

Research project
"Reduction of Avian Mortality
in Operating Wind Farms"

Eolpop User Guide

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Introduction

The objective of the *eolpop* application is to quantify the cumulative demographic impact over time of avian mortality caused by collisions with wind turbines.

Why such a tool?

It is important to understand the difference between the *number of mortalities* caused each year by a wind farm and their *demographic impact* on a bird or chiropteran population. While estimating the *number of annual mortalities* is a crucial step in assessing the impact of a wind farm, this figure alone tells us nothing about the consequences of these collisions on the **future and viability of populations**. However, if we wish to make informed decisions regarding the conservation of species¹, it is essential to evaluate these consequences in terms of impact on the **viability of populations, and** therefore in terms of *demographic impact*. Measuring the demographic impact will allow us to know to what extent the population will be affected by these mortalities, which accumulate over time (e.g., % population decline after 30 years). It is from this information (and not from a single number of annual mortalities) that we will be able to evaluate the real consequence of collisions on the viability of a population.

It is therefore crucial to distinguish between (i) methods that aim to estimate the actual *number of annual collisions* (mortality monitoring, GENEST tool, etc.), and (ii) the demographic tool *eolpop*, which aims to estimate a demographic impact, i.e. to **"translate a number of mortalities into a consequence for the trajectory of a population"**. Estimating the number of deaths (with the GENEST tool, for example) is therefore a preliminary step to using *eolpop*. Indeed, it is one of the required inputs, but not the only one. The demographic impact is in fact determined by several parameters:

- The number of annual mortalities.
- The size of the population. It is understandable that an abundant population will have a better capacity to "absorb and compensate" for mortality than a population that is already small.
- Population trend (growth rate). It is understandable that a rapidly growing population will be better able to "absorb and compensate" for mortality than a declining population.

From this information, the *eolpop* tool allows to simulate population trajectories and thus to quantify (including uncertainties) the demographic impact of collisions. For more details on the justification

¹ We recall here that the purpose of the *eolpop* tool is to *provide insight into* any form of decision or reflection involving the evaluation of the consequences of mortality on an animal population. Our tool, and this document, are in no way intended to call into question the regulations in force which prohibit the destruction of protected species (L.411-1 and L.411-2 CE), **even if it is only a single pair or individual**. We recall that when such a risk is proven, the project owner of the site is obliged to request a derogation authorizing the destruction of protected species. It is at this stage that the question of demographic impact arises, since this exemption can only be granted if it does not *harm the maintenance in a favorable conservation status of the populations of the species concerned*, in their natural range. The regulations may change in the future. In any case, the information provided by the *eolpop* tool will remain relevant, whether it is used in the regulatory framework or in another framework (information, planning, etc.).

of this methodological choice, you can refer to the synthesis note, [available here](#), that we wrote in the framework of the MAPE research program (workpackage 2).

Tool principle and overview

The *eolpop* tool simulates population trajectories at a given *time horizon* (typically HT = 30 years) for (i) a baseline "no collision" scenario and (ii) one or more "with collision" scenarios. The demographic impact is then estimated from the *relative difference* (%) in population size between the "with collision" scenario(s) and the reference scenario. Details of the demographic model used by *eolpop* are documented in a technical document, [available here](#). The typical workflow of an analysis session with *eolpop* is as follows (Figure 1). We describe each step in detail in the following sections.

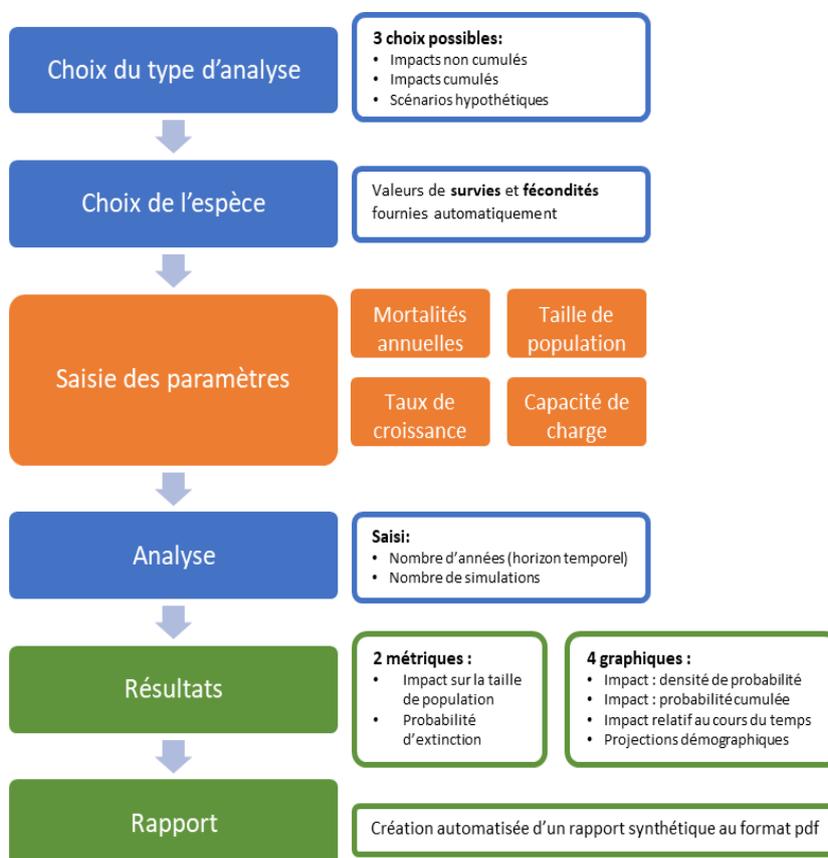


Figure 1. Schematic illustration of the *typical workflow* of an analysis session in *eolpop*.

Choice of the type of analysis desired

Three types of analysis can be performed with *eolpop*:

- **"Non-cumulative impacts:** With this option, only one scenario is analyzed, corresponding to the mortalities of a single wind farm. The user will then provide only one mortality value,

generally corresponding to collisions caused by a single wind farm. See below for details on the input (section "Input parameters > Annual mortalities").

- **"Cumulative Impacts":** With this option, the cumulative impact of several wind farms affecting the same population can be analyzed. The user will have to provide the mortality values of each wind farm, as well as their year of operation. The input will be done in a table, where each row corresponds to each wind farm. See below for details on the input. (Section "Input parameters > Annual mortalities")
- **"Hypothetical scenarios":** With this option, the impact of several (hypothetical) mortality scenarios can be analyzed. This type of analysis can notably help the State services to determine the mortality threshold ("quota") from which a given level of demographic impact is exceeded (for example: an "acceptable" limit, in relation to the conservation objectives of the species). In this case, the user will have to enter a mortality value for each scenario he wishes to evaluate. See below for details on the input (section "Input parameters > Annual mortalities").

The first step for the user is to select the type of analysis desired from these three possibilities.

Choice of species

The user must then select the target species from a drop-down list. As a general rule, only one species will be analyzed at a time, since the concept of population (and therefore demographic impact) necessarily refers to a single species. This drop-down list contains the 60 priority species of the MAPE program, listed in alphabetical order (according to their French vernacular name), as well as a "Generic Species" option at the end of the list to analyze other species. When a species is selected, several pieces of information are updated in the general panel "Analysis choice and species" (Figure 2). The updated information is as follows:

- The table showing the **survival** and **fecundity** values, by age class, for the species in question.
- **Intrinsic growth rate.**
This value is provided for information purposes and does not necessarily correspond to the actual local population trend. This growth rate is simply calculated from the survival and fecundity matrix of the species (Leslie matrix), before considering the local population trend, which the user will provide in the "Enter parameters > Growth rate" section.
- The **dispersal distances** of the species.
These values can guide the choice of spatial scale to be used to define population contours, as described in the guidance document ([available here](#)) entitled "How to Delineate a Population."

NOTE: If the "Generic species" option is selected in the list, then none of this information is displayed. The user must then provide the survival and fecundity values himself, as explained in the next section.

Changing demographic parameters

It is possible to manually modify the survival and fertility values, as well as to add age classes. This option should only be used when reliable estimates of these parameters are available for the target population. To do this, click on the "Modify demographic parameters" button in the upper right corner of the "Analysis choices and species" panel (Figure 2). You can then modify the number of age classes and the survival and fecundity values directly in the table that appears (as shown in the Figure 3).

