Reducing uncertainty in IA with continuous monitoring & adaptative management

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INTRODUCTION

There is still much uncertainty associated with environmental impact assessment (IA), particularly when it comes to determining collision risk at wind farms (WF). Collision risk models (CRM) allow to reduce uncertainty to some extent through quantification of the impact by predicting fatalities due to collision with turbines.

Currently, traditional approaches in IA focus on qualitative assessments from specialists and monitoring data. For WFs, a prediction of the expected number collisions is an important aspect. High fatalities can negatively impact populations (May *et al.,* 2019). Therefore, mitigation measures are usually triggered in response to such results from monitoring surveys in IA studies. However, the mitigation hierarchy (Jacob *et al.* 2016) tells us to avoid before mitigating which means preventing before reacting. Thus, it is crucial to anticipate negative impacts and implement proactive measures and prevent impacts whenever possible. CRMs aim to provide a prediction of the number of collisions that may occur in a WF (Masden & Cook, 2016). They can be useful in the decision-making process, prior to the construction phase, at licencing and mitigation level (Normandeau, 2012). Additionally, such predictions may help reduce uncertainty associated with the expected impacts. However, doubts in whether CRM can correctly predict fatalities are still an issue and not yet fully validated (Masden & Cook, 2016).

Our main goal was to understand if CRM can provide useful information for IA, thus reducing uncertainty. To do so, we had two main questions to answer using a case study. **Question 1:** would we have made different recommendations along the IA process had we used CRM? We compared results and recommendations we adopted while using the "traditional approach" (i.e., with no CRM) with hypothetical recommendations based on results if a CRM was used (i.e., "CRM approach"). Then, our **question 2:** can CRM replace expensive carcass surveys and how reliable are the results? Again, we compared the "traditional approach", in this case the fatality estimates from carcass searches with the "CRM approach" given by the number of precited collisions of CRM.

METHODOLOGY

To address our goals, we selected the "Serra dos Candeeiros" wind farm as case study. Located in Portugal, it has the particularity of being placed in a category II protected area within the "Serras de Aire e Candeeiros" National Park, partially coincident with a Natura 2000 site (PTCON0015). Consequently, this WF is subject to monitoring until decommissioning, resulting in a long-term series of monitoring data (over 10 years). In terms of project timeline, a general monitoring programme of birds was initiated in 2003, during pre-construction phase; operation started in 2005, as did mortality monitoring. High levels of Kestrel (*Falco tinnunculus*) mortality led to a monitoring program adaptation to focus on this species in 2008. A mitigation/compensation plan was initiated in 2013. Mortality levels slightly decreased, leading to the review of the mitigation program in 2018. Additionally, the WF area suffered several external factors, such as wildfires and shrubs clearance next to turbines as a wildfire prevention measure (see Figure 3).

In terms of CRM, we used the Band model (Band, 2012) along with modifications developed by Masden (2015) which allowed to account for uncertainty associated with input parameters and thus reflecting uncertainty in the results. However, these versions were developed for offshore sites. Offshore and onshore data differ mainly in the way bird data is collected. To use onshore data as input, we made some alterations so that we could still benefit from not the updates introduced in Band's 2012 version, but also from the Masden's updates. We bypassed the first steps of the Band/Masden approach and used calculations described by Band's 2007 model which supported onshore data (Band *et al.*, 2007; see Figure 1).

To answer to question 2 defined in our goals, we compared the number of predicted collisions from this adapted CRM approach with fatality estimates obtained using onsite carcass searches. The fatality estimator used was GenEst (v1.4.0.1; Dalthrop *et al.,* 2019).

