
[12]	Bird occupancy at rotor swept heights in risk area per annum	$\text{sec} = ([11]*[6])*3600$				
[13]	Flight risk volume	$\text{m}^3 = ([7]*10000)*[15]$				
[14]	Number of turbines ^d		5400	637	423	69

[15]	Rotor diameter	m	21.9	19.2	17.6	42
[16]	Rotor depth	m	1	1	1	1.5
[17]	Bird length	m	0.77	0.77	0.77	0.77
[18]	Volume swept by rotor blades	$([16]+[17])*Pi([15]/2)^2*[14]$				
[19]	Bird occupancy of rotor swept volume	$[12]*([18]/[13])$				
[20]	Flight speed	m/sec	15	15	15	15
[21]	Time taken for transit through rotors	$sec = ([16]+[17])/[20]$				
[22]	Number of transits through rotors	$[19]/[21]$				
[23]	BAND collision (From Stage 2 calculation) % of transits		21.6	23.6	25.2	11.7
[24]	Collisions per annum (no avoidance) for N turbines in step [14]		16075	48.8	88.9	323.4

Notes:

^a Uses instant sampling of proportion of observations when eagles seen corrected by proportion of these observations when birds were flying, rather than steps [2] and [3].

^b Taken simply as the area given by a 50 m radius circle around each of the given number of turbines used as the basis for observed mortality estimates (see step [14] and text). The area chosen here is inconsequential on calculations, provided the same value is used in the next step.

^c At this step (or the previous step – it does not matter where it is incorporated so far as later steps are concerned) the proportion of time during which birds are at risk of collision needs to be accounted for. Two factors are pertinent here: the first is that turbines are not operational at all times, due to wind speed effects or that turbines break down and require maintenance to restore operation; the second is that diurnal raptors probably do not fly in all conditions for all daylight hours due to weather conditions and diurnal constraints.

^d It is important that the estimated mortality rate after avoidance refers to the same number of turbines as given here; the number used depends on how source studies presented or derived mortality rates, either being the whole wind farm (e.g. Altamont) or the sample searched for carcasses (e.g. Tehachapi).

Table 2. Estimated avoidance rates (%) for golden eagles according to wind farm and the mortality estimate used in calculations (= *N* observed collisions after avoidance). A = Altamont Pass WRA, T = Tehachapi Pass WRA, SG = San Gorgonio WRA, FCR = Foote Creek Rim. Equation (1) of Smallwood (2007) was used, along with observed results of scavenger trials, to produce mortality estimates ‘adjusted by observed scavenger trials’. Equation (2) and the Appendix (large raptors) of Smallwood (2007) was used to produce mortality estimates ‘adjusted by expected carcass persistence’, assuming observed scavenger trials did not use representative species.

Mortality estimate	Wind farm			
	A	T	SG	FCR
Mean adjusted	99.58	-	-	-
Upper 80 % CL adjusted	99.32	-	-	-
Lower 80 % CL adjusted	99.84	-	-	-
Unadjusted for biases	-	99.32	99.48	99.89
Adjusted by observed scavenger trials	-	74.35	83.25	99.82
Adjusted by expected carcass persistence	-	99.06	99.17	99.88
Adjusted by doubling observed rate	-	98.64	98.96	-

Figure legends

Fig. 1. An example of the calculations in MS Excel used to derive an estimated avoidance rate, for golden eagles at Altamont Pass WRA, using mean mortality rate (Smallwood & Thelander 2008).

Plot area	28.27 ha, 300 m radius S&T 04
Obs time	7236 min
GE flying time	35 min
Prop time GE fly at rotor height	0.36 Smallwood & Thelander 2004 Fig 8-13
Prop obs time GE fly at rotor height	0.001741294
Prob rotor height flights per ha	6.15951E-05
Flight risk area	4241.2 ha, 50m around 5400 turbines
Prop time GE fly at rotor height within flight risk area	0.261237146
occupancy days per annum	365 d
flight hours per day	6.6 hr, adjusting for time when turbine inoperative, see Note 1
occupancy	2409 hr/yr
GE occupancy at rotor swept heights in risk area	629.3202857 hr/yr
	2265553.029 sec/yr
Flight risk volume	928822800 m3
N turbines	5400
Rotor diameter	21.9
Rotor depth	1
Bird length	0.77
Vol swept by rotor blades	3600353.444
Bird occupancy of rotor swept volume	8781.859844 bird-sec per yr
Flight speed	15 m/sec
Time taken for transit through rotors	0.118
N transits through rotors	74422.54105 per yr
BAND collision rate	21.60%
Eagle strikes (no avoidance)	16075.26887
Avoidance rate	0.004167893 99.58%
Eagle strikes (with avoidance)	67 mean

Note 1: Assumed turbines operating for 0.55 of time (Smallwood et al 2003):
Proportion operating per month gives 0.49
Proportion operating from average wind speed on site gives 0.58

Annex 1

Discussion of the differences in avoidance rates derived by the present study and those presented by Fernley (2008)

Fernley (2008) estimated avoidance rates of 99.95 %, 100 %, 99.99 % and 100 % for Altamont, Tehachapi, San Geronio and Foote Creek Rim, respectively. The results from the present study produced lower estimates of avoidance rates than those presented by Fernley (2008; hereafter termed F2008) even though there was substantial overlap in the choice of wind farms in the studies. It is therefore worth discussing the possible reasons for these differences.

