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# Methodological approaches to assessing population-level impacts of bird collisions with wind turbines: a critical perspective

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1 Methodological approaches to assess population-level impacts of bird  
2 collisions with wind turbines: a critical perspective

3

4 **Running head:** Assessing population impact of collisions

5

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10

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12 mortalities, Population projections, Potential Biological Removal, Population Viability  
13 Analysis.

14

## 15 Abstract

16 Wind energy is a source of collision fatalities for birds and bats. To evaluate the risk  
17 that wind power development projects might pose to the conservation of protected  
18 species, it is essential to quantify the impact of collisions on the dynamics of wild  
19 populations. To address this challenge, two approaches are primarily employed:  
20 Potential Biological Removal (PBR) and Population Projection Analysis (PPA). PBR  
21 is a decision rule designed to calculate a sustainable fatality limit for a given  
22 population, while PPA relies on simulation-based modelling to forecast a population's  
23 future trajectory under various scenarios. In the context of environmental impact  
24 assessments (EIAs), we argue that PPA offers a more suitable method than PBR for  
25 evaluating population-level impacts resulting from collisions with wind turbines. Unlike  
26 PBR, PPA can be focused on a single source of disturbance, aligning with the  
27 perspective of the EIA process. In contrast, PBR necessarily adopts a population-  
28 centered perspective, and is therefore only relevant when considering all sources of  
29 mortality that jointly affect a population. Furthermore, robust utilization of the PBR  
30 approach requires the definition of quantitative conservation objectives and the  
31 implementation of a comprehensive management strategy evaluation, neither of  
32 which is ever undertaken within the context of EIA.

## 33 Introduction

34 Almost everywhere around the world, the development of wind energy stands as one  
35 of the pillars of the energy transition (Teske et al. 2019). However, this mode of  
36 energy production is also a source of negative impacts on biodiversity, particularly for  
37 birds and bats (Drewitt & Langston 2006; Schuster et al. 2015; Barclay et al. 2017;  
38 Thaxter et al. 2017; Serrano et al. 2020). Wind power plants can have two types of  
39 negative effects on these volant animals. First, birds and bats are susceptible to  
40 direct mortalities caused by collisions with wind turbines or by barotrauma (Barclay et  
41 al. 2017; De Lucas & Perrow 2017). Second, like all large artificial infrastructures,  
42 wind power plants are responsible for indirect impacts, such as habitat loss,  
43 disturbance and barrier effects (Drewitt & Langston 2006; Schuster et al. 2015; Fox &  
44 Petersen 2019). Wind energy is currently developing very rapidly around the world  
45 and this rate is projected to continue accelerating in the near future (Teske et al.  
46 2019). In this context, assessing and mitigating the harmful impacts that this  
47 development will have on wildlife has become a primary concern for biodiversity  
48 conservation (Fox & Petersen 2019; Serrano et al. 2020; Durá-Alemañ et al. 2023).

49 In many countries around the globe, the construction of wind power plants is  
50 regulated by environmental protection laws, which usually require pre- and post-  
51 construction impact studies to assess the extent of negative effects on wildlife,  
52 notably protected species (Saidur et al. 2010). Regarding the risk of direct mortality of  
53 birds and bats, environmental impact assessments (EIAs) have historically focused  
54 on estimating fatality risk at the individual level (May et al. 2019) by simply  
55 addressing the question as to how many individuals of a given species are at risk of  
56 dying from collision. However, for species conservation purposes, it is crucial to  
57 assess the consequences that such mortality risk might have at the population level

58 (May et al. 2019). So far, the few EIA studies that have attempted to quantitatively  
59 assess population-level impacts have usually relied on one of two approaches. Some  
60 studies have applied a decision rule called the 'Potential Biological Removal' (PBR) in  
61 an effort to calculate quantitative limits of 'sustainable' collision fatalities (e.g. Poot et  
62 al. 2011; Leopold et al. 2014; Busch & Garthe 2016; NIRAS 2016). Other studies  
63 have focused on simulating population trajectories to predict the fate of populations  
64 exposed to collisions with wind turbines (e.g. Carrete et al. 2009; Masden 2010;  
65 García-Ripollés & López-López 2011; Poot et al. 2011; Rydell et al. 2012; Schaub  
66 2012; Sanz-Aguilar et al. 2015; Grünkorn et al. 2016; Korner-Nievergelt et al. 2016).