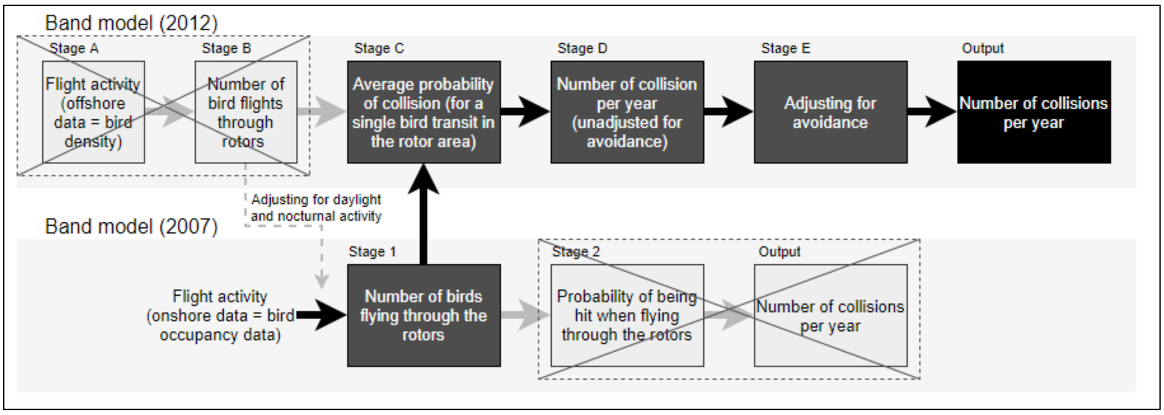

Figure 1 - Calculation steps used to estimate number of collisions per year. Two versions of the Band model were used in a merged approach: the first steps followed 2007 version to use onshore data; the later stages/calculations followed 2012 version to take advantage of its updates.

Additionally, we tested a "spatial" approach of the CRM to understand if it could identify critical areas in terms of expected collisions in the WF area and provide useful information for IA. Band (2012) suggested that collision risk is directly proportional to bird flight at rotor risk height. We followed his suggestion and adapted our approach (Figure 2) to calculate the collision risk. We collected data from vantage points in the format of georeferenced routes (instead of just bird counts) for the overall area of the WF and overlaid it with a 500x500m grid. Flight activity was obtained by summing data associated with the proportion of routes that fell within each grid cell.

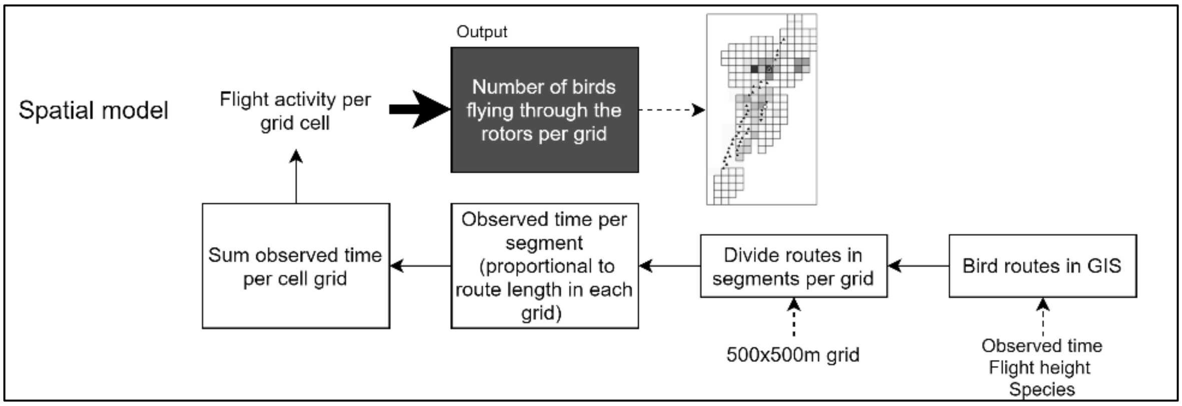

Figure 2 - Band model adaptation for "spatial" approach. To calculate collision risk per area, first we georeferenced bird routes in a geographic information system, adding duration (seconds) and flight height. Then, we split each route using a 500x500m grid to calculate route segments length per cell and proportionally split their duration. Finally, we summed all routes duration in each cell which corresponded to flight activity per cell.

FINDINGS

Question 1: Would we have made different recommendations had we used CRM?

We started by analysing the decisions made during pre-construction phase. In the "traditional approach" (i.e., with no CRM) impacts such as displacement, habitat loss and mortality due to collision were predicted. Although birds of prey and soaring birds were flagged as more susceptible, no target species were identified because data collected during pre-construction did not raised concerns. However, this was a qualitative analysis, based on expert's opinion on flight activity observed in the area. No model was used to relate flight activity and collisions. However, had a "CRM approach" been adopted at this stage, CRM would have predicted mortality of Kestrels and this species may have been identified as a target species right from the start of the IA.