Data from other sites

F2008 also included data from the site known as Diablo Winds (West Inc. 2006, Smallwood 2006). These data were not used in the present analyses because this site can not be considered as independent from Altamont Pass. The site is part of Altamont Pass and has had old-style turbines replaced by a more modern type, but several wind farms have a mixture of different types or different-dated operational phases and/or sections and for none of these can the differences be considered as generating independent data. Results for Diablo Winds, therefore, can not be considered as independent.

The present study did not include data from Buffalo Ridge (Johnson et al. 2000b), for the reasons given in the main text, although here the estimated avoidance rate was 100 %. Buffalo Ridge data were also not included in the F2008 study, because (P. 4) *“the level of activity is so low that the corpse survey result, no Golden Eagle corpses were found, has little significance”*. As noted in the main text of the present report, it is the combination of low eagle activity and the number of turbine-year searches which renders results from Buffalo Ridge potentially dubious, not eagle activity level *per se*. Interestingly, F2008 did not exclude Tehachapi Pass data from analysis, even though on the activity level criterion (F2008, P.4; apparently why Buffalo Ridge was excluded) it should perhaps have done so, given that golden eagle activity at the two sites is comparatively and similarly low (Erickson et al. 2002, Table 11).

Records of eagle deaths

Some of the differences behind the study's estimates are obvious, and one of these is use of mortality estimates. For Tehachapi and Foote Creek Rim, F2008 assumed no eagles had been killed, apparently not accounting for records of deaths at these two sites documented by Erickson et al. (2002) and Young et al. (2003b). F2008 used a mortality rate for Altamont representing a compromise between several available, but not that given by Smallwood & Thelander (2008), used by the present study, which attempted to account for previous estimates' failings and has been published in a peer-reviewed journal. The estimate used by F2008 was lower than that used by the present study (which also included effects of uncertainty in the mean estimate). Lower mortality estimates used by F2008 will increase the estimated avoidance rates.

Non-operation of turbines

Another obvious difference between studies is that F2008 assumed non-operation of turbines and/or no eagle activity for 2 h of the day at all wind farms. The present study made this assumption only for the 'modern' wind farm at Foote Creek Rim, but for the 'old' wind farms at the other three sites estimated that turbines did not operate for 5.4 h of the day. This was based on detailed results presented for Altamont (see main text for references) and the assumption that the similar turbines at the other Californian sites would have a similar rate of non-operation. It is not obvious why F2008 did not make this correction as F2008 refers to Table 1-1 of Smallwood & Thelander (2004) where it is presented that turbines had relatively low rates of operation, although further exploration of the considerable datasets presented by the Altamont studies is required to obtain the most likely estimate of non-operation. When turbines at the Californian sites apparently did not present a risk of collision for nearly half the time, if this is not accounted for then it will elevate the estimated ability of birds to avoid collision.

Calculation of collision probability

Another difference which applied to all estimates was that F2008 used a simplified approximation method to estimate the Stage 2 collision probability, whereas the present

study used the method as presented by Band et al. (2007). The calculation used by F2008 tends to produce higher estimates of avoidance rates than that given by Band et al. (2007). The present study used Band et al. (2007) because, the method used by F2008 is an approximation and while more complicated and requiring more data on turbine blade specifications than the F2008 method (Fernley et al. 2007), it is more frequently used and has been independently audited (Chamberlain et al. 2005).

Number of turbines used in calculations

Other differences between studies appear to be restricted to specific steps in calculations for particular sites. A potential error in the calculations of F2008 for San Gorgonio is that they assumed that the unadjusted mortality rate (0.5 deaths per year) applied to the whole wind farm (c. 3,000 turbines) but this mortality rate referred only to the number of turbines which were searched for victims (423; Anderson et al. 2005). While the single death recorded was an 'incidental' find, it was apparently found within the search area. F2008's application of the observed unadjusted mortality rate to a larger number of turbines than was appropriate will elevate the avoidance rate estimate.

Eagle activity at Altamont

Another potential error in F2008 calculations involves Altamont and the estimate of eagle activity. Unfortunately, despite considerable field efforts, the reporting of results of the bird use surveys in Thelander et al. (2003) and Smallwood & Thelander (2004) suffers from lack of clarity, and can be very confusing without efforts to discern how the records were collected, how they have been reported, and how they can be used as metric values for collision risk modelling and avoidance rate derivation. Thelander et al. (2003) report that their observations were recorded to 300 m from observation points (i.e. 28.3 ha, P.13) but that their 20 study plots were 297.5 ha (P. 12 & Table 2) or, once records were assigned to different distances (up to 300 m from turbines) were 139 ha ($2780/20 = 139$ ha: P. 17).