Choix d'analyse et espèce

Type d'analyse ?

- Impacts non cumulés
- Impacts cumulés
- Scénarios hypothétiques

Sélectionner une espèce ?

Aigle royal

Distances de dispersion ?

Distance moyenne de dispersion : 35.3 km

Seuil de distance équiv. 3% de dispersion : 123.8 km
 Seuil de distance équiv. 5% de dispersion : 105.7 km
 Seuil de distance équiv. 10% de dispersion : 81.3 km

Paramètres démographiques ?

| | Survie | Fécondité |
|----|--------|-----------|
| A0 | 0.71 | 0 |
| A1 | 0.85 | 0 |
| A2 | 0.85 | 0 |
| A3 | 0.85 | 0.24* |
| A4 | 0.87 | 0.24* |
| A5 | 0.9 | 0.48 |

Taux de croissance intrinsèque ?

Croissance : 7% par an

* Les valeurs marquées d'une astérisque ne sont pas issues de la littérature. Elles ont été inférées à partir des autres valeurs de paramètres. Il y a donc plus d'incertitude quant à leur exactitude.

Modifier les paramètres démographiques

Figure 2 . General panel "analysis choice and species".
 Red box: information that is updated when the selected species (red arrow) is modified in the species drop-down list.
 Green arrow: Button to manually modify the survival and fecundity values.

Modifier les paramètres démographiques

Nombre de classes d'age

4

| | Survie | Fécondité |
|-------|--------|-----------|
| Age 0 | | |
| Age 1 | | |
| Age 2 | | |
| Age 3 | | |

Figure 3 . Option to modify the number of age classes and the values for survival and fertility.

Input parameters

To perform the analysis, the user must provide four input parameters (the fourth is not always required; see explanations below):

1. The number of annual mortalities due to collisions.
2. The size of the current population.
3. The annual population growth rate, in the absence of a collision.
4. The carrying capacity of the environment.

Carrying capacity is defined here as the **maximum size that** the population in question can reach, in the *absence of collisions and other wind turbine disturbances* (see details below).

This is only required for growing populations.

A more detailed description of each of these required inputs is provided below. Each of these inputs can be provided with a degree of uncertainty, in the form of an interval for example (see section "Taking uncertainties into account"). To access the input of each of the parameters, simply click on the button corresponding to the parameter in question in the general panel "Input of parameters" (Figure 4).

To simulate population trajectories, the demographic parameters of the species (survival and fecundity by age class) are also required, but these have been pre-filled in *eo/pop* for the list of 60 priority bird species of the MAPE program. The survival and fecundity values are updated when the user changes the species selection (see previous step). If the user wants to do the analysis for another species, it is possible, but he will have to provide these values himself.

Saisie des paramètres ?

Mortalités annuelles Taille de la population Taux de croissance Capacité de charge

Unité

- Nombre de mortalités
- Taux de mortalité (%)

Type de saisie

- Intervalle
- Valeurs
- Elicitation d'expert
- Tendance population

Moyenne (mortalités annuelles)

Erreur-type (mortalités annuelles)

Type de saisie

- Intervalle
- Valeurs
- Elicitation d'expert
- Tendance population

Borne inférieure (taux d'accroissement en %)

Borne supérieure (taux d'accroissement en %)

Calibrer survies et fécondités

Figure 4 . General "Parameter Entry" panel, with the four buttons for entering the four input parameters. In this example, the "Annual Mortalities" and "Growth Rate" buttons have been clicked. This displays the input boxes for these two parameters, allowing the user to enter values.

Consideration of uncertainties

To account for **uncertainty** in the values provided for each of the four inputs, at least three input options are available to the user:

1. "For example, for a population size, one could enter 150 - 250, if it has been estimated that the population size is between 150 and 250 couples. For example, for a population size, one could enter 150 - 250, if it has been estimated that the population size is between 150 and 250 pairs.
2. "Values": the user will then provide an estimate (central) of the value of the parameter and the associated standard error (SE). For example, for a mortality rate, we can enter an estimate of 3.6% with a SE = 0.8%.
3. "Expert elicitation": the user will then fill a table (Figure 5) with the values provided by different experts, in an expert elicitation according to the method described by (Martin et al. 2012) and (Frick et al. 2017). The details on the conduct of this expert elicitation method are provided in an annexed document ([available here](#)). For each expert (1 expert = 1 row of the table), the following five fields (1 field = 1 column) must be filled in:
 - a) "**Weight**", the relative weight given to the expert;
 - b) "**Min**", the minimum value of the parameter provided by the expert;
 - c) "**Best**", the central value (best estimate) of the parameter provided by the expert;
 - d) "**Max**" is the maximum value of the parameter provided by the expert;
 - e) "**% CI**", the percentage covered by the interval between the Min and Max bounds. This percentage is also provided by the expert.

IMPORTANT: Remember to press the "use expert values" button (see Figure 5) once the table has been filled in. This step is essential to launch the analysis of the values provided in the table and to calculate a central value (+ SE) which will be used in the analysis. A graph of the distributions of the parameter, from each expert and from the analysis (average curve) will then be displayed in the bottom panel, tab "Parameter distribution".

Type de saisie

Intervalle
 Valeurs
 Elicitation d'expert

Nombre d'experts

4

| | Poids | Min | Best | Max | %IC |
|----|-------|-----|------|-----|-----|
| #1 | 1 | 150 | 200 | 250 | 0.8 |
| #2 | 0.5 | 120 | 180 | 240 | 0.9 |
| #3 | 0.8 | 170 | 250 | 310 | 0.9 |
| #4 | 0.3 | 180 | 200 | 230 | 0.7 |

Utiliser valeurs experts

Figure 5. "Expert Elicitation" input table.

Annual Mortality

The information provided should be an estimate of *total annual* mortalities for the selected species at each wind farm included in the analysis. There are several points here that are important to note:

- These are the total mortalities **over a year**, i.e. accumulated over 12 months
- These are the **total mortalities on the farm** in question, i.e. the sum of the expected mortalities on all the wind turbines of a farm.
- **These are actual estimated** mortalities, not observed. If we rely on post-implantation mortality monitoring, this implies having applied the necessary corrections (observer bias, persistence bias, etc.) upstream, for example by using the Huso (2011) or the GENEST tool². In pre-implementation, predictive models of the risk of collision can be used (Band et al. 2007; Masden & Cook 2016).

This data will be provided in one of the following units, by checking the appropriate option (Figure 6) :

- Either in the form of a **number of** annual mortalities.
- Either as a **rate** (in %) of annual mortalities.

In addition to the question of the unit in which one chooses to express mortality, this choice is important in modeling population trajectories. By choosing the "**number of deaths**" option, the same number of deaths (+/- the associated uncertainty) will be applied each year by the demographic model, even if the population size changes over time. This amounts to *assuming a constant number of deaths* (in expectation, because the model includes uncertainties and stochasticity), whereas the

² <https://www.usgs.gov/software/genest-a-generalized-estimator-mortality>

mortality rate³ may vary if the population size varies. This choice will be relevant in the case of highly territorial species (e.g. Golden Eagle), where a constant number of individuals is considered to be exposed to the risk of collision each year (e.g. the few pairs whose territories are located near the wind farm). By choosing the "mortality **rate**" option, the same mortality rate (+/- the associated uncertainty) will be applied each year by the demographic model. Thus, if the population size changes over time, the number of expected mortalities will change in order to keep *the mortality rate constant*. This choice will be relevant in the case of non-territorial, colonial and/or feeding species (e.g. kestrel). In such cases, it is expected that the number of individuals exposed to the risk of collision is proportional (constant rate) to the population size.

Non-cumulative Impacts" Analysis

In the case of a "Non-cumulative Impacts" analysis, the user will have to provide values (in the form of an interval, estimate + SE, or in the "Expert Elicitation" table) corresponding to the mortalities of a single scenario, typically the collisions caused by a single wind farm. The value entry module is then presented in the form illustrated in the Figure 6.

Figure 6 . Module for choosing the unit, input type, and values (here of an interval) for the "Annual Mortalities" parameter, in the case of a "Non-cumulative Impacts" analysis.