67 In this paper, we argue that PBR, as currently used in the context of EIA, is ill-  
68 adapted to the task of assessing population-level impacts of wind energy  
69 infrastructures. On the other hand, the use of population projections, in combination  
70 with metrics of relative impact as a decision rule, is much better suited to this task.

## 71 The Potential Biological Removal (PBR)

### 72 What is the PBR?

73 The PBR is a 'harvest' control rule that was originally developed as a means to define  
74 sustainable limits of cetacean incidental catches by commercial fishing vessels, in  
75 data-poor situations (NMFS 1994; Wade 1998; Moore et al. 2013). The harvest  
76 quota, expressed as a number of individuals removed each year, is based on a  
77 simple formula (Wade 1998):

$$PBR = F_R \frac{R_{max}}{2} N_{min} \quad (1)$$

78 where  $R_{max}$  corresponds to the theoretical maximum growth rate of the population,  
79 i.e. when it is at low density and in the absence of anthropogenic mortalities;  $N_{min}$  is a

80 conservative estimate of the population size; and  $F_R$  is a coefficient between 0.1 and  
81 1, often referred to as the 'recovery factor' (Wade 1998; Dillingham & Fletcher 2008).  
82  $R_{max}$  and  $N_{min}$  are biological parameters that must be estimated for the studied  
83 population. Parameter  $N_{min}$  is usually estimated from field data and, for birds,  $R_{max}$  is  
84 often approximated using allometric relationships that only require knowing the  
85 species' average adult survival and its age at first reproduction (Niel & Lebreton  
86 2005). The recovery factor  $F_R$  is not a biological parameter, but an adjustment  
87 parameter that must be tuned to ensure that the PBR quota fulfills a predetermined  
88 conservation objective even in the presence of uncertainties. The tuning of  $F_R$   
89 requires simulating population trajectories under a realistic demographic model, often  
90 called the 'operational model' (Moore et al. 2013), and testing the influence of a  
91 range of  $F_R$  values on the population's fate (Wade 1998; Dillingham & Fletcher 2008).  
92 Based on these simulation results, a  $F_R$  value is chosen to ensure that, when the  
93 associated PBR harvest rule is implemented, the population will have a high  
94 probability of stabilizing at a level that is equal or greater than the predefined long-  
95 term conservation objective (Figure 1). This tuning and assessment procedure, the  
96 purpose of which is to test the robustness of the PBR decision rule in a specific  
97 context, is called a Management Strategy Evaluation (MSE; Bunnefeld et al. 2011).  
98 Implementing such an MSE not only requires building an operational model for the  
99 species being targeted, but also implies that a quantitative conservation objective has  
100 been clearly defined beforehand (e.g. Haider et al. 2017; Richard & Abraham 2013).  
101 This means setting a population size threshold, often expressed as a fraction of  
102 carrying capacity (NMFS 1994; Wade 1998), above which it is desired to maintain the  
103 population in the long run (Moore et al. 2013). When correctly implemented, the PBR

104 approach can be effective in preventing or reversing population collapses (Cooke et  
105 al. 2012; Moore et al. 2013).

### 106 Why is the PBR not suited to the context of EIA?

107 First, there is a fundamental difference of scope between EIA and the PBR. EIA is a  
108 disturbance-centered endeavor, in the sense that it focuses on assessing the impact  
109 of a given infrastructure development project. This means that the entry point of the  
110 impact analysis is necessarily the source of disturbance itself, not the population. On  
111 the other hand, the PBR is a population-centered approach, in which every source of  
112 disturbance affecting a given population must be considered (Dillingham & Fletcher  
113 2011). Indeed, the rationale for the PBR approach is to find the total amount of non-  
114 natural mortalities (removals) that a population can sustain (Wade 1998). Using the  
115 PBR decision rule in an EIA context is thus a gross oversimplification because it  
116 considers a single source of anthropic mortality, ignoring all others that populations  
117 suffer (Green et al. 2016; O'Brien et al. 2017).