It is apparent from Smallwood (2006), however, that fundamentally the survey plot used was a 300 m radius circle from the observer (circular point count: Reynolds et al. 1980), since Smallwood (2006) criticises the use of larger distances and that this basic method

was used to generate species-specific exploitation functions and flight-time estimates over a wider area, according to three distances from turbines (as reported, for example by Thelander et al. 2003) across the 20 study plots (presumably 139 ha, rather than 297.5 ha, despite what is presented in Table 2 of Thelander et al. 2003). On the other hand, this is difficult to reconcile with Thelander et al. (2003) stating that (P. 12): “*within each study plot, a location was selected from which behavioral observations took place. The observation point was a fixed location used for all behavioral data collection...*”. In other words, Thelander et al. (2003) strongly infer that each of 20 study plots had a single fixed observation point, but this is inconsistent with the description of each plot as either 297.5 ha or 139 ha if each (single per plot) observation point was a 300 m radius circle (28.3 ha).

It seems most likely, from material presented later than Thelander et al. (2003), that there were actually several fixed observation points (300 m radius) per study plot (297.5 ha) and that these were used to generate survey areas (139 ha) around turbines buffered up to 300 m (e.g. Smallwood & Thelander 2004, Fig. 8-2). Confusion over which parameter values for golden eagle flight activity should be used in deriving avoidance rate estimates is easy, nevertheless. Hence, in the present study, the straightforward descriptions of results from 30 min observation periods, provided by Smallwood & Thelander (2004) for 300 m radius observation areas, were employed: 120.6 h of observation (Smallwood & Thelander 2004: section 8.3.1) which recorded 35 min of eagle flight (Smallwood & Thelander 2004: Table 8-3).

F2008 seems to have applied the basic observation plot size (300 m radius), which is correct, but then used the results presented by Thelander et al. (2003) for those generated for the ‘wider’ study plots, which is not appropriate. F2008 (P. 8) confirms that the survey plot used in calculations was a 300 m radius circle (i.e. 28.3 ha) but then uses a result, presented in Thelander et al. (2003: Table 7) of the mean flying time for golden eagles of 3.12 min, which with a flight speed¹ of 13 m/s gives an estimated average flight length of 2,434 m. As noted by Fernley et al. (2007), however, a reasonable approximation of the average flight length of a bird across a circle of a given diameter D

¹ The present study assumed a flight speed of 15 m/s for golden eagle, following the review of Provan & Whitfield (2007); the difference in the two studies’ assumptions will only make a minor contribution to differences in final results.

is given by: $D * (\pi/4)$, which in this instance gives 471 m. This is much lower (< 20 %) than the estimate of flight length used by F2008. Since eagles at Altamont do not appear to engage disproportionately in circular flight behaviours such as soaring upwards which would retain flight activity within a constrained area, but appear to glide or fly through observation plots relatively frequently (Smallwood & Thelander 2004), then the mean estimate of flight length used by F2008 appears to be seriously excessive. This supposition is confirmed if Table 11 of Thelander et al. (2003) is consulted where a higher 'mean flying time' (3.75 min) is presented for an area ≤ 50 m from a turbine. Using the same calculations employed by F2008 and Fernley et al. (2007), this would respectively give an 'observed' flight length of 2,925 m against an 'expected' flight length of 79 m. Clearly, this difference is even more difficult to reconcile with eagle behaviour than the calculations for a 300 m radius plot.

What is apparent, therefore, is that the results for 'mean flying time' presented by Thelander et al. (2003) and as used by F2008 are derivatives for a wider study area and not referable to the basic 300 m radius observation plot. Thus, by using the value of 'eagle flight minutes' presented by Thelander et al. (2003) for a wider study area and applying it to a much smaller plot, F2008 has markedly overestimated the eagle flight activity around the turbines at Altamont. This will generate inflated estimates of avoidance rates.

F2008 and Whitfield & Band (in prep.)

F2008 refers to an earlier study, Whitfield & Band (in prep.; hereafter termed W&B), which had also estimated avoidance rates in golden eagles at five wind farms, and in several other raptor species. Unfortunately, the W&B note had been circulated in a preliminary form drafted several years ago and the present report represents the continuing process of updating and revising these original estimates, for a number of raptors and non-raptors; a process begun by Whitfield & Madders (2006a, b) and Whitfield (2007). Appropriately, F2008 has criticised W&B as it presented no calculations, but this was because it was a draft note in preparation which was not intended for circulation. In the present study these calculations have been reviewed and updated, for golden eagles, and contrasted against the values found by F2008 in this Annex.

It is apparent (F2008: section 3.4) that the estimates presented by W&B are lower than those given by the present study, except for Foote Creek Rim. The reasons for these differences primarily relate to the difficulties in determining the appropriate eagle activity levels at Altamont and that W&B had used Altamont as a basis for assessing activity levels at Tehachapi and San Geronio, using Erickson et al (2002). Subsequent to the drafting of W&B much more information has come to light, notably Anderson et al. (2004, 2005), clarification of Altamont studies' methods and results (e.g. Smallwood & Thelander 2008, Smallwood 2006), and the timely review of Smallwood (2007). Thus, while the present study criticises F2008 for its approach in some areas, it also agrees with F2008 in many aspects by criticising W&B implicitly.