Analysis "Cumulative Impacts

³ We recall the relationship: $\text{taux de mortalité} = \frac{\text{nombre de mortalités}}{\text{effectif population}}$

In the case of a "Cumulative Impacts" analysis, the user will first have to indicate the number of wind farms involved in his analysis, and then fill in a table to indicate the values (estimate and standard error) of mortalities of each wind farm, as well as their year of operation, planned or actual (Figure 7). In this table, each row corresponds to a wind farm.

Nombre de parcs éoliens

3

Mortalités dans chaque parc ?

| | Valeur centrale | Erreur-type | Année (début) |
|---------------|-----------------|-------------|---------------|
| Parc 1 | 2 | 0.5 | 2010 |
| Parc 2 | 5 | 0.5 | 2015 |
| Parc 3 | 3 | 0.5 | 2018 |

Figure 7 . Mortality table for several wind farms in the case of a "Cumulative Impacts" analysis.

Population size

The population size can be provided in one of two units (by checking the appropriate option):

- Number of couples
- Total number of employees

If the "total number" option is checked, the value provided should include both sexes (males + females) and all age classes, including immatures and subadults, except current year juveniles. If the "number of pairs" option is chosen, then the numbers per age class will be estimated from the stable age structure of the species (Caswell 2001). If the "number of pairs" option is chosen, then the numbers per age class will be estimated from the stable age structure of the species, calculated from the survival and fertility matrix. In both cases, the numbers per age class are displayed at the bottom of the "Population size" module, for information purposes.

Since the objective of this tool is to evaluate the impact of collisions at the population level, the "population size" parameter is of primary importance. Indeed, it is from this value that the mortalities are placed on a "population" scale. The results of the analysis are therefore very sensitive to it. The value indicated here must therefore correspond to the size of a relevant population, from the biological point of view or from the point of view of the conservation objectives for the species, and whose contours have been clearly delimited beforehand. There are several possible approaches to delineating the population to be included in the analysis. To assist the user in this task, which is rarely easy, we have developed a guidance document ([available here](#)).

Taille de la population

Taux de croissance

Unité

Nombre de couples

Effectif total

Type de saisie

Intervalle

Valeurs

Elicitation d'expert

Borne inférieure (taille population)

Borne supérieure (taille population)

Effectifs par classe d'âge

| A0 | A1 | A2 | A3 | A4 |
|------|-----|-----|-----|-----|
| 1336 | 677 | 387 | 220 | 993 |

Figure 1. Input module for the "Population size" parameter.

Growth rate

This parameter is the annual growth rate (%) of the **defined population** in the absence of collisions. It will be a :

- *positive value* if the population is *growing* (e.g. enter "3" to indicate a growth of 3% per year); or if it **would be growing** in the absence of existing collisions.
- *negative value* if the population is *declining* (e.g. enter "-4" to indicate a decline of 4% per year).
- finally, a value of "0" corresponds to a *stable* population.

As before, it is of course possible to include uncertainty, by entering an interval, an estimate and its standard error (SE), or from expert elicitation. Note that an interval can overlap with the value 0. For example, an interval [-2 ; 5] will include as possibilities decline (up to 2%/year), stability (0%) and growth (up to 5%/year).

When the user is not able to provide numerical values to delimit the range of possible growth rates, he/she may choose to check the "population trend" option, which will offer several qualitative choices (Figure 9) :

- Trend: declining, stable or growing
- Intensity (of this trend; whether *declining* or *growing*): low, medium, high

By selecting this option, *default* values for average growth rates (and SE) will be applied. For a "declining" trend, the average values used will be -3% (low decline), -6% (medium decline) and -9% (high decline) per year. For a "growing" trend, the average growth rates used will be +4% (low growth), +8% (medium growth) and +12% (high growth) per year. For a "stable" trend, an average growth of 0% will be used. In all cases, a 5% SE will be applied to represent the uncertainty in these annual trend values.

IMPORTANT: We emphasize that the growth rate values (range, etc.) provided or the trend indicated must correspond to the growth of the population *under current conditions*, excluding collisions. If the population has already been colliding for several years, then it will be necessary to assess what the trend and/or growth rate would be without the collisions. This can be estimated by a small retrospective analysis or approximated by deducting the "observed" annual mortality rate (after bias corrections) over the past years from the "observed" growth rate.

Once the growth rate has been defined, it is possible to "calibrate" the survival and fecundity values by age class; that is, they will be adjusted to match the average growth rate indicated by the user's input. To do this, simply click on the "Calibrate Survival and Fecundity" button (Figure 9). This action will update the survival and fecundity values displayed in the general "Analysis and Species Selection" panel (**Erreur! Source du renvoi introuvable.**). This adjustment is made using an optimization procedure. The degree of relative adjustment applied to a given demographic parameter is based on the sensitivity of the growth rate to that parameter. The higher the sensitivity, the less the parameter will be adjusted. For example, for a long-lived species, the adjustment will concern fecundity and juvenile survival more than adult survival, because the latter is the most sensitive (notion of "environmental channeling" ; Pfister 1998; Gaillard & Yoccoz 2003).

Figure 2 . Visualization of the input module for the "Growth rate" parameter, after selecting the "population trend" input option.

Load capacity

Carrying capacity (K) is the *maximum* size that the population could reach in its environment (within the spatial boundaries used to define the population contours), in the *absence of collisions and other wind-related disturbances*. This parameter K is required to calibrate the density-dependence relationship that is included in the model when the population is growing. This density-dependency mechanism is indeed essential to model realistic demographic trajectories and avoid that the population grows infinitely.

NOTE: The carrying capacity value should be provided in the same unit as the population size. If the "number of pairs" option was chosen for the population size, then the value of K should be expressed as the maximum *number of pairs* that could be supported by the environment. If the "total number" option was chosen, then the value of K will be expressed as the maximum *total number of individuals* (excluding young-of-the-year) that could be supported by the environment.

It is often very difficult to estimate this parameter, but here are several points to consider:

- This parameter is only important in the case of a growing population. For strictly declining and/or stable populations, it has no influence. In this case it will be possible to check the option "Unknown value" (Figure 10).
- In the case of a growing population, this parameter is important (especially in the case of relatively strong growth: $> 4\%$), but the results of the analysis are only moderately sensitive to this parameter. The user does not necessarily need to obtain a very high precision on this parameter. A relatively wide range (e.g. 50 to 200 pairs or 10 000 to 30 000 pairs) will suffice.

- What is important here is to provide a relevant *range of the order of magnitude of the* carrying capacity. This is usually done by eliciting information from experts on the species. For example, if the experts estimate that the population could grow to "a few thousand pairs," we know right away that a relevant range for K will be between 1,000 and 10,000 pairs. It will then suffice to narrow the range a little more (by continuing to question the experts) to arrive at, for example, a range of "2,000 to 6,000" pairs, which will be sufficiently precise for the exercise.

Figure 3. Module for entering the "Load capacity" parameter.

Display of the entered values

Once the values of a parameter have been entered, it is possible to view the distribution curve of this parameter in the bottom panel, tab "Parameter distribution" (Figure 11).

In addition, the mean value and standard error of each of these four input parameters are recalled in the "Selected values" panel (Figure 11).