118 Second, because EIA lacks a population-centered perspective, no quantitative  
119 conservation objective is usually defined for the impacted population. This deficiency  
120 has been consistently observed (e.g. Poot et al. 2011; Leopold et al. 2014; Busch &  
121 Garthe 2016; NIRAS 2016) in studies that employed the PBR formula as a decision-  
122 making tool within the context of wind energy's impact on bird populations. As  
123 highlighted above, using the PBR as a decision criterion first requires the  
124 establishment of such an objective, because it constitutes a vital component of the  
125 MSE framework, within which the effectiveness of the decision rule can be rigorously  
126 evaluated.

127 Third, in the context of EIA, the PBR decision rule has been used without  
128 implementing an operational model and simulations to assess its robustness to  
129 uncertainties and tune the value of the recovery factor  $F_R$  (e.g. Poot et al. 2011;  
130 Leopold et al. 2014; Busch & Garthe 2016; NIRAS 2016). Instead, generic values of  
131  $F_R$ , which were derived in a completely different context (marine mammal bycatch in  
132 North America; Wade 1998), have been blindly applied. Therefore, there is no  
133 guarantee that the harvest quota computed through this formula would effectively  
134 align with the conservation objective, assuming such an objective would have been  
135 defined for the population under consideration.

136 Finally, it is important to keep in mind that the PBR method as formulated by  
137 Wade (1998) implicitly assumes the existence of a compensatory density-  
138 dependence relationship, which means that the population growth rate is expected to  
139 increase in response to the removal of individuals, thus partially compensating for  
140 anthropogenic mortalities (Rose et al. 2001; Beverton & Holt 2012). This density-  
141 dependent mechanism is what allows a population to stabilize at some new  
142 equilibrium when facing a sustainable level of mortalities (Wade 1998). In the  
143 absence of such a mechanism, a population exposed to additional mortalities will  
144 constantly decline, necessarily reaching extinction at some point. In birds, however,  
145 this type of compensatory mechanism cannot always be evidenced (Horswill et al.  
146 2017). Applying removal quotas based on the PBR approach in such situations could  
147 trigger or reinforce an unstoppable population decline and therefore have  
148 catastrophic consequences (O'Brien et al. 2017; Miller et al. 2019).



## 149 Population Projection Analysis (PPA)

150 Population Projection Analysis (PPA), also sometimes referred to as  
151 Population Viability Analysis (PVA), is a simulation-based method to predict the  
152 future trajectory of a population under various scenarios (Boyce 1992; Beissinger &  
153 McCullough 2002). PPA relies on a demographic model that bears resemblance to  
154 the operational models utilized within the MSE framework to evaluate decision rules  
155 like the PBR.

156 In our opinion, the PPA method is well suited for assessing population impacts  
157 in the context of EIA because it can easily be framed as a disturbance-centered  
158 assessment exercise, in complete alignment with the EIA framework (Green et al.  
159 2016). To frame a PPA as a disturbance-centered analysis, the most relevant  
160 approach consists in running population projections under two alternative scenarios:  
161 (1) a baseline scenario without collisions and (2) an impact scenario that includes  
162 additional mortalities due to collisions (Cook & Robinson 2017). The comparison of  
163 population trajectories under each of these two scenarios allows calculation of  
164 various metrics of impact induced specifically by the infrastructure (Figure 2). In the  
165 absence of a clear population conservation objective, which is the common situation  
166 in EIA, we recommend using metrics of relative impact, such as the proportional  
167 difference in population size after a given time (e.g. 25 years) between the two  
168 scenarios (Green et al. 2016). This comparative and relative approach, referred to as  
169 the 'Counterfactual of Impacted to Unimpacted' population (CIU), has been shown to  
170 be less sensitive to uncertainties (Cook & Robinson 2017). Indeed, if some model  
171 parameters are inaccurate or some model assumptions happen to be violated, their  
172 influence on the final result will be limited because they apply equally to both  
173 scenarios.