Then, we looked at decisions made during operation phase. High levels of Kestrel mortality were unexpected because they were not predicted during pre-construction phase. High mortality led to monitoring adjustments to target Kestrels. Had CRM been used, these high levels of mortality would have been predicted and mitigation measures may have been suggested earlier on, rather than a few years later. Therefore, mitigation was a consequence of the observed impacts with the "traditional approach". On the contrary, the "CRM approach" would have predicted and anticipated impacts on Kestrel and maybe triggered earlier mitigation.

Results from CRM "spatial" with the purpose of identifying critical areas in the WF were particularly interesting because they are usually not included in traditional IA reports. The resulting risk maps systematically indicated the middle section of the WF had higher risk of collision (Figure 3). This is relevant as in the "traditional approach" mitigation measures were applied at turbine level (i.e., to specific turbines with higher fatality). However, fatality levels in each turbine changed from year to year. The "spatial" CRM approach could have predicted broader areas with higher risk, identifying potentially problematic areas. This provides a general idea of where mitigation would be most effective in a larger scale, rather than at turbine level.

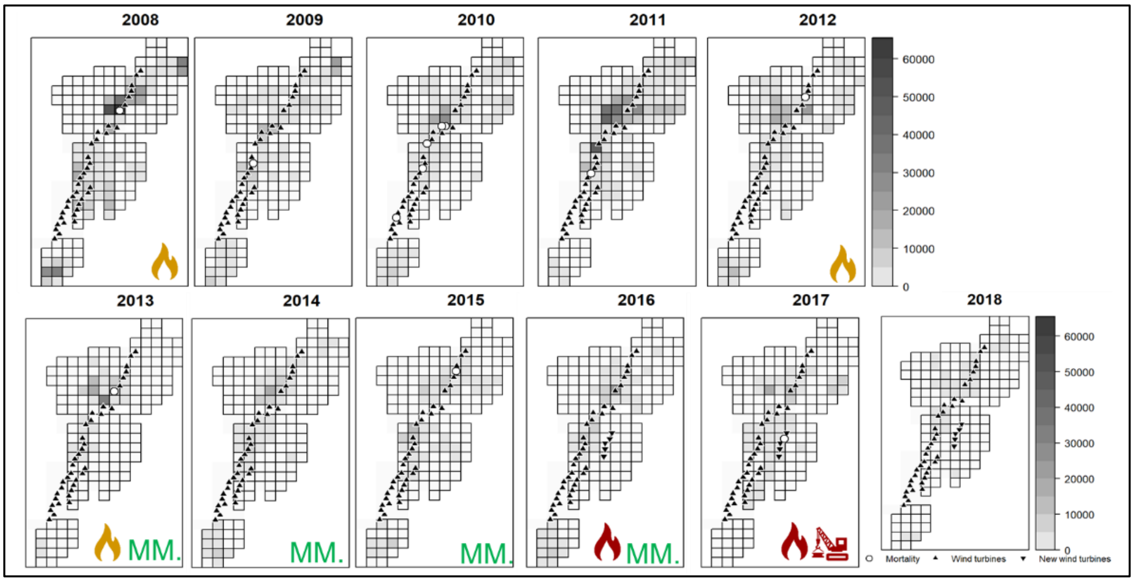

*Figure 3 – Collision risk maps obtained using "spatial" CRM for Kestrels (*Falco tinnunucus*) from 2008-2018. Legend: shades of grey: collision risk (darker shades indicate higher risk); black triangles: turbines' position; circles: collision events; flames: wildfires (orange: 1-10 km away; red: less than 1 km away from WF); MM – mitigation measures; red tractor: shrubs clearance activities next to turbines as wildfire prevention measure.*

Question 2: Can CRM replace expensive carcass surveys and how reliable are the results?

In the "traditional approach", monitoring programs include field work to search for carcasses to estimate fatality. They require great effort and regular visits to the WF to detect carcasses and calculate correcting factors, such as carcass removal rates and carcass detectability. If CRM can predict a number of collisions similar to the expected fatality, theoretically, carcass monitoring could be replaced by bird activity monitoring to feed collision models.

In our case study, we compared the estimated number of fatalities predicted from carcass searches using GenEst with the number of collisions per year predicted by the CRM (Figure 4). We used a Wilcoxon rank test to analyse statistical differences, after testing that our data was not parametric. Results indicated no significant differences between predicted collisions and expected fatalities (p-value > 0.05). Additionally, since our goal was to analyse results in terms of IA context, we analysed CRM accuracy in terms of how different our recommendations would have been using a CRM approach instead of using typical data from carcass searches.