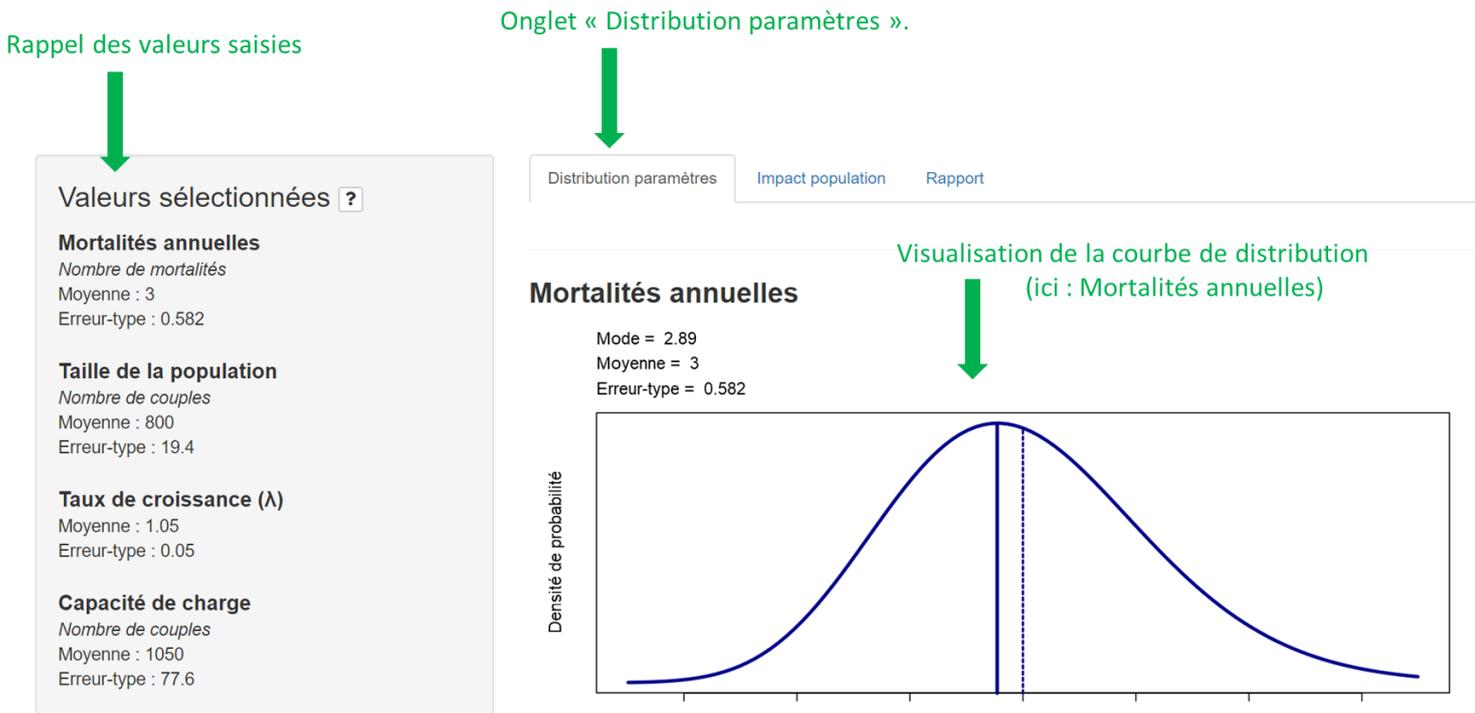


Figure 4. Display area allowing to visualize (i) the values entered for each of the four parameters (on the left) and (ii) the distribution curve of one of the parameters (as desired).

Analysis

Once the values for the four input parameters have been entered, the user can proceed to the demographic analysis step by selecting the "Population Impact" tab in the bottom panel (Figure 12). Two additional variables must then be provided before running the analysis:

- Number of years (= time horizon)
- Number of simulations

By default, the number of years is set to 30 years, but you can change it if needed. Regarding the number of simulations, we recommend to run between 500 and 1,000 to cover the range of possible trajectories (variability due to parameter uncertainty and stochasticity mechanisms) and to have stable results. Be careful, the number of simulations affects the computation time.

Once these two input variables have been provided, simply press the "Start Analysis" button to start the simulations (Figure 12). A "Simulation Progress" bar will appear at the bottom right to show the progress of the simulations. The analysis can take several tens of minutes, or even longer if you have chosen to run a lot of simulations (> 1000).

NOTE: The calculation time will be longer for a growing population (positive growth rate) than for a declining trend, because of the density-dependence modeling that is only involved in the former case.

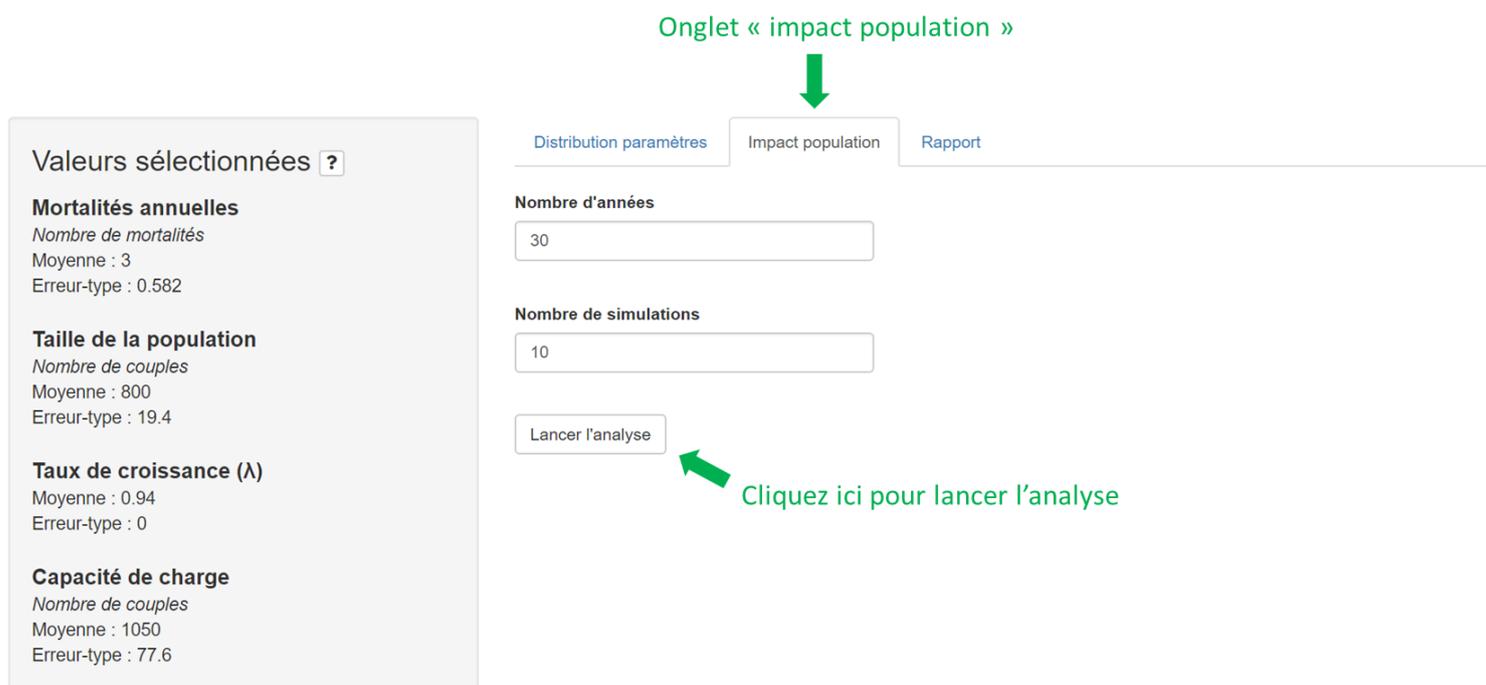


Figure 5. Visualization of the "Population Impact" panel to launch the analyses.

Results

Once the analysis is complete, the following results are provided in two tables and four graphs.

Tables

Table 1: Estimated relative impact at the selected time horizon (e.g. after 30 years). This impact metric is the *relative difference (%) in population size* between the collision scenario(s) and the no-collision baseline scenario. The degree of coverage (%) of the confidence interval associated with this impact estimate can be modulated by the user using a sliding button (Figure 13). Depending on the type of analysis, each row of the table corresponds to :

- The impact of the only scenario (e.g., single park) analyzed, in the case of a "non-cumulative impacts" analysis (Figure 13).
- Cumulative impact of wind farms, added in chronological order of commissioning, in the case of a "Cumulative Impacts" analysis (Figure 14). For example, "... + Park 3" is the cumulative impact of Parks 1, 2, and 3 (but excluding Parks 4, 5, 6, ... if applicable); Parks 1 and 2 are prior to Park 3, and Parks 4, 5, 6, ... are subsequent to it.
- the individual impact of each scenario tested, in the case of a "what-if" analysis

Table 2: Probability of population extinction, at the chosen time horizon, for each scenario. Here, the baseline scenario (no wind farm) is also included, so that we can compare how this extinction risk changes with the addition of the wind farm(s). In the case of a "Cumulative Impacts" analysis, each scenario corresponds to the addition of one more wind farm, in chronological order of commissioning.