174 In the context of EIA, the use of the CIU approach also has the advantage of  
175 not requiring the definition, *a priori*, of a quantitative population objective, namely a  
176 threshold of critical population size (Green et al. 2016). The lack of a quantitative  
177 conservation objective is not an inherent feature of the PPA method, but rather  
178 reflects the regulatory framework governing the EIA process (Wathern 2013). Indeed,  
179 in this framework, the quantification of impact is separated from the decision of what  
180 level of impact qualifies as 'significant' or not (Schrage 2008).

181 Finally, when using the CIU approach based on PPA, the impact assessment  
182 does not necessarily rely on the assumption of compensatory density-dependence.  
183 The consequences of collision mortalities can thus be explored in situations where  
184 the population would not be expected to stabilize at a new equilibrium. Overall, the  
185 PPA method offers a great deal of flexibility regarding the assumptions and the level  
186 of complexity of the demographic model being used, which allows the right balance to  
187 be found between realism and practicality (Boyce 1992; Morris & Doak 2002).

188

## 189 Conclusion

190 The Potential Biological Removal (PBR) is not simply a formula that can be applied  
191 *ex nihilo* to any species or situation (Moore et al. 2013; O'Brien et al. 2017). It must  
192 be applied from a population-centered perspective, where all sources of non-natural  
193 mortalities are being considered, and it must be embedded in a Management  
194 Strategy Evaluation framework with a clear and quantitative conservation objective  
195 (Wade 1998; Dillingham & Fletcher 2008; Bunnefeld et al. 2011). Our experience  
196 indicates that within the EIA process for wind energy projects, the PBR decision rule  
197 has often been utilized mechanically, without much consideration for these  
198 constraints (Poot et al. 2011; Leopold et al. 2014; Busch & Garthe 2016; NIRAS  
199 2016). From our perspective, it appears that using Population Projection Analysis  
200 (PPA) to quantify relative metrics of impact is better suited to the EIA process, which  
201 has a disturbance-centered perspective. With the PPA approach, one can readily  
202 keep the impact assessment and decision steps separated, as is usually done in EIA.  
203 However, this approach should not lead to neglect of the definition of clear decision-  
204 making rules, as an absence of decision is often detrimental to population  
205 conservation (Cooke et al. 2012).

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344

345

## 346 Credit author statement

347 **Thierry Chambert:** Conceptualization, Literature review, Writing - Original Draft  
348 Preparation, Writing - Review & Editing.

349 **Olivier Duriez:** Conceptualization, Writing - Review & Editing.

350 **Aurélien Besnard:** Conceptualization, Literature review, Writing - Review & Editing.

## 351 Declaration of competing interest

352 The authors declare that they have no competing financial interests or personal  
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## 354 Data accessibility

355 This article does not contain data.

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364 [projet/financeurs/](https://mape.cnrs.fr/le-projet/financeurs/)).

## 365 Figures legends

366 **Figure 1.** Theoretical trajectory of two populations with two different  
367 initial states (red, green), suffering the same rate of annual mortality,  
368 which is equal to the PBR (here, with  $F = 1$ ). Independently from their  
369 initial state, each population tends toward the same equilibrium, which is  
370 equal to half the carrying capacity ( $K/2$ , blue horizontal line). The black  
371 horizontal line represents the full carrying capacity  $K$ .

372

373 **Figure 2.** Example of possible population trajectories according to two  
374 scenarios: (i) without collision mortality (in green) and (ii) with collision  
375 mortality due to the presence of a windfarm (in black). The impact can be  
376 defined as the relative difference in population size between these two  
377 scenarios after some time (e.g., 30 years).

378