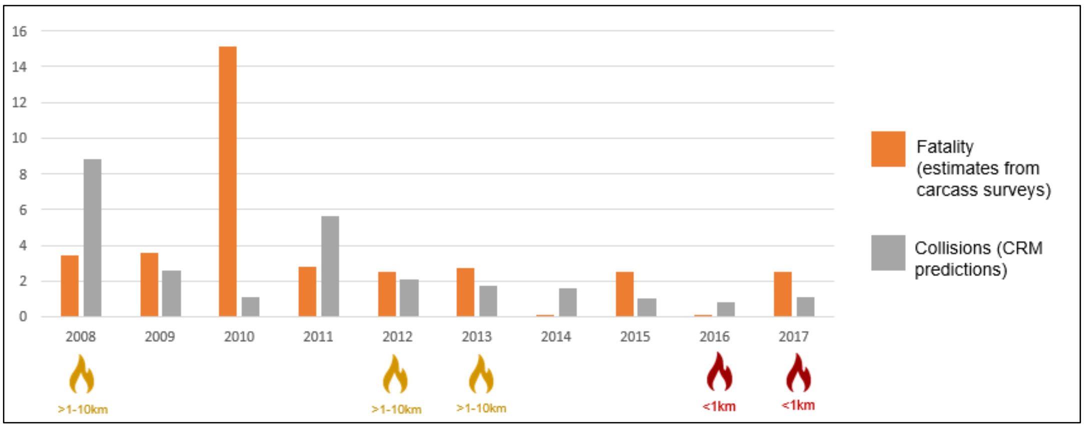

Figure 4 – Fatalities prediction from carcass searches using GenEst estimator (orange bars) and predicted number of collisions using CRM (grey bars). Flames indicate wildfires (orange: 1-10 km away; red: less than 1 km away from WF).

Despite the fact that no significant statistical differences were found between fatalities and collisions, there is a particular year in need of discussion. During our time series, the highest fatality of Kestrels was recorded in 2010. Yet, bird activity was actually lower than previous years, resulting in lower collision estimates. This indicates that CRM cannot predict collisions which may result from extreme events. The “spatial” CRM approach was also unable to predict higher risk of collision in 2010. Nevertheless, results revealed that CRM was able to predict 67% of the carcasses locations, i.e., carcasses were found within areas identified in the risk maps as high risk areas (Figure 3).

Overall, our findings suggest that the “traditional approach” with carcass surveys provides better mortality estimates, including mortality caused by extreme events of mortality. However, obtaining carcass searches data is expensive compared to obtaining flight activity data to feed CRM models. The “CRM approach” can predict a number of collisions with a satisfactory range of accuracy (in terms of an IA context) and it would have not triggered different recommendations from the “traditional approach”. Nonetheless, it is relevant to point out that CRM fails to predict extreme events of mortality. However, these events are isolated events in time and do not trigger different actions in terms of IA.

FINAL CONSIDERATIONS

Based on our case study, we believe that CRMs can be used to reduce uncertainty in IA because they provide quantitative data rather than qualitative information based mainly on how experts analyse monitoring data. Therefore, we conclude that CRM use in IA can provide useful and relevant information. Our findings indicate that CRM can predict the number of collisions in a WF with a satisfactory accuracy level, considering that the differences between the CRM predictions and the estimated fatality obtained from carcass searches would not have triggered different actions and recommendations in the IA process. Additionally, using a CRM would have enabled to better anticipate impacts still in pre-construction phase as well as indicating an expected level of fatality per year during operation phase. Therefore, CRM should be used both for pre-construction and operation phases. Although CRM can predict collisions within a satisfactory accuracy level considering an IA context, it failed to account for unusually high levels of fatality caused by unknown events. Consequently, CRM should not be used to replace carcass searches, but rather used as a complementary analysis. Therefore, the need for continuous monitoring remains. Finally, a “spatial” approach is extremely useful in IA because it can identify critical areas in a WF at a broader scale rather than turbine level.

Overall, CRM can reduce uncertainty and provide useful information for IA. It adds value to the process, making it clearer and less subjective. Additionally, earlier and more proactively recommendations can be made than using monitoring results which trigger reactive. Nevertheless, there is still much uncertainty and CRM does not eliminate the need of monitoring programs. Rather, CRM adds information and helps providing more meaningful and supported recommendations.

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