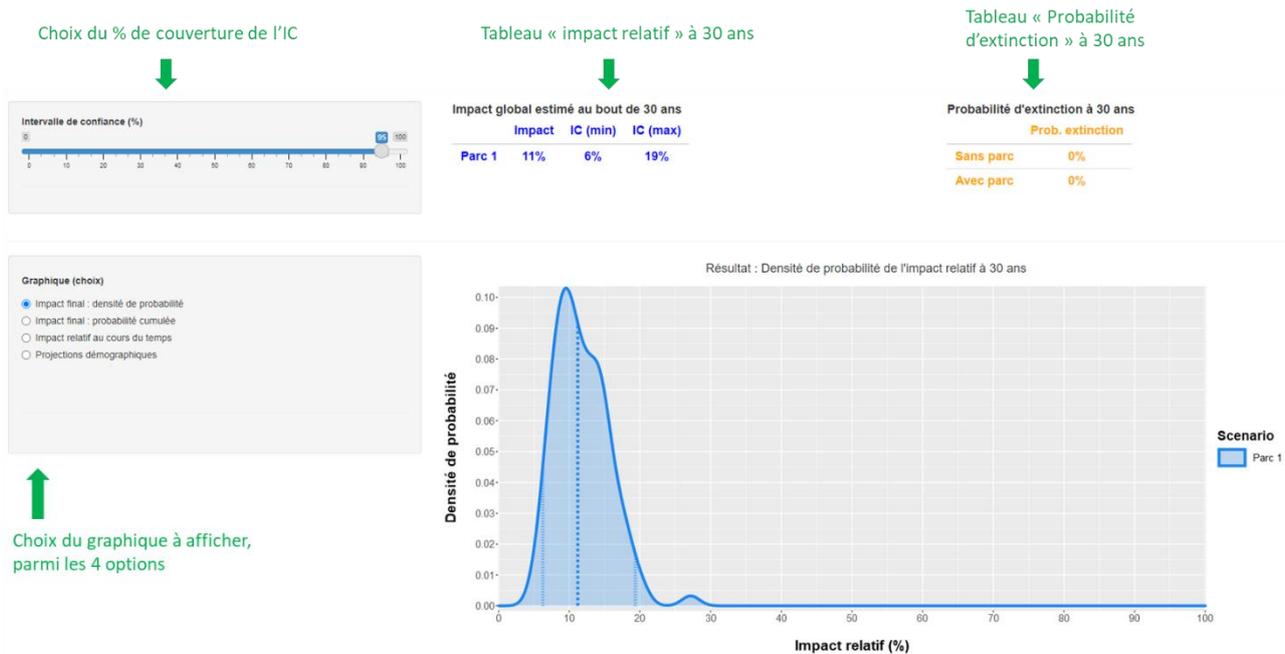


Figure 6 . Visualization of results after analysis. This is a "non-cumulative impact" analysis, i.e. a single park.

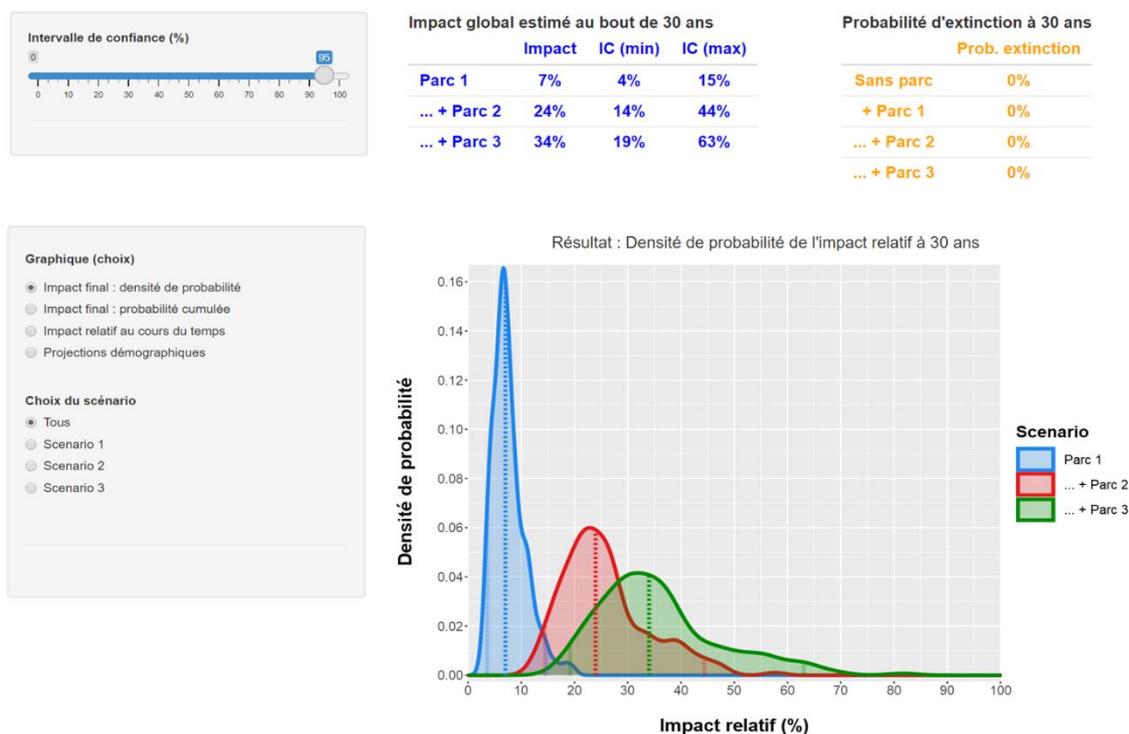


Figure 7 . Visualization of the results after a "cumulative impact" analysis with 3 parks.

Graphics

Only one graph is displayed at a time. The user can choose which graph to display by checking the corresponding box in the left-hand module (Figure 13).

Figure 1: Probability density of the "final" relative impact, i.e. at the chosen time horizon (Figure 15). This curve shows the probability of the different possible levels of relative impact (between 0% and 100%). The central estimate (median) and the upper and lower bounds of the confidence interval are indicated (dotted vertical lines) on the graph. These three values correspond to the values (estimate + confidence interval) in Table 1 described above. The degree of coverage (%) of the confidence interval is modulated via the same sliding button as for the confidence interval in table (Figure 12). As the button is moved, the vertical lines of the confidence interval in the graph will narrow or widen around the central estimate.

NOTE: Tighter bounds (narrower interval) necessarily correspond to a lower level of confidence. We recall that in general, in Science, a 95% confidence interval is used.

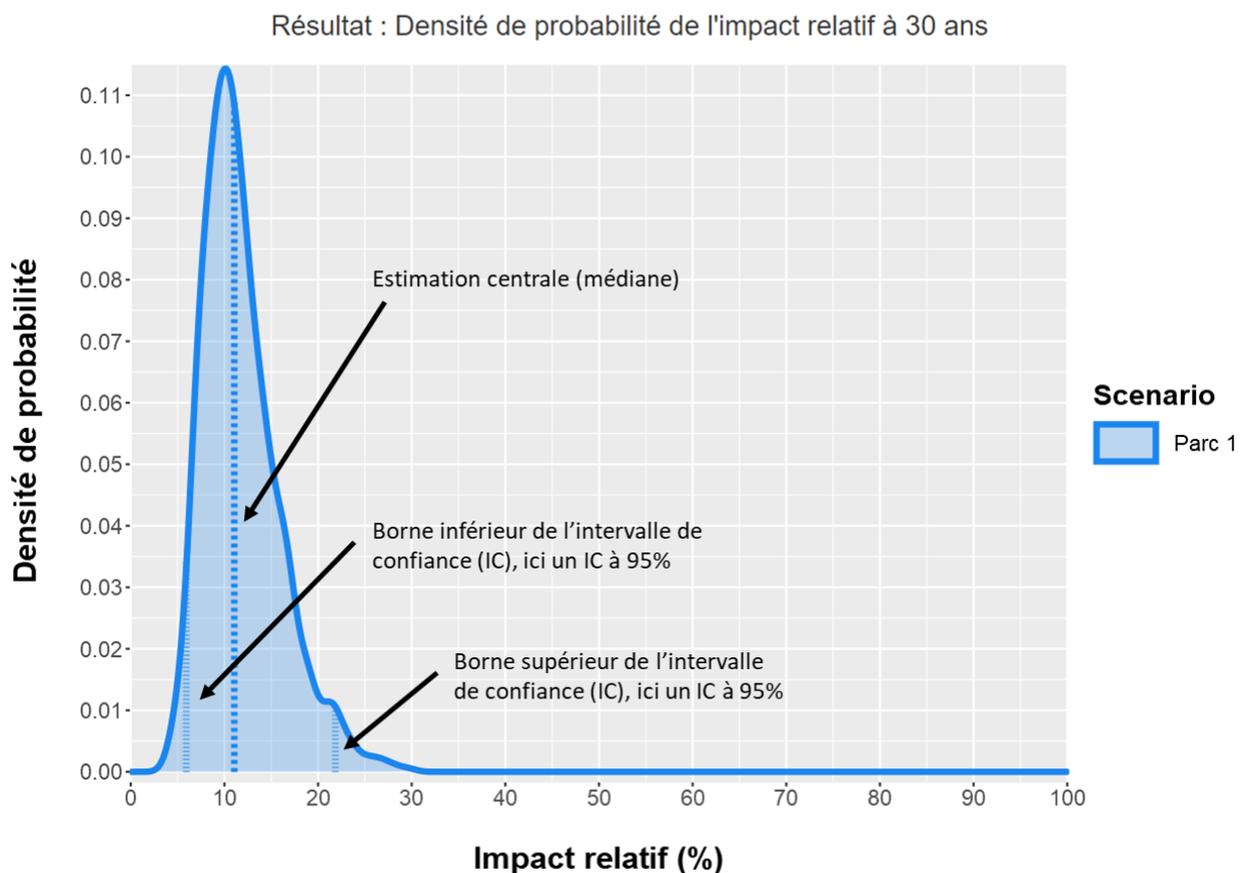


Figure 8 . Figure 1. Probability density of the "final" relative impact.

The central estimate (median) and the bounds of the confidence interval are indicated by the vertical dotted lines.

Figure 2: Cumulative probability of the "final" relative impact, i.e. at the chosen time horizon (Figure 17). This graph is probably the most important for interpreting the results and informing decision-making based on the demographic impact of the wind farm(s) studied.

A cumulative probability is the probability that the impact is "at most" equal to a given value (quantile X). For example, on the Figure 17For example, in the diagram, we see a cumulative probability equal to 95% (Y axis) for a relative impact of about 20% (X axis). This is interpreted as follows: "there is a 95% chance that the relative impact is less than or equal to 20%". In other words, "there is only a **5% chance** that the relative impact is greater than 20%". This "5% chance" is the *risk of underestimating the impact* by using the 20% impact quantile to make a decision. In other words, it is the *risk of making a bad decision* (from the point of view of population conservation) based on an estimated impact of 20% (e.g., by comparing this 20% value to an acceptability threshold). The user has the possibility to modulate this *risk* thanks to a sliding button (module located at the bottom left on the Figure 17). The value of the quantile (impact) at the chosen risk level is also indicated in text form (19.8% on the Figure 17). The higher the risk level, the lower the impact quantile value, and vice versa. For example, in the example above, if the risk tolerance is increased to 10%, then a decision would be made that the impact on the population is 17% (not 20%).

NOTE: A risk level of 50% is equivalent to using the median (central impact estimate). The impact value used in this case for decision making would be 11% (see Figure 1 and **Erreur ! Source du renvoi introuvable.**). It is important to understand that this means that there is a 50/50 chance that the actual impact is greater than 11%. This would not be a conservative approach. A risk level of 2.5% is equivalent to using the upper bound of the 95% confidence interval.

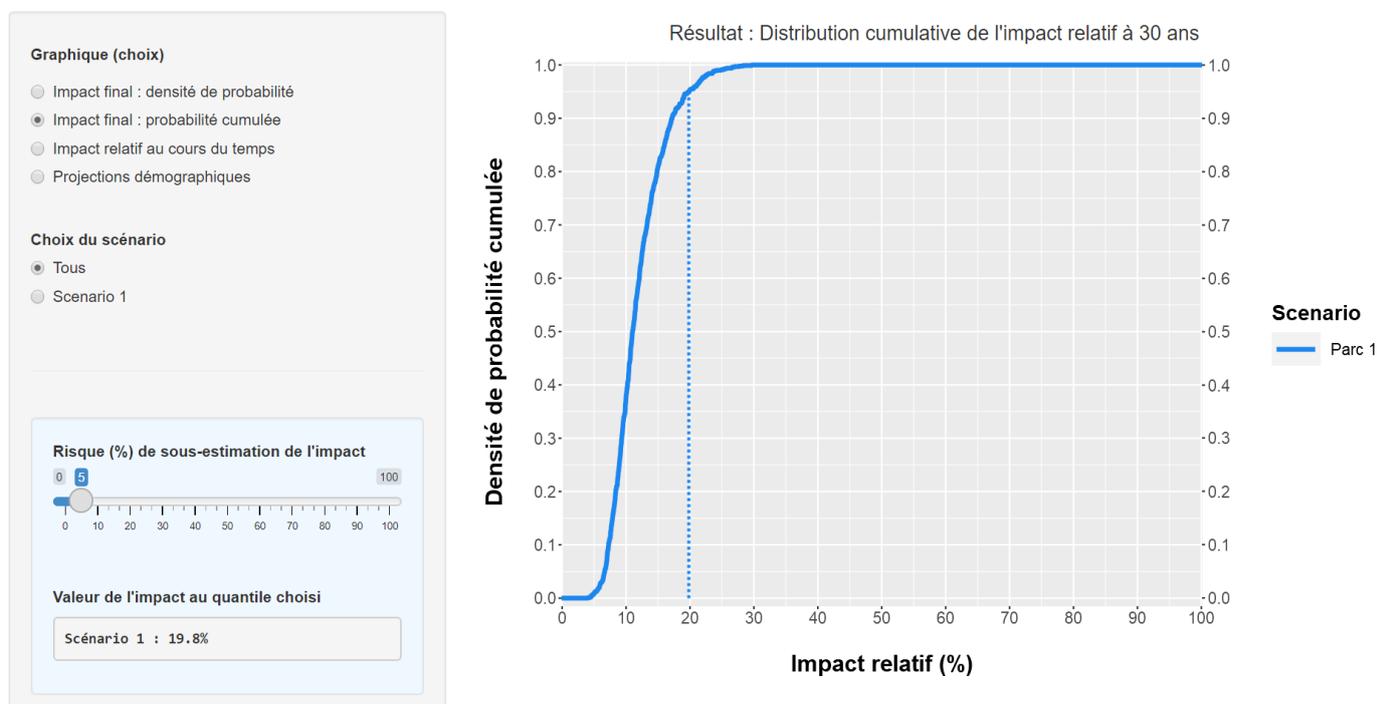


Figure 2 . Figure 2: Cumulative probability of "final" relative impact.

Figure 3: Evolution of the relative impact over time, from year 1 to the chosen time horizon (Figure 18). Relative impact is also defined here as the relative difference (in %) in population size between the collision scenario(s) and the no collision scenario. This plot shows how the demographic impact of collisions accumulates over time. The confidence interval chosen by the user (see above) is also visible around the central curve.

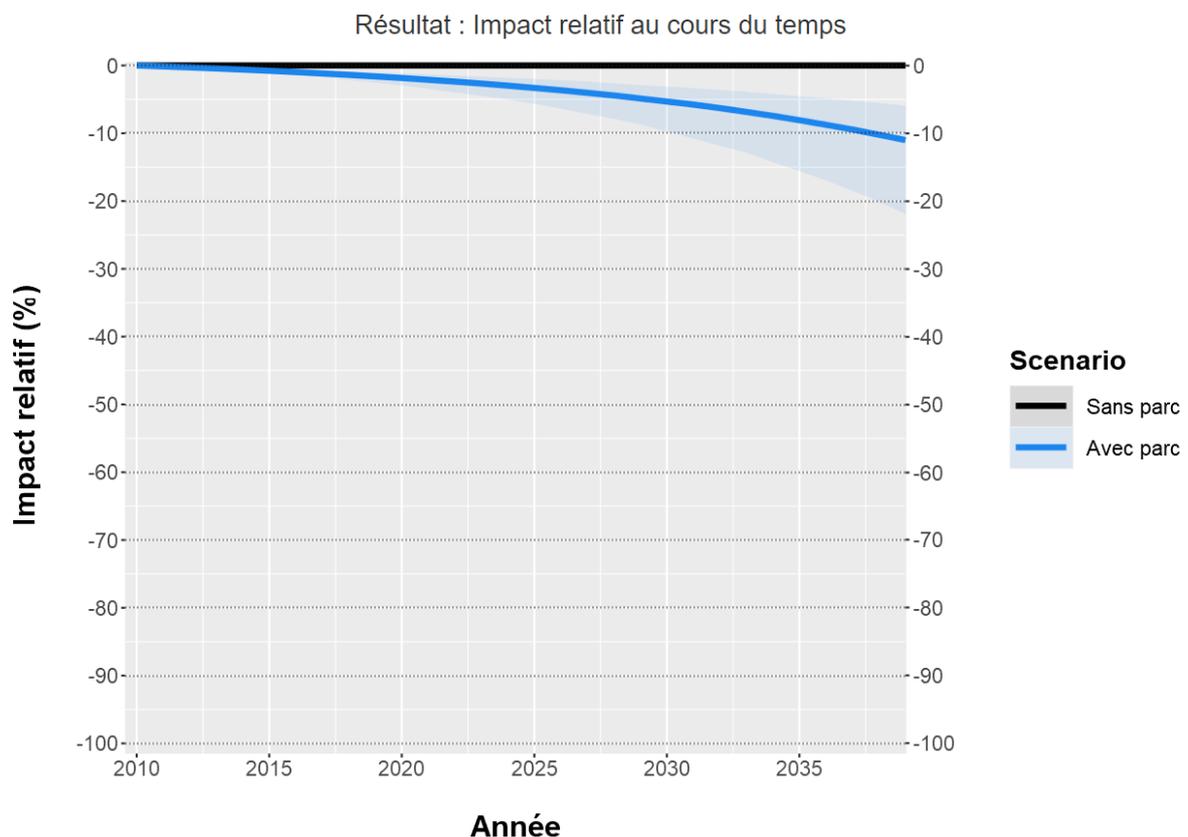


Figure 3. Figure 3: Evolution of the relative impact (blue curve) over time.

Figure 4: Population trajectories under each scenario, including the baseline no-collision scenario (Figure 19). These trajectories show the predicted change in population size over time. The user can choose between the following three definitions of "population size", including more or less classes of individuals: (i) all ages, except juveniles; (ii) all ages, including juveniles; and (iii) breeding pairs only.

IMPORTANT: This graph is provided for information purposes, so that large inconsistencies can be identified. In no case should this graph be interpreted as a "precise" prediction of the future evolution of the population. This is not the objective of this tool. The actual trajectory of a bird population depends on many factors (besides the impact of the wind turbines) that are not under control, that are often poorly understood, and that can change over time. These unknown and changing factors cannot of course be modeled in this tool.

It is important to understand that the trajectories predicted by the tool are necessarily conditional on the accuracy and precision of the input parameters provided by the user. They are therefore

predictions "based on the current state of knowledge" (and therefore on the elements provided). Moreover, these predictions make the assumption that these conditions remain stable in the future, which no one can guarantee.

It should be noted that the objective of this tool is not to accurately predict the future evolution of a bird population, which depends on too many unknown variables. **The objective is to provide a robust estimate of the relative impact** of mortality caused by wind turbine collisions. For this reason, the main results (Tables and Charts 1 to 3 above) are based on a comparison with a baseline scenario (without mortalities), *all other things being equal*. It is therefore important to distinguish between *relative impact* (here the term "relative" refers to the reference scenario) and the *real trajectory* of a population. The latter can hardly be predicted with precision, because of the many unknowns; on the other hand, the relative impact of a given level of mortality will remain more or less the same even if the real trajectory of the population turns out to be slightly different from what is predicted by the model. This is because all other components of the model are identical between the two scenarios. Of course, in the case of strongly different trajectories, the relative impact could also be substantially different.

Graphique : Trajectoires démographiques

Attention : Il s'agit de prédictions en l'état actuel des connaissances. Personne ne peut prédire comment les facteurs d'influence démographique (environnement, etc.) vont évoluer dans le futur. Donc personne ne peut prédire de façon exacte ce que sera la taille de population dans plusieurs années. Ce graphique est simplement fourni à titre informatif. Attention à ne pas le sur-interpréter. L'impact des collisions doit être évalué à partir des valeurs et du graphique ci-dessus, qui fournissent une estimation plus robuste (c-à-d. moins sensibles aux postulats et incertitudes) de cet impact.

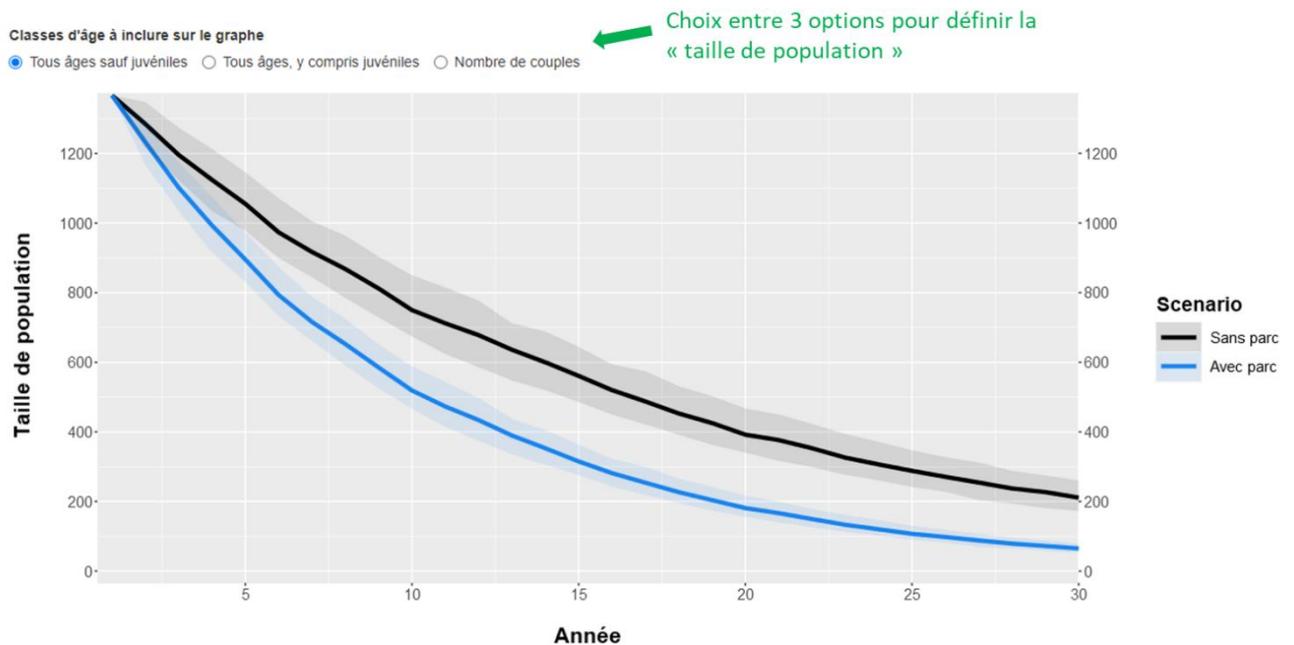


Figure 4 . Figure 4: Population trajectories under each scenario.

Creating a report

Once the analysis is completed, the user can also generate a summary report in PDF format, directly from the *eo/pop* application. To do this, simply go to the "Report" tab and click on the "Generate a report" button (Figure 20). In this tab, two text boxes are available for the user to provide some details about (i) the context in which this impact study is being conducted and (ii) how the study's target population was delineated. This text is intended to provide additional context and interpretation in the report produced by the tool.

In this summary report (see Figure 21), the following information is provided:

General :

- Date of creation of the report
- Type of analysis performed
- Species analyzed
- Time horizon
- Context of the study (text written in the box provided)
- Definition of the impacted population (text in the box provided)

Input parameters used:

- Annual Mortalities (unit, type of entry, values)
- Population size (unit, input type, values)
- Annual growth rate (input type, values)
- Load capacity (unit, input type, values)
- Table of demographic parameter values (survival and fertility by age group)

Results:

- Table 1: Estimated Relative Impact, at the Selected Time Horizon
- Table 2: Value of the impact at the chosen quantile, i.e. corresponding to the risk of underestimating the chosen impact (see explanations above concerning graph 3 "cumulative probability")
- Table 3: Probability of population extinction, at the chosen time horizon.
- Figure 1: Probability density of the relative impact, at the chosen time horizon.
- Figure 2: Cumulative probability of relative impact, at the chosen time horizon.
- Figure 3: Evolution of relative impact over time.

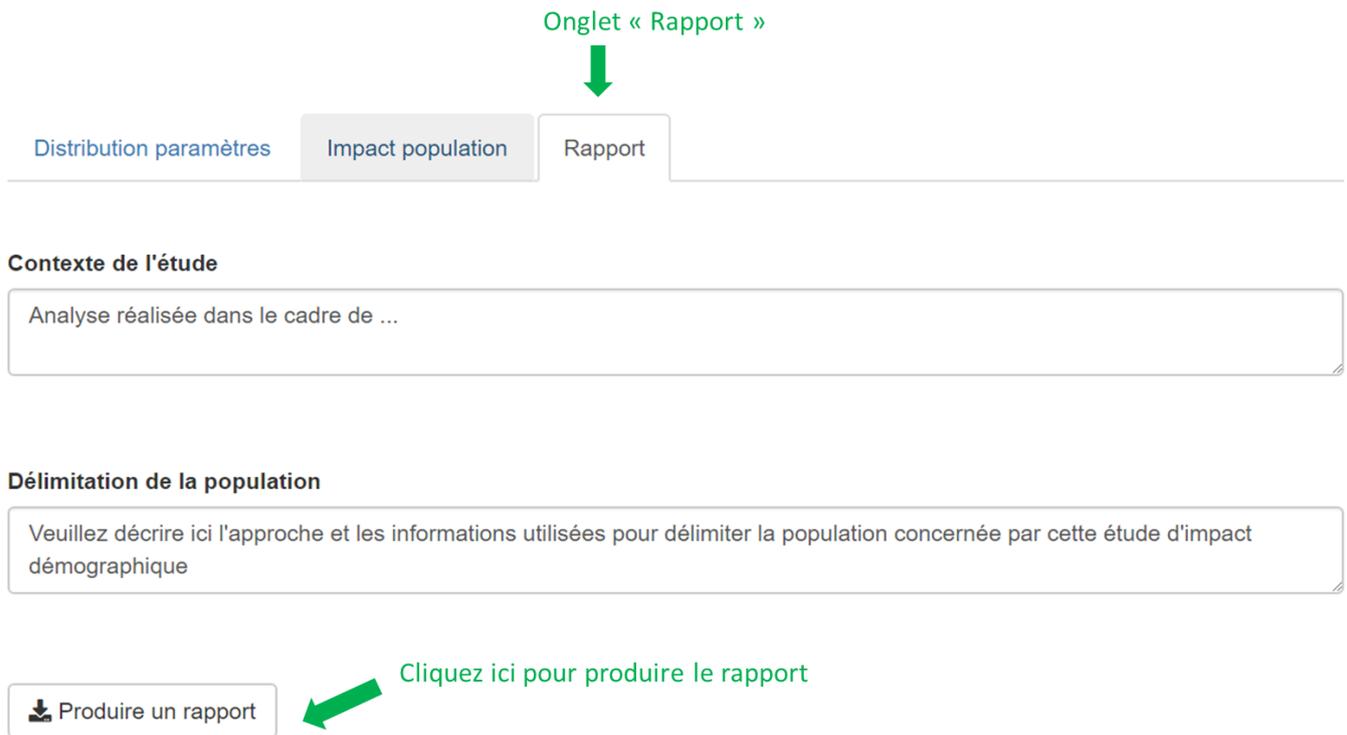


Figure 5. "Report" tab to generate a report in PDF format.

Rapport : analyse démographique (eolpop)

Date de création: 10/12/2021

Type d'analyse réalisée : Impacts non cumulés

Espèce analysée: Aigle de Bonelli

Horizon temporel: 30 ans

Contexte de l'étude

Analyse réalisée dans le cadre de ...

Définition de la population impactée

Veuillez décrire ici l'approche et les informations utilisées pour délimiter la population concernée par cette étude d'impact démographique

Paramètres d'entrée utilisés

Mortalités annuelles

Unité : nombre de mortalités annuelles
Saisie : intervalle

Min : 1.5 mortalités ; Max : 4.5 mortalités

Taille de la population

Unité : nombre de couples
Saisie : intervalle

Min : 750 couples ; Max : 850 couples

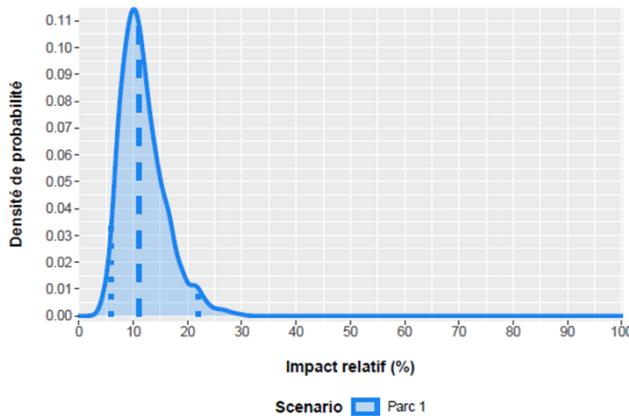
Taux de croissance annuel

Saisie : intervalle

Min : -6% ; Max : -6%

1

Graphique 1 : Densité de probabilité de l'impact relatif (à 30 ans)



Note : La médiane et l'intervalle de confiance (IC à 95%) sont montrés sur le graphe.

3

Capacité de charge

Unité : nombre de couples
Saisie : intervalle

Min : 850 couples ; Max : 1250 couples

Paramètres démographiques

| | Survie | Fécondité |
|----|--------|-----------|
| A0 | 0.47 | 0.00 |
| A1 | 0.53 | 0.00 |
| A2 | 0.53 | 0.33 |
| A3 | 0.72 | 0.84 |
| A4 | 0.81 | 0.84 |

Résultats

Impact global estimé au bout de 30 ans

| | Impact | IC (min) | IC (max) |
|--------|--------|----------|----------|
| Parc 1 | 11% | 6% | 22% |

Note : Intervalle de confiance (IC) à 95%

Valeur de l'impact au quantile de 50%

(soit un risque de 50% de sous-estimer l'impact)

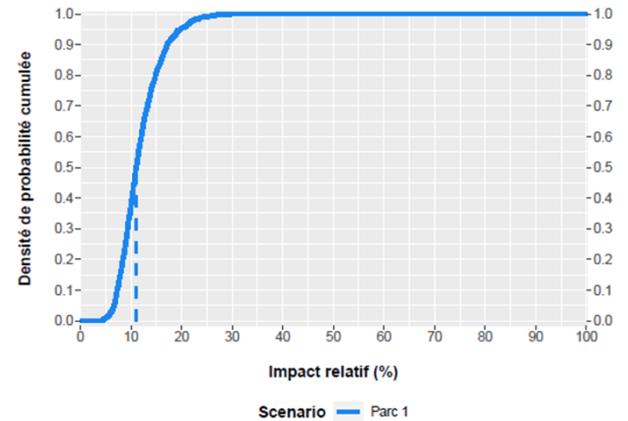
| | Impact au quantile |
|--------|--------------------|
| Parc 1 | 11% |

Probabilité d'extinction à 30 ans

| | Prob. extinction |
|-----------|------------------|
| Sans parc | 0% |
| Avec parc | 0% |

2

Graphique 2 : Probabilité cumulée de l'impact relatif (à 30 ans)



Note : Quantile = 50%,
soit un risque de 50% de sous-estimer l'impact

4

Figure 6. Screenshot showing the first 4 pages of the PDF report generated by eolpop.